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VOLUME 69 • NUMBER 1 • SPRING/SUMMER 1983

RICHARD J. SCRANTON

President, Boston Society of Civil Engineers Section, ASCE
1983-1984

New President's Message

In September of 1848, a young surveyor and former congressman from Illinois by the name of Abraham Lincoln--still twelve years away from his own presidency--gave a speech at Boston's Tremont Temple urging the election of Zachary Taylor. In July of that same year the Boston Society of Civil Engineers was founded and just four years later, the the American Society of Civil Engineers was organized.

BSCES/ASCE stems from a marriage of the two. While we enjoy the rich heritage of both, this heritage has established high standards of professional service for all of us.

In 1948, opportunities for obtaining a formal engineering education were minimal. Professional challenges, however, included railroad development and operation, provision of public water supply and harnessing of water power for industrial use. Today, opportunities for formal education are numerous and we face challenges including the repair of a decaying infrastructure and solving the problems associated with hazardous waste, acid rain, energy provision, and water supply.

Since 1848, our members, and civil engineers in general, have responded successfully to these challenges. At a seminar that I attended several years ago Joseph Coates, then Director of the Office of Technology Assessment of the United States Congress, postulated that civil engineers, through their works, have saved more lives throughout history than members of the medical profession. Our Journal contains many descriptions of our organization's activities and the dedication to service exhibited by our members over the years. On May 10 of this year, we dedicated the Borden Base Line as an ASCE National Historic Civil Engineering Landmark. Simeon Borden, using equipment of his own design, established a phenomenally accurate survey-base line from Hatfield to South Deerfield, Massachusetts, between 1830 and 1941. Simeon Borden was an active member and served as President and Vice President of the Boston Society of Civil Engineers.

I believe that it is this spirit of participation and dedication that has allowed our organization to serve our members and thereby to contribute to the betterment of society in general. This spirit is illustrated further in a letter from former BSCE and ASCE President, John R. Freeman. His letter is dated March 18, 1925 donating a fund of $25,000 to the Boston Society of Civil Engineers. Here are three paragraphs excerpted from letter:

> "I owe a debt to the old Boston Society of Civil Engineers, for inspiration and encouragement it gave me in my younger days through friendships and acquaintances made at the society meetings.
>
> It was forty-four years ago that I joined the Society. Month after month for about four years I felt well repaid by what its monthly meetings had to give for making a sixty-mile round trip with a return after midnight. Yet today, forty years later, I have a still deeper appreciation of what the Society association may mean to a young engineer.
>
> It seems only fair that, when one has found lifelong happiness, and attained a competence from his profession, he should recognize the debt he owes to those who went before him and whose data he used, and should in some way try to help those young men in his profession who are following after."

This letter reflects the spirit which underlies the vitality of our organization. Even though we live in complicated and economically trying times, our profession has served all of us well. I ask that all of you ponder the importance and potential contributions of BSCES/ASCE to other civil engineers, to society in general, and to each of us and that you resolve to contribute personally. There are many ways including:

1. Volunteering to serve on our committees and technical groups
2. Communicating ideas to Section officers
3. Attending and supporting Section-sponsored functions
4. Contributing to our Newsletter and Journal
5. Urging and supporting whole-hearted participation by other civil engineers

This latter effort is probably as important as any and is an obligation that falls heavily, but not solely, on those in education and those who enjoy other influential positions in our profession or in private firms.

I look forward to the continued intellectual and real growth of BSCES in the year ahead and to your vigorous participation. I thank you for the opportunity to serve as BSCES President for the coming year.

Richard J. Scranton
President, 1983-1984

JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS SECTION

Presidential Address

AMERICAN SOCIETY OF CIVIL ENGINEERS

A PEOPLE SERVING PROFESSION

Presidential Address of Stanley C. Rossier[1]

One hundred thirty-five years ago today, five civil engineers gathered at the United States Hotel in Boston to unite for professional growth through self-development. They were dedicated to improving the value of life by creating public water supplies, transit systems and structures to meet human needs of their time. They shared common experiences in using the materials and forces of nature, educated one another concerning the application of mathematical and scientific principles, and worked to improve their leadership skills.

That informal meeting on April 26, 1848 sparked a professional and human endeavor that took root in the Boston community and grew rapidly. Their first regular meeting occurred just 68 days later on July 3, 1848, and by 1851 the state legislature chartered the Boston Society of Civil Engineers in recognition of our pioneer founders' dedication to professional development.

In some respects the world has changed dramatically since those founders of professional engineering served their fellow citizens through dedication to a creative environment in which a better life could be achieved. Technology has become very complex, and the process has become the object of our attention. Our minds are absorbed in many details, while our professional outlook tends to focus upon the intrinsic value of applied technology.

In other respects the world has changed very little. As a part of society we continue to proclaim self-fulfillment as the reason for serving people, not serving people as the reason for self-fulfillment. We see economic growth as the reason for our professional service, not professional service as the reason for our economic growth.

[1] Presented at Part I of the Annual Meeting of the Boston Society of Civil Engineers Section, ASCE, April 26, 1983

We can and must dedicate ourselves as professionals to do no less than those founders of BSCE under whose heritage we labor. The technical challenges of our nuclear space age, though awesome, are surely solvable through the systematic application of scientific principles and our will to accomplish complex tasks. Our ability to apply logic, reason with elements of a problem, and place the solved pieces within a larger framework leading to a solution of the total problem has been demonstrated over and over again.

Leadership challenges of our age remain in greater question, for they may not be solved without a level of individual and personal effort beyond that which any of us has demonstrated. Our knowledge of leadership skills, our imagination, and our expertise in dealing with complex human interactions must continue to develop, through a greater understanding of our very selves, if we are to move forward in providing the professional leadership desperately needed by fellow citizens.

There is a strong creative drive in each of us to bring about new concepts and to solve problems that are complex and overpowering. Creation is an ongoing process viewed as a challenge we cannot leave alone. Our world is a dynamic environment where human souls continually struggle to create, as well as to destroy. Each of us, as part of this process, is faced daily with decisions on how to invest our time, our talent, and ourselves.

When we ponder a course of action by asking what type of project should our firm pursue, what type of job should we seek, or what assignment shall we accept, do we ask ourselves: Should I participate in creating a safe disposal system or a toxic tumult, a space structure for scientific research or a satellite for spying on others, a new town to support human life or a supersophisticated bomb to destroy life? Such questions appear too simple and their answers become dismissed as obvious. For many engineers working in areas of "high technology" the answers take on shades of gray and are by no means clear. Many of us working as civil engineers now face this dilemma.

How can I effectively contribute my own time and talent in pursuit of a necessary step toward a stable world order? The daily decisions each of us makes may seem but a tiny element in such a complex world, and yet each personal as well as corporate decision in answer to such questions can be vital in helping to develop the ultimate environment we simply must create.

As engineers, we often discount the importance of our part within the process of creating human acceptance, human understanding, and eventual human trust on a scale that can become large enough to attain world peace. We are a profession capable of providing a unique measure of leadership, as well as technical talent! Witness if you will the role played so successfully by our student chapter at Northeastern University over the past dozen years in discerning a human need, citing a means of serving others, conceptualizing a total project, identifying the key elements involved, finding sources of funds, seeking solutions for each element of the project, and creating the total concept. Their leadership and talent provided an outdoor development facility for autistic children, constructed play therapy facilities for the Boston Children's Service Association, and created a playground for children at Kennedy Memorial where children now develop motor skills and sensory stimulation. The list goes on and we cannot stand by, for we must acknowledge these examples and learn from our students!

I believe that as professionals we are called on to apply our unique talents, not only in the solution of technical problems, but in filling the leadership needs of our time through deliberate actions that build trust in a world of fear. There is an unknown and unmeasured potential within each of us. Our greatest reward can come from exploring that potential while striving to provide a unique service of leadership in meeting the needs of others in a divided world.

SEISMIC DESIGN OF GRAVITY RETAINING WALLS WITH REFERENCE TO THE MASSACHUSETTS BUILDING CODE

Cetin Soydemir[1]

I. INTRODUCTION

The comprehensive state-of-the-art report by Seed and Whitman (22) in 1970 brought a new awareness to the importance of earthquake resistant design of earth retaining structures. The report also incorporated design recommendations expanding the pioneering work of Mononobe (17) and Okabe (19) presented in the 1920's. The so-called Mononobe-Okabe pseudo-static method is still the most widely used procedure in practice for the seismic design of earth retaining structures.

A survey of literature indicates that other than Prof. L. S. Jacobsen's (11) illuminating work carried out at Stanford University (1930's) relative to the major projects of the Tennessee Valley Authority, research on the seismic behavior of earth retaining structures prior to the 1960's was primarily undertaken in Japan. However, during the last decade, researchers in the United States, New Zealand, and India have made significant theoretical and experimental contributions.

Up until the 1970's, work carried out has been almost exclusively an expansion of the Mononobe-Okabe pseudo-static model dealing only with unsaturated backfills. Seismic design of retaining structures with saturated backfills (not subject to liquefaction) is still at an early stage of development and quite empirical, even though major structures such as quay walls and drydock walls belong to this category.

In 1979 Richards and Elms (21, 4) proposed a new approach for the seismic analysis of gravity retaining walls as an alternative to the previous pseudo-static (seismic coefficient) methods. This fundamentally sound approach is based on the fact that under seismic activity gravity walls essentially experience a finite, permanent displacement rather than a complete collapse (i.e., failure).

This paper in general deals with the Richards-Elms model, and reviews it with particular reference to the Massachusetts State Building Code (25), Section 716.6.10, Retaining Walls. Richards-Elms method has been adopted in current design practice in the United States (5) and New Zealand (15).

---

(1) Senior Engineer, Haley & Aldrich, Inc., Cambridge, MA.

II. MONONOBE-OKABE PSEUDO-STATIC METHOD

The Mononobe-Okabe (M-O) pseudo-static (seismic coefficient) method is an extension of the Coulomb sliding-wedge theory taking into account horizontal and vertical inertia forces acting on the retaining wall. The analysis was described in detail by Seed and Whitman (22). The method makes the following assumptions:

1. The wall is free to move sufficiently that the soil shear strength will be mobilized along the potential failure surface (i.e., active limiting equilibrium condition).
2. The backfill consists of unsaturated cohesionless material.

Force equilibrium consideration on the soil wedge (Figure 1)* behind the wall leads to the magnitude of P_{AE}, the combined static and dynamic (seismic) load exerted on the wall (and vice versa):

$$P_{AE} = 1/2\ \gamma\ H^2\ (1-k_v)\ K_{AE} \tag{1}$$

where,

K_{AE} = the seismic active pressure coefficient given by the M-O expression:

$$K_{AE} = \frac{\cos^2\ (\phi - \theta - \beta)}{\cos\ \theta\ \ \cos^2\beta\ \cos\ (\delta + \beta + \theta)\ \left[1 + \left(\frac{\sin\ (\phi + \delta)\ \sin\ (\phi - \theta - i)}{\cos\ (\delta + \beta + \theta)\ \cos\ (i - \beta)}\right)^{1/2}\right]^2} \tag{2}$$

(see Figure 1c):

γ = total unit weight of soil (unsaturated)

H = height of wall (soil face)

ϕ = angle of internal friction of backfill

δ = angle of friction at wall-backfill interface

i = backfill slope angle

β = slope angle of wall at soil-wall interface (negative, as shown)

$$\theta = \tan^{-1} \frac{k_h}{1 - k_v}$$

---

*At end of paper.

k_h, k_v = horizontal and vertical acceleration (seismic) coefficient, respectively.

Also in reference to Figure 1,

W_s = weight of the soil failure-wedge

W_w = weight of the wall (includes the weight of the confined backfill in Figure 1b)

h_a = line of action of the resultant soil force measured from the base of the wall.

Whitman (26) noted that Eq. 1 essentially corresponds to the static Coulomb equation for the condition where the wall and backfill are rotated by an angle θ such that i becomes $(i + \theta)$ and β becomes $(\beta + \theta)$.

In Figure 2, $K_{AE} \cos \delta$ has been plotted vs. k_h for the condition $k_v = \beta = i = 0$, $\delta = 1/2 \ \phi$. A straight line approximation for the curves has also been incorporated (26). From Figure 2, for the simplified straight line approximation:

$$K_{AE} \cos \delta = K_A + 3/4 \ k_h \tag{3}$$

where, K_A = the static active coefficient.

The first and second term (right side) of Eq. 3 corresponds to the static and dynamic components of the M-O coefficient, K_{AE}, respectively. Eq.3 was originally proposed by Seed and Whitman (22).

Rewriting Eq. 3 with $\delta = 0$:

$$K_{AE} = K_A + \Delta K_{AE} \tag{4}$$

where,

ΔK_{AE} = active coefficient for the dynamic increment, one obtains:

$$\Delta K_{AE} \cong 3/4 \ k_h \tag{5}$$

Thus, the dynamic soil force component is:

$$\Delta P_{AE} \cong 1/2 \ \gamma \ H^2 \ 3/4 \ k_h = 3/8 \ \gamma \ H^2 \ k_h \tag{6}$$

III. MASSACHUSETTS BUILDING CODE ON SEISMIC DESIGN OF RETAINING WALLS

Section 716.6.10 (Retaining Walls) of the Code (25) specifies that:

"Retaining walls shall be designed to resist at least the superimposed effects of the total static lateral pressure, excluding the pressure caused by any temporary surcharge, plus an earthquake force of 0.045 $\gamma_t H^2$ (horizontal backfill surface). The earthquake force from the backfill shall be distributed as an inverse triangle over the height of the wall...If the backfill consists of loose saturated granular soil, consideration shall be given to the potential liquefaction of the backfill during the seismic loading."

In this study, only unsaturated backfills are considered. Liquefaction problem and its related effects were investigated earlier (23) in reference to Massachusetts.

"DESIGN EARTHQUAKE" FOR MASSACHUSETTS

In Section 716.7 (Dynamic Analysis), the Code (25) specifies that:

"Any building or structure is deemed to have complied with the provisions of Section 716.0 if a qualified registered engineer determines that there is negligible risk to life safety if the building or structure experiences an earthquake with a peak acceleration of 0.12 g and a frequency content similar to that implied by the appropriate response spectrum in Figure 716.2".

Figure 716.2 of the Code (25) also incorporates amplification effects of local subsoil conditions (i.e., thickness, strength) supporting a structure. Section 716.7 does not make any direct reference to the magnitude or duration of the "design earthquake".

The Code's "design earthquake" with a peak acceleration of 0.12 g is primarily proposed for buildings. However, it also provides a basis for the seismic input to be considered in earthquake design of retaining walls. The selection of a "design acceleration coefficient" for pseudo-static seismic analysis of a proposed facility (e.g., building, retaining wall, gravity or embankment dam) is indeed a difficult task and often done arbitrarily.

SOME NOTES ON SECTION 716.6.10 OF THE CODE

Section 716.6.10 (25) considers retaining walls in general. Quite understandably, the Code does not make specific reference to the type of wall (e.g., gravity wall, cantilever wall, bridge abutment, building basement wall, quay wall). This truly important aspect must not escape the attention of the design engineer who may use the same criterion for all types of earth retaining structures regardless of their structural rigidity-flexibility and yielding-nonyielding character.

It is also noted that Section 716.6.10 (25) does not make a reference to the inertia effect of the retaining wall itself. It is not known whether this is intentional or not, since "current procedures generally assume that the inertia forces due to the mass of the retaining wall itself may be neglected in considering the seismic behavior and seismic design of gravity retaining walls." (21, pg. 454) This is certainly not correct, since the weight of the wall provides the primary resisting potential against movement of the wall. The inertial loading on the wall itself should definitely be included in design analysis (22, 27).

BASIS OF SECTION 716.6.10.

Considering Eq. 6 and substituting k_h=0.12, one obtains:

$$\Delta P_{AE} \cong 3/8 \gamma H^2 (0.12) = 0.045 \gamma H^2 \qquad (7)$$

which is the expression specified by the Code to determine the dynamic (seismic)loading acting on a retaining wall during ground shaking.

As to the line of action of the dynamic component, ΔP_{AE}, the original"Mononobe-Okabe solution by itself tells nothing about location of the dynamic earth pressure." (26, p. 1442) Based on test data (model walls on shaking table) reported by Jacobsen (11) and Matsuo (16) and theoretical analysis of Prakash and Basavanna (20), Seed and Whitman (22) suggested that the resultant dynamic increment acts at a height varying from 0.5H to 0.67H above the base of the wall. Section 716.6.10 (25) reflects this opinion. Later Whitman (26) restated that as a simplification, while the static component, P_A, acts at 1/3 of the wall height, the additional dynamic component, P_{AE}, acts at about 2/3 of the wall height.

IV. MODE OF EARTHQUAKE INDUCED DAMAGE ON RETAINING WALLS

In their state-of-the-art review Seed and Whitman (22) for unsaturated backfills cited a retaining wall failure in 1970 Chilean earthquake, and outward movement of the wingwalls of a bridge in 1964 Niigata earthquake. On the lack of reported cases of earthquake induced damage on retaining walls, Seed and Whitman suspected that this may be more so due to the type of damage not being as dramatic compared to other rather catastrophic failures.Seed and Whitman, however stated that "many earthquake damage reports contain accounts of the movements of bridge abutments due to increased lateral pressures resulting from earthquake effects. In such cases, wall movement causes severe distortion or possibly collapse of the bridge superstructure." (22, p. 140) Thus, Seed and Whitman concluded that the possibility of movements of earth retaining structures due to earthquake induced increased lateral pressures must be a significant design problem in seismic regions.

More recent reported cases have confirmed that earthquake induced movements of abutments indeed played a major role in associated bridge damage. Evans (7) surveyed the damage to bridges in the 1968, M = 7 Inangahna earthquake in New Zealand. Out of 39 bridges within 30 miles of the epicenter, 23 showed distinct abutment movement and 15 experienced structural abutment failures. Abutment movements followed the pattern of outward lurching relative to the base, and rotation about the top due to restraint by the bridge deck. Ellison's (3) pictorial report illustrated the damage on bridge abutments in the 1970, M = 7.1 Madang earthquake in New Guinea, where some abutments moved as much as 20 inches. Fung et. al. (9) and, Clough and Fragaszy (2) reported damages to abutments and floodway retaining structures in the 1971 San Fernando, California earthquake. A common feature in these case histories is the small to excessive outward movement of bridge abutments and other retaining structures caused by earthquake induced large lateral earth pressures.

V. RICHARDS-ELMS MODEL BASED ON SLIDING BLOCK ANALOGY

In 1979 Richards and Elms (21, 4) proposed a procedure for earthquake design of retaining walls, which was based on field observations that a retaining wall does not fail when the base ground acceleration results in a sliding factor of safety equal to 1.0, but rather the wall simply develops a finite, permanent displacement relative to the base ground. Further, Richards and Elms demonstrated that this relative displacement is calculable. On this basis, they developed a design model fundamentally different than the previous pseudo-static (seismic coefficient) models.

Using the Richards-Elms model, the design engineer initially chooses an allowable permanent (irreversible) displacement for the wall, uses it to compute a "rational" (27) design acceleration (seismic coefficient), and then estimates the wall weight required for the specified condition.

Richards-Elms model is based on the analogy of sliding block which was originally introduced and used by Newmark (18) in analysis of earthquake induced displacements in embankment dams.

Whitman (27) presented an illustration of the sliding block analogy applied to the seismic behavior of gravity retaining walls, as follows. The forces acting on a gravity wall during an earthquake for the condition of active limiting equilibrium are shown in Figure 3. At the moment the earthquake induced acceleration acting upon the failure wedge and the wall (Figure 1) exceeds the limiting value of Ng, the wall and the failure wedge are unable to follow the base ground motion and a slip occurs along the base of the wall as well as the failure plane through the backfill. The limiting acceleration coefficient N is, by definition, equal to k_h in Eq. 1 and 2. The slip will stop when the base ground acceleration falls below Ng. The permanent relative displacement as a result of a single slip will be rather small. With a base ground motion, having a number of peak accelerations, there will be a number of intervals of slip, each followed by intervals during which the wall moves together with the base ground (i.e., they both have the same velocity). This progressive behavior is illustrated in Figure 4.

Referring to Figure 3, and disregarding any tilting and vertical acceleration of the wall and the failure wedge, the value of the limiting acceleration Ng, may be derived as follows (27). Applying equations for force equilibrium (Figure 3):

$$F = W_W + P_{AE}\ (N)\ \sin\delta \tag{8}$$

$$W_w N + P_{AE} (N) \cos \delta = F \tan \phi_b \qquad (9)$$

Assuming $\delta = 0$, and using Simplified Seed model (Eq. 3):

$$P_{AE} = 1/2 \ \gamma \ H^2 \ (K_A + 3/4 \ N) \qquad (10)$$

Introducing a safety factor (F.S.) against sliding under static loading,

$$F.S. = \frac{W_w \tan \phi_b}{1/2 \ \gamma \ H^2 \ K_a} \qquad (11)$$

and substituting Eqs. 11, 10 and 8 into Eq. 9:

$$N = \frac{F.S. -1.0}{(3/4 \ K_a + \frac{F.S.}{\tan \phi_b})} \qquad (12)$$

Having established the limiting acceleration Ng for a gravity retaining wall-backfill system, cumulative relative displacement may be estimated for a given earthquake record (Figure 4). Newmark (18) performed such analyses for four different earthquake records. For comparison of resulting displacements, Newmark (18) normalized the earthquake records in each case to a maximum acceleration of 0.5g and a maximum velocity of 30 in. per sec. Franklin and Chang (8) extended Newmark's work by analyzing 169 horizontal, 10 vertical accellerograms and several synthetic records, also normalized to Newmark's scale of 0.5g and 30 in.per sec. Upper bound envelope curves of permanent displacements analyzed by Franklin and Chang (8) are depicted in Figure 5. Upper bound envelope curves proposed by Newmark (18) are also incorporated in Figure 5.

Based on Figure 5, Richards and Elms (21, 4) proposed that for standardized maximum displacements in the medium to low range, a suitable approximation is given by the expression:

$$d \text{ (inch)} = 0.087 \frac{V^2}{Ag} \left(\frac{N}{A}\right)^{-4} \qquad (13)$$

where,

d = cumulative relative displacement of a wall subjected to an earthquake record whose maximum horizontal acceleration coefficient is A and maximum horizontal velocity is V (in. per sec.),

N = the limiting acceleration coefficient (equal to k_h in Eq. 1, 2).

EFFECT OF WALL INERTIA

A key feature in the Richards-Elms analysis is the consideration of the effect of wall inertia. The free-body diagram of a retaining wall at seismic active limiting equilibrium condition is shown in Figure 6.

From force equilibrium:

$$F = (1 - k_v)\ W_w + P_{AE}\ \sin\ (\delta + \beta) \tag{14}$$

$$T = P_{AE}\ \cos\ (\delta + \beta) + k_h\ W_w \tag{15}$$

At incipient sliding,

$$T = F\ \tan\ \phi_b \tag{16}$$

Substituting from Eqs. 16 and 14 into Eq. 15,

$$P_{AE}\ [\cos\ (\delta + \beta) - \sin\ (\delta + \beta)\ \tan\ \phi_b] = W_w\ [(1 - k_v)\ \tan\ \phi_b - k_h] \tag{17}$$

Recalling from Eqs. 1,2,

$$P_{AE} = 1/2\ \gamma\ H^2\ (1 - k_v)\ K_{AE},\ \text{and}\ \tan\ \theta = \frac{k_h}{1 - k_v}$$

Eq. 17 may be re-written for W_w:

$$W_w = \frac{1/2\ \gamma\ H^2\ [\cos\ (\delta + \beta) - \sin\ (\delta + \beta)\ \tan\ \phi_b]}{\tan\ \phi_b - \tan\ \theta}\ K_{AE} \tag{18}$$

or as,

$$W_w = \frac{[\cos\ (\delta + \beta) - \sin\ (\delta + \beta)\ \tan\ \phi_b]}{(1 - k_v)\ (\tan\ \phi_b - \tan\ \theta)}\ P_{AE} \tag{19}$$

Eq. 18 or 19 is used to compute the required wall weight for the condition of F.S. = 1.0 against sliding during ground shaking.

To investigate the additional wall weight required to resist the wall inertia effect in comparison to the total design weight, Richards and Elms (21,4) expressed Eq. 19 in the form:

$$W_w = C_{IE} \quad P_{AE} \tag{20}$$

where,

$$C_{IE} = \frac{\cos (\delta + \beta) - \sin (\delta + \beta) \tan \phi_b}{(1 - k_v) \ (\tan \phi_b - \tan \theta)} \tag{21}$$

Further, they introduced two factors; a soil thrust factor, F_T and a wall inertia factor, F_I by normalizing the dynamic effect of the soil failure wedge and the wall with respective static values;

$$F_T = \frac{K_{AE} \ (1 - k_v)}{K_A} \tag{22}$$

$$F_I = \frac{C_{IE}}{C_I} \tag{23}$$

where,

$$C_I = \frac{\cos (\delta + \beta) - \sin (\delta + \beta) \tan \phi_b}{\tan \phi_b} \tag{24}$$

Richards and Elms (21,4) demonstrated that magnitudes of F_T and F_I are of the same magnitude in the range of $k_h = 0$ to 0.5, and therefore the wall inertia force is as important as the dynamic soil thrust. Thus, the wall inertia effect cannot be ignored in the seismic design of gravity retaining walls.

VI. SEISMIC DESIGN OF GRAVITY RETAINING WALLS FOR LIMITING DISPLACEMENT

Based on the background presented in previous sections, Richards-Elms procedure for seismic design of gravity retaining walls includes the following steps:

1. For the gravity wall under consideration, select an acceptable maximum displacement, d, relative to the base ground.

2. Recalling,

$$d \text{ (inch)} = 0.087 \ \frac{V^2}{Ag} \left(\frac{N}{A}\right)^{-4} \tag{13}$$

and substituting,

$N = k_h$

$A = A_a$ (24)

V(in./sec.) = $30\ A_v$ (24, p.301)

$g = 386.4$ in./sec.^{2}

where A_a and A_v, both dimensionless parameters, are defined as "effective peak acceleration coefficient" and "velocity-related acceleration coefficient" respectively (24). Eq. 13 may be inverted as:

$$k_h = A_a \left[\frac{0.2\ A_v^2}{A_a\ d\ (\text{in.})} \right]^{1/4} \tag{25}$$

where $(k_h \cdot g)$ is the cut-off acceleration for slipping corresponding to d (in.) and the regional seismicity represented by A_a, A_v. Eq. 25 provides a rational way of determining k_h.

3. Incorporate k_h in Eq. 2 to compute corresponding K_{AE}. Incorporate K_{AE} in Eq. 18 to estimate the required wall weight, W_w.

4. Apply a suitable factor of safety F.S. to W_w.

In their original work, Richards and Elms (21) recommended a safety factor of 1.5 to be used for the estimated wall weight. However, recently Elms (6) has noted that small scale tests conducted at the University of Canterbury, New Zealand (13, 14) have confirmed the reasonableness of the original Richards-Elms assumptions such that one can have more confidence in the analysis, and thus a lower safety factor (i.e., 1.2 to 1.3) would be appropriate.

5. In proportioning the wall geometry, make certain that it would "fail" by sliding rather than by tilting. In order that the wall would slide rather than tilt (overturn) Elms and Richards (4) showed that the location of the resultant of forces acting on the base of the wall, measured from the inner toe of the wall, x_o (Figure 7) should be at least equal to:

$$x_o = \frac{h\ [\cos\ (\beta + \delta) + \tan\beta\ \sin\ (\beta + \delta) + C_{IE} F.S[k_h \bar{y} + (1 - k_v)\ \bar{x}]}{\sin\ (\beta + \delta) + (1 - k_v)\ C_{IE}\ F.S} \tag{26}$$

where,

h = height of the resultant soil force from the base of wall (may be taken as $h = H/2$)

$\bar{x}$, $\bar{y}$ = coordinates of wall center of gravity

Whitman (27) used a different approach to determine the cut-off acceleration (coefficient) for sliding, $N = k_h$, from Eq. 13 or other expressions relating A, V and N proposed by Newmark (18)(Figure 5). In order to relate peak velocity, V, to peak acceleration coefficient, A, Whitman (27) suggested two ratios: V/A= 1250 mm/sec.(soft soil) and V/A=750 mm/sec., (very firm soil/rock) which represent the two "ends" of the typical range for this rate.

VII. SAMPLE DESIGN PROBLEM OF GRAVITY RETAINING WALL

A sample gravity wall design problem was worked out to develop a comparative picture of the required wall weights estimated by various procedures reviewed in the study. All analyses were conducted for the condition of "failure" induced by sliding. Seismic parameters proposed for Massachusetts by the Code (25) and the ATC 3-06 (24) were incorporated in respective analyses. The design parameters assigned for the sample problem were as follows:

H (height of gravity retaining wall) = 16 ft.

ϕ (angle of internal friction for backfill) = 33°

δ (angle of friction along wall-backfill interface) = 16.5°

ϕ_b (angle of friction along wall-base ground interface) = 33°

γ_s (total unit weight of unsaturated backfill) = 100 pcf.

γ_c (unit weight of concrete/masonry) = 150 pcf.

β (angle of inclination of wall-backfill interface measured from vertical) = 0°

i (slope angle of backfill surface measured from horizontal) = 0°

d (selected permanent displacement in Richards-Elms analysis) = 0.5 in.

First, a static analysis was made to form a reference base. A static safety factor of 1.5 against sliding was adopted in analysis. It was estimated that a wall weight of 6,605 lb/ft. would be required.

Second, the sample problem was analyzed for earthquake condition in accordance with the Code (25), Section 716.6.10. As stated previously the Code makes reference neither to wall inertia component nor to safety factor(s) to be incorporated in design analysis. Herein, the wall inertia effect was taken into account, and a static safety factor of 1.5 was used against sliding. Furthermore, load factors of 1.15 and 1.0 were adopted for wall inertia effect and dynamic soil thrust, respectively. It was estimated that a wall weight of 10,640 lb/ft. would be required.

Third, the sample problem was analyzed following the Richards-Elms limiting displacement procedure. As recommended by Richards and Elms (21), ATC 3-06 (24) was used to obtain the representative seismic parameters A_a and A_v proposed for Massachusetts: $A_a = 0.10$ and $A_v = 0.10$. A limiting displacement of 0.5 in. was chosen. Corresponding to d = 0.5 in., the limiting acceleration coefficient was computed to be N = 0.045 (Eq. 25). For an overall (i.e., static and dynamic) factor of safety of 1.0, the required weight of the wall was estimated to be 4,830 lb/ft from Eq. 18. A conservative overall safety factor of 1.5 would require a wall weight of 7,250 lb/ft. On the other hand a more realistic safety factor, such as 1.3 (6) would require a wall weight of 6,280 lb/ft. A somewhat more elaborate analysis, considering a static factor of safety of 1.5 and a load factor of 1.15 for dynamic component disclosed that a wall weight of 7,000 lb/ft. would be required.

Fourth, Richards-Elms analysis was conducted, following the approach used by Whitman (27) to obtain the limiting acceleration for sliding (Eq.13). With the "end" values of V/A = 1250 mm/sec. and V/A = 750 mm/sec., limiting acceleration coefficients N =0.072 and 0.056 were computed, respectively. Using these values, it was estimated by Eq. 18 that wall weights of 5,330 lb/ft. and 5,020 lb/ft. would be required respectively for a safety factor of 1.0. Considering a safety factor of 1.3 would increase these values to 6,930 lb/ft. and 6,520 lb/ft., respectively.

Computed design weights for the sample gravity wall by different procedures are summarized in Table I.

VIII. SOME FINAL REMARKS

1. The results from design analyses of the sample problem given in Table I suggest that a gravity retaining wall which is free to experience a "reasonable" permanent displacement due to ground shaking may be considerably lighter than that designed in accordance with the Code (25), Section 716.6.10 with the wall inertia included. Elms and Martin (5) recommended that acceleration coefficient, k_h, in Mononobe-Okabe model (Eqs. 1, 2) be taken as $0.5A_a$ (i.e., in place of A_a) for the design of gravity retaining walls, provided that an allowance is made for an outward displacement of 10 A_a (inch) to occur.

2. The results (Table I) suggest that if a gravity retaining wall is designed for static loading conditions with a safety factor of 1.5 against sliding, the wall is almost capable of supporting seismic loading as well (i.e., for Massachusetts seismicity), provided that a reasonable permanent displacement of the wall is allowed.

3. The Code (25) does not make a distinction between rigid vs. flexible and yielding vs. nonyielding retaining walls. As a matter of fact, if a retaining wall is fully restrained against movements (i.e., it is rigid and nonyielding), seismically induced soil thrust and wall inertia effect would necessitate considerably heavier walls to meet design requirements. Simplified elastic solutions presented by Wood (28, 29) indicate that for rigid-nonyielding retaining walls, dynamic thrust could be twice that given by the Mononobe-Okabe model.

4. Possible amplification of the ground shaking through wall backfill may also increase dynamic thrust. Such amplification effects are quite complex for analysis and are excluded in the design of ordinary retaining walls.

5. Richards-Elms (21, 4) analysis for design of gravity retaining walls uses a highly simplified model which excludes several relevant factors such as vertical motion of the backfill, vertical acceleration of the base ground and tilting of the wall during seismic activity (27). Zarrabi (30) refined the Richards-Elms model, considering the wall and soil failure wedge as separate components and including the change in the active seismic lateral thrust during wall movement. Vertical base ground accelerations were also accounted for. Reanalysis of Lai's (13) model wall test data

by Jacobson (12) disclosed that Zarrabi model gave a somewhat better description of the seismic behavior of the wall.

6. Aitken's (1) recent shaking tests carried out on a model gravity retaining wall designed to fail by sliding have shown that:

i. If the sand behind a gravity retaining wall is compacted at above its critical density (void ratio), then the initial movement of the wall will require higher horizontal ground accelerations than will subsequent movements.

ii. Once a well developed failure surface (wedge) was formed, the assumptions used in the Richards-Elms model appear to be essentially correct. This includes the basic assumption that once the threshhold acceleration is reached the wall will continue to move at that acceleration until the ground and wall velocities match.

iii. Within the accuracy imposed by limitations on the knowledge of soil properties along the failure surface, the Richards-Elms (21, 4) model provides a good prediction of wall displacement, and further refinement of the model is not justified for gravity walls designed to "fail" by sliding.

7. The seismic behavior of overturning (rotating) gravity walls is substantially more complicated than for the mode of sliding. The seismic behavior of overturning gravity walls are currently (1982) being investigated at the Massachusetts Institute of Technology and University of Canterbury. New findings should be incorporated in design analysis as they become available.

ACKNOWLEDGEMENT

The author owes much to Prof. R. V. Whitman, Massachusetts Institute of Technology; Prof. D.G. Elms, University of Canterbury, New Zealand; Dr. J. H. Wood, Central Laboratories, Ministry of Works and Development, New Zealand; Prof. R. Richards, Jr., University of Buffalo, New York; and Dr. I. M. Idriss, Woodward-Clyde Consultants, California, who have provided extensive material, guidance and inspiration to the author. Help received from the Earthquake Engineering Research Laboratory Library, University of California is highly appreciated. The author is grateful for the continuing support provided by Haley & Aldrich, Inc., Professional Development Program. Ms. L. Butterworth typed the manuscript and Ms. A. Welch drafted the figures.

TABLE I

Estimated Required Weights, W_w, for the Sample Gravity Retaining Wall Problem

Design Parameters: H = 16 ft., $\phi = 33^\circ$, $\delta = 16.5^\circ$, $\phi_b = 33^\circ$,

γ_s (soil) = 100 p.c.f., γ(concrete) = 150 p.c.f.

Procedure/Condition	Estimated W_w (lb/ft)
1. Static: F.S. = 1.5	6,605
2. Mass Building Code (Section 716.6.10)	
F.S. (static) = 1.5, (dynamic) = 1.0,	
(wall inertia) = 1.15	10,640
3. Richards-Elms; ATC 3-06	
Limiting Displacement = 0.5 in.	
F.S. (static) = 1.5,(dynamic) = 1.5	7,250
F.S. (static) = 1.3, (dynamic) = 1.3	6,280
F.S. (static) = 1.5, (dynamic) = 1.15 (approximate)	7,000
4. Richards-Elms; Whitman (21)	
Limiting Displacement = 0.5 in.	
V/A = 750 mm/sec, F.S. (static) = 1.3, (dynamic) = 1.3	6,520
V/A= 1,250 mm/sec, F.S. (static) = 1.3, (dynamic) = 1.3	6,930

NOTE: The mode of failure is by sliding.

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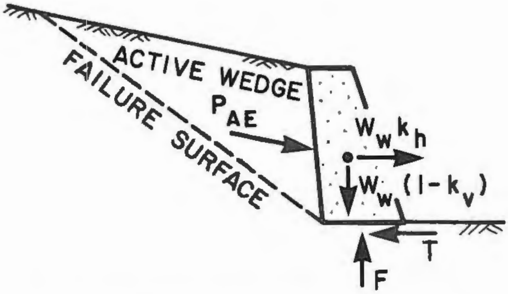
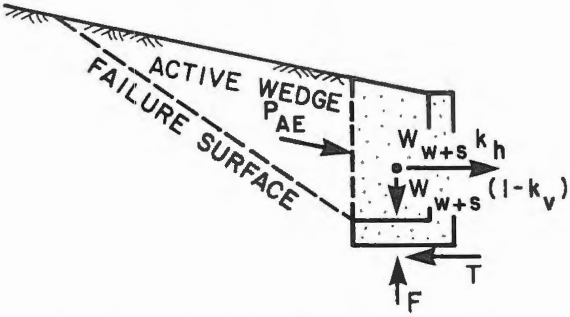
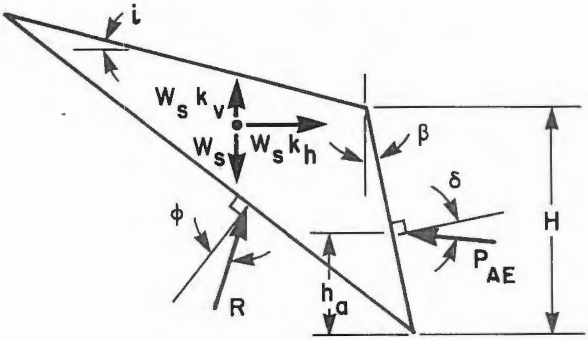


a. GRAVITY RETAINING WALL



b. CANTILEVER RETAINING WALL



c. ACTIVE SOIL WEDGE

Figure 1. FORCE DIAGRAMS FOR ACTIVE LIMITING EQUILIBRIUM CONDITION

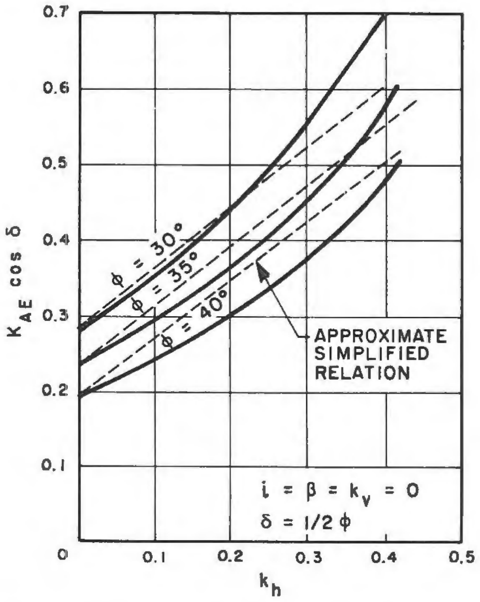
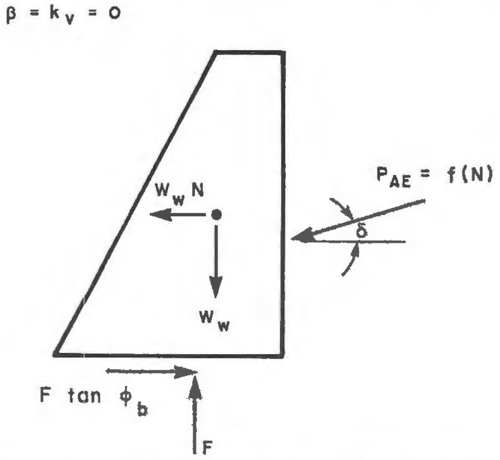


Figure 2. INFLUENCE OF ANGLE OF FRICTION OF BACKFILL ON DYNAMIC LATERAL PRESSURES DETERMINED BY MONONOBE-OKABE ANALYSIS (AFTER WHITMAN, 26)



N = LIMITING ACCELERATION COEFFICIENT (EQUIVALENT TO k_h IN MONONOBE-OKABE ANALYSIS)

ϕ_b = ANGLE OF FRICTION ALONG THE WALL-BASE GROUND INTERFACE

Figure 3. FORCES ON GRAVITY RETAINING WALL FOR LIMITING ACCELERATION (AFTER WHITMAN, 27)

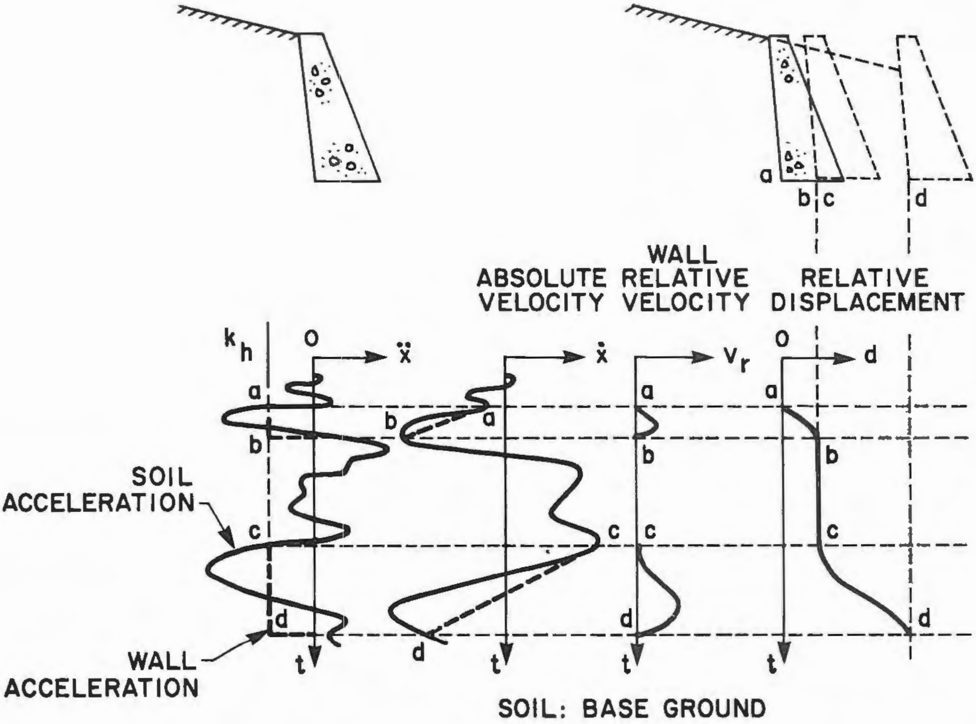


Figure 4. RELATION BETWEEN RELATIVE DISPLACEMENT AND ACCELERATION, VELOCITY TIME HISTORIES OF SOIL AND WALL (AFTER RICHARDS AND ELMS, 21)

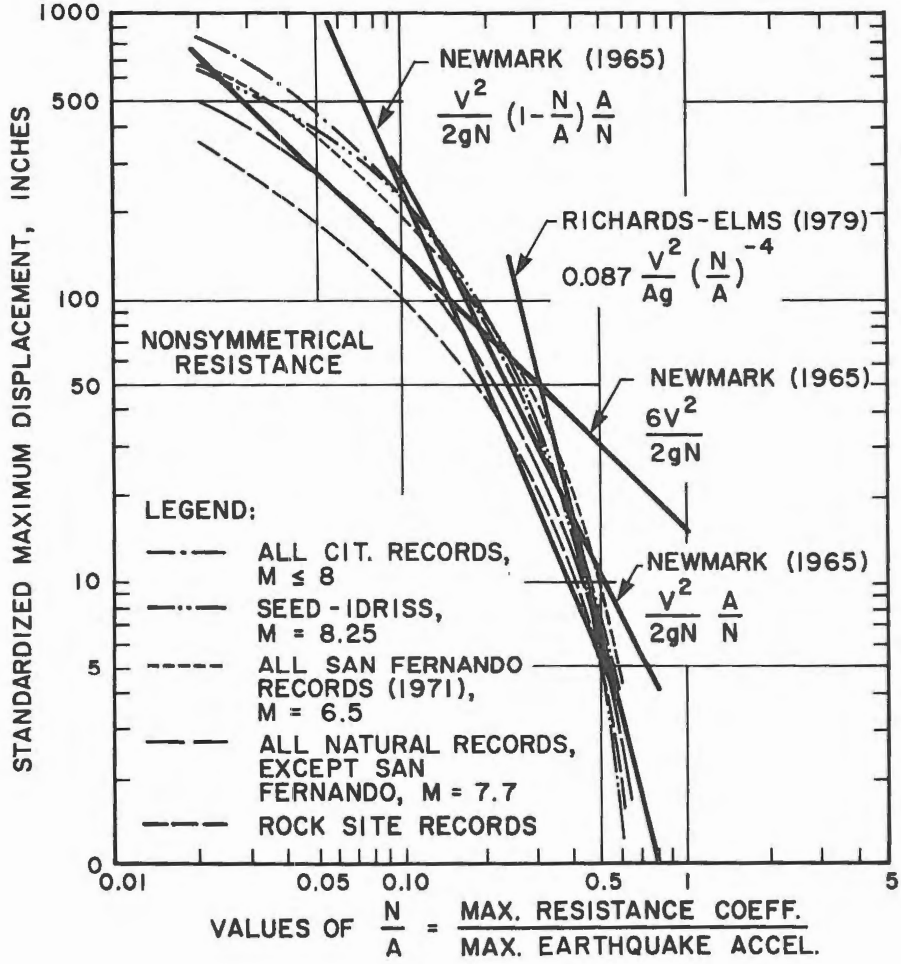
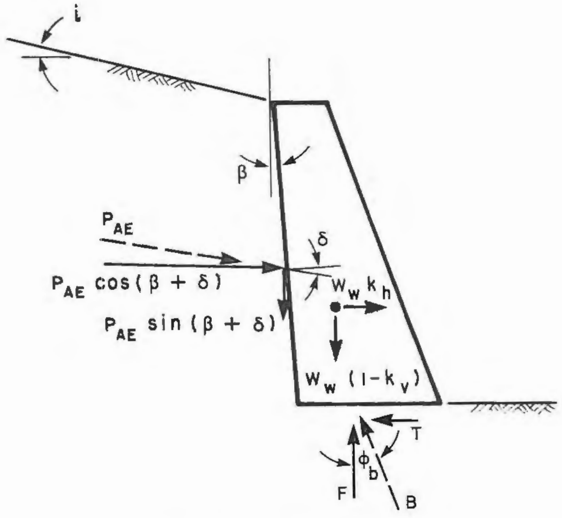
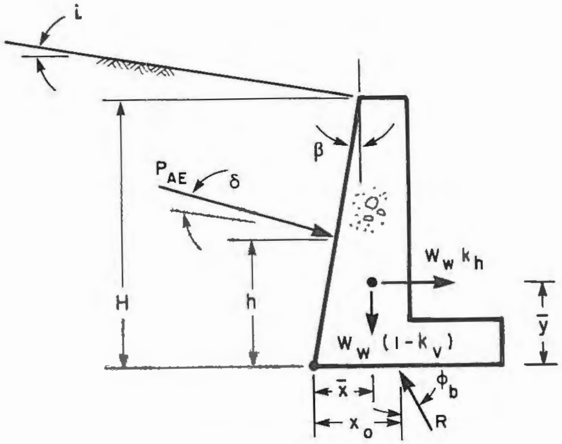


Figure 5. UPPER BOUND ENVELOPES (AFTER NEWMARK, 18, FRANKLIN AND CHANG, 8, RICHARD AND ELMS, 21)



β AS SHOWN IS NEGATIVE

Figure 6. FORCES ON GRAVITY RETAINING WALL AT SEISMIC-ACTIVE LIMITING EQUILIBRIUM



β AS SHOWN IS NEGATIVE

Figure 7. FREE BODY DIAGRAM OF GRAVITY RETAINING WALL AT ACTIVE LIMITING EQUILIBRIUM (AFTER ELMS AND RICHARDS, 4)

COMPUTER BASED STRUCTURAL ANALYSIS IN ENGINEERING PRACTICE[1]

Christian Meyer[2]

INTRODUCTION

The structural analysis task can be described as the task of predicting the behavior of a given structure which is subjected to certain prescribed actions. The actions can be as diverse as gravity loads, other forces, temperature, or boundary displacements. They can be of static or dynamic nature. They may be known with a certain degree of confidence or, more commonly, not much is known about them. The loads resulting from some future earthquake, for example, are hardly known at all.

Once the structural behavior has been predicted by solving the structural analysis problem, the behavior has to be evaluated by comparing it with prescribed norms of behavior. This includes the determination whether the resulting stresses, strains, displacements, velocities or accelerations remain within certain prescribed limits established as desirable behavior.

In this paper, modern computer analysis techniques will be surveyed. Before getting started, however, it should be stated very clearly that the application of computer methods is appropriate only for certain types of problems. It is up to the engineer to decide when and where a computer analysis is called for, and when not. To make such a decision requires

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a certain amount of experience.

Hand calculations, aided nowadays by those marvellous electronic calculators, are still sufficient in most design situations and are always needed for overall checks on computer analyses. We need them as backup to assure that the computer results make sense. But we should not overrate hand calculations either. Engineers who claim that they can analyze a space truss with 2000 members just as fast and accurately as somebody with a big computer usually make such claims only to cover up the fact that they never bothered to learn the proper use of computers themselves.

It requires a considerable amount of experience to choose the appropriate analysis tool -- whether static or dynamic; linear or nonlinear; using an approximate model with just a few equivalent beam elements, or a complex finite element model with 10,000 degrees of freedom. Familiarity with the tools available to us is necessary, as is the establishment of criteria by which certain analytical tools are chosen for a given problem. Most important, we have to know how to idealize structures correctly for analysis. This we can do only through hands-on experience by analyzing many structures and by critically studying the results. I can give only some guidelines; the actual learning process is the responsibility of each individual engineer.

Structural analysis in engineering practice involves four different fields of knowledge: 1) structural mechanics, 2) numerical methods, 3) software engineering, and 4) engineering applications.

Fundamental knowledge of structural mechanics is needed to understand the physical behavior of the structure and the laws of mechanics it obeys. But it does not solve a problem. For that purpose, accurate and stable numerical methods are needed. For accuracy, the good old sliderule used to set a useful standard: a few percent error on the safe side was generally acceptable. And what is meant by stable? If small variations of input parameters result in only small changes of output results, we know the structure is stable, and so is the solution method. If a 5% change of Young's modulus changes certain stresses by 100%, we know we have a problem.

Software engineering is a relatively new term and will be dealt with in some detail later. It basically assures that solution methods are implemented on the computer in an optimum way. It is primarily the domain of program developers.

When turning to engineering applications, we have to integrate all theory and apply it to real structures in a practical environment, subject to all the plights of real life, such as limited budgets, deadlines, and fussy bosses. This is the world of program users. They have to know how to idealize structures. They should be able to decide when and where to use a computer and, if needed, how to use it wisely, correctly and efficiently. This means program users have to know both computers and structures, i.e., be knowledgeable to some extent in all four areas mentioned above. Let them be amiss in any one, and they may easily get into trouble. It is true that program developers generally take care of the first three disciplines, but if they don't know anything about applications, they may end up solving the wrong problems or answering questions that have never been asked. On the other hand, users specialize in their own field of expertise, and they are all too often inclined to ignore or downplay the first three disciplines. This is known as the black box disease. It can be dangerous, even fatal in extreme cases, namely when structures collapse because the engineer believed that computers can make no mistakes.

Our problem is that we have powerful computers and software systems, which are not utilized to their full potential, because of a large gap between theoreticians and program developers on the one side, and practitioners on the other. This paper shall be a contribution to help bridge this gap. We don't want the university professors to talk only to each other and write papers which nobody else can understand. In the course of their research, they seem too often to lose sight of what the real problems are. But we don't want users who consider a program as a black box either. It has been estimated that half or more of all finite element analyses made in engineering practice are outright wrong. What is worse, the users are not even aware of this. So let us stamp out the black box disease. You don't have to be an expert in all three other disciplines besides your own. You only have to be able to ask the right person the right question. And team effort can also succeed, provided the various members of the team talk to each other and make an effort to understand each other's language.

Since this paper is addressed primarily to practicing engineers, the theoretical content will be limited, but it cannot be eliminated completely because, you know, to bridge a gap you best start from both sides.

BASIC REQUIREMENTS OF STRUCTURAL MECHANICS

Before turning to specific subjects, it is well to remember that all structural analysis has to satisfy three fundamental requirements of structural mechanics: equilibrium, compatibility, and constitutive equations.

No matter how we choose to look at a structure or any of its elements on a macroscopic or microscopic level, each of its elements has to be in static or dynamic equilibrium, whether we are considering finite elements like beams, columns, plates or infinitesimal particles. This fact gives us a welcome assurance, because no matter how we choose to cut a free body from a structure--if equilibrium is not satisfied, we know we have a problem.

Adjacent elements that fit together before deformation have to remain compatible also in the deformed state. If in reality some embarrassing cracks appear somewhere, an accurate analytical model will incorporate this fact in the basic formulation such that the sum of all deformations still adds up to a compatible system--on a finite element level as well as on a microscopic infinitesimal level.

The stress-strain relationships should satisfy the material law as it has been determined by experiment. This material law is prescribed on the microscopic level. When dealing with finite elements, the infinitesimal behavior has to be integrated in order to furnish force-displacement equations characteristic for the element.

STIFFNESS METHOD OF ANALYSIS

Even though each engineer graduating from an accredited engineering school should have at least one course in matrix theory of structures, it may be helpful to recall the major steps involved in a typical stiffness analysis, because almost all major structural analysis programs are employing this method, and it is always refreshing to recall some simple facts long forgotten.

The structural analysis problem is solved in two phases, an element level solution phase and a structural level solution phase. In the first phase, elements are considered individually for the derivation of appropriate force-displacement relations. This requires the "exact" solution of the governing differential equations or an approximate finite element solution. This extends the concepts of stiffness and force-displacement relationships, long known for frame members, to elements of two- and three-dimensional continua. In the second analysis phase, the individual elements are assembled such that equilibrium and compatibility at all structure nodes are satisified.

The individual steps of the analysis procedure can be briefly summarized as follows.(1,2)

1. Discretize the structure into a number of elements which may be physically discrete (beams, columns, e.g.) or only imaginary discrete. It is this subdivision of two- or three-dimensional continua into a number of imaginary discrete elements for which the analyst requires considerable skill, experience, and insight into the behavior of structures.

2. Identify for each element the degree of freedom and possible element loads to adequately represent the element behavior. This choice is usually built into programs by the developers, but the user has to be aware of this. Fig. 1a* illustrates the simplest of all elements, a truss bar with only axial stiffness. This element is fully described with one degree of freedom per end node, and its stiffness matrix is easily derived. The planar beam element of Fig. 1b is likewise familiar to engineers, with three freedoms per node (or six for a space frame member), and the stiffness coefficients are well known. Subdividing plane stress or plane strain continua into imaginary finite elements, Fig. 1c,

*At end of paper.

requires the introduction of two freedoms per node. The stiffness for this element cannot be written down easily; a finite element problem has to be solved for a more or less approximate stiffness. A similar situation is encountered when discretizing a plate bending problem, Fig. 1d, where three freedoms per node are required, one normal displacement and two rotations. In order to appreciate this, some background knowledge in plate theory will prove to be quite helpful. Again, the derivation of a general element stiffness matrix is possible only with the aid of finite element theory, and the actual stiffness is generally evaluated only numerically. Three-dimensional solids may be discretized with isoparametric curvilinear solid elements, Fig. 1e, with three displacement freedoms per node. A popular element employs midside nodes, thus leading up to 21 nodes with 63 freedoms. Again, the stiffness matrix, now a 63 by 63 matrix, is generally evaluated numerically.

3. Compute for each element the stiffness properties and nodal loads, which are statically equivalent to the loads distributed over the element. For truss and beam elements this is straightforward, and closed-form expressions are easily given. For two- and three-dimensional elements, finite element theory is used to compute the stiffness coefficients.

4. Transform element stiffnesses and load vectors to a coordinate system common to all structural elements. It should be noted that different coordinate systems may be assigned for different nodal points, but for a given node, all the stiffness coefficients of all elements connected to this node must be expressed in a common reference frame, so that they may be added algebraically.

5. Form the equilibrium equations for all nodal degrees

of freedom of the structure. This step requires the assemblage of the structure stiffness matrix such that all element stiffnesses contriubting to the same freedoms are added algebraically. At the same time, the structure load vector is assembled from the individual element load vectors and other loads that may be applied directly to the nodes.

6. Apply the specified boundary conditions to the equilibrium equations. Physically, a structure without boundary conditions will fly away under load -- it has rigid body modes. Mathematically, the structure stiffness is singular, i.e., its determinant is zero, and the equations cannot be solved uniquely. For this reason, we have to introduce as many linearly independent constraints (boundary conditions) as there are rigid body modes.

7. Solve the equilibrium equations for the unknown nodal displacements (and reactions). This is usually the most time-consuming step, often taxing even the fastest and biggest computers available. The large amount of numerical computations and demand on computer memory space can be drastically reduced by taking advantage of the facts that the equations are:
1) symmetric (because of Maxwell-Betti's law of reciprocity),
2) positive-definite (because the strain energy associated with any mode of deformation must always be positive), and
3) sparse (because of limited connectivity between the various structure nodes, most stiffness coefficients are zero). The actual number of operations and storage requirements of the solutions process depend very much on the sequence in which the unknowns are eliminated. Numerous efficient solution schemes are available.(3,4) The most common ones are band-solvers and frontal solvers, for which, respectively, the bandwidth or wavefront has to be minimized for maximum

efficiency. The availability of new generations of computers and the continuing decrease in cost per unit calculation require a continued reevaluation of solution methods in regard to total cost requirements. Taken as a fraction of the total analysis cost, equation solution cost is now of such insignificant that further optimization of solution algorithms is seldom justified when the solution cost is compared with the cost of the total man-hours for an entire project. In nonlinear dynamic analysis, on the other hand, where large sets of equations may have to be solved possibly thousands of times, significant savings in cost can be effected by the use of an optimized solver. The emergence of personal computers is also changing the economy of computation. If a problem is running on my own machine, cost is no problem anymore, but running time may be. But even if a problem runs for hours, it will have only minor impact on overall solution strategy. The good news is then that the cost factor in computation is becoming less important, and that the analyst gets more freedom in choosing the finite element mesh to suit a given problem, almost apart from cost consideratons.

8. Determine the element deformations and stresses or forces from the displacements. This step completes the structural analysis.

FINITE ELEMENT THEORY

Although the basic concepts underlying finite element theory have been known to applied mathematicians for some time, the direct application to problems in structural mechanics dates back only 25 years, if one considers the classical paper by Turner, et al. (5) as the birthdate of finite element analysis. By now, the finite element method has established itself as an indispensible tool for the analysis of complex structures.

The fundamental idea is extremely simple. If some choice for the displacement field in a continuum is made, the principle of minimum potential energy can be used to derive a stiffness matrix for the domain over which the displacement field is assumed to be applicable. The theory is well-documented in several textbooks (6,7,8), and no attempt will be made here to go into details. It should only be noted that the finite element method is an approximate method, because the "true" displacement variation is approximated by some assumed variation. As a consequence, internal stress equilibrium is not satisfied exactly (at least for such "displacement models"), and users should be aware of this fact. But the errors become smaller, i.e., results converge towards theoretical solutions, if either the element mesh is refined, or if the order of the displacement field is increased, or both.

The real power of the method derives from the flexibility with which arbitrary boundary geometries, varying material properties, and individual element thicknesses can be represented. Also, the method is readily extendable to dynamic loads, large displacements and nonlinear materials. The main difficulty associated with finite element analysis derives from the need to develop large mathematical models with many degrees of freedom, if meaningful results are expected, and complex computer programs are required as well as sophisticated users to run them. It takes a lot of training and experience to construct proper mathematical models and to obtain correct results from them. We shall return to this subject later.

NONLINEAR ANALYSIS

The more difficult the class of problems to be solved is, the more likely it will be that we need advanced computer programs to perform the lengthy arithmetic calculations. Nonlinear programs are a good case in point. Although many problems in engineering practice can be approximated by linear elastic theory, there are some classes of problems which do require nonlinear analysis, if any meaningful results are to be obtained.

The first such groups of problems are those with geometric nonlinearities. These are structures with large displacements or instability problems. Also pseudo-nonlinear problems belong in this category, such as structures with members characterized by one-way action or contact problems. Cables and hangers with only tensile strength are a common example. Another example is a pipe, which deflects until a specified gap is closed, whereupon the pipe is supported, introducing a pseudo-geometric nonlinearity. Among the most difficult problems are those involving friction. A pipeline, resting on the sea floor and subjected to temperature variations, might move, but the resulting displacements and stresses are functions of the friction forces and very difficult to simulate numerically.

The other group of nonlinear problems involves material nonlinearities. All common structural materials exhibit this behavior. Steel flows plastically after reaching its yield stress. Concrete cracks at very low tensile stresses, and in compression the stress-strain behavior is nonlinear, starting at rather low stress levels. In addition, there is creep behavior, very pronounced for concrete, but also for metals, especially at elevated temperatures. Temperature loads also often introduce nonlinearities. Then there are other materials with pronounced nonlinear properties. Soils are, of course, the most common ones, but there are also new structural materials (such as composites, plastics and foams, synthetic rubbers and vinyls) used to cover large open spaces.

The analysis of nonlinear problems represents a challenge which demands considerable skills and knowledge on the part of the analyst. We shall return to this subject later.

DYNAMIC ANALYSIS

Most loads encountered in practice are of a dynamic nature, even though for engineering purposes it is often permissible to neglect the dynamic effects. Dynamic loads can be subdivided into two groups. The first one contains those loads involving many cyclic load reversals, such as traffic, earthquakes, wind, waves and machinery. If these loads are rich in frquencies at or near important structural frequencies, then this fact may strongly influence the response. The other group includes short, intense, impulse-like loads such as those due to blast and missile impact. Because of the very high strain rates associated with these loads, the material rate effects will generally have to be considered, especially at the front of a shock wave traveling through the structure or medium.

Traffic loads on highway or railway bridges seldom require dynamic analysis. In engineering practice, the dynamic effects are usually simulated by impact factors, to be included in the static analyses. Even if the dynamic effects are computed more accurately the structure response under such service loads is usually linear, so that nonlinear dynamic analysis is seldom if ever necessary.

Earthquakes belong to the important natural phenomena, which have to be considered in many parts of the world. While actual ground ruptures are localized to the immediate fault vicinity, the ground motion is more important, because possibly thousands of square miles may be subjected to vibratory motion. The designer is interested primarily in the intensity, duration, and frequency content of this ground motion. Since the strain rates are only moderate (up to about 0.05 in/in/sec), mathematical models derived for static loads are generally adequate to simulate earthquake response.

While earthquakes produce vibrations about a zero mean, wind presssure fluctuates about certain nonzero mean values, so that it may be decomposed into a steady-state mean pressure and dynamic pressure variations about this mean. The superposition of these two components is straightforward, unless the combined response enters the nonlinear range, in which case nonlinear superposition should be used. The strain rates of wind loadings are of the same order of magnitude as those associated with earthquake ground motions and seldom need to be considered when developing mathematical material models.

Another source of dynamic loads is represented by ocean waves, for which structures such as off-shore drilling platforms have to be designed. In the North Sea, for example, the design load is a 30 m wave with a horizontal force of 40,000 tons. In addition, underwater currents have to be considered, which are also of dynamic nature.

Earthquakes, wind, and waves have in common strain rates small enough to permit the use of static material models. And all three are of a random nature, so that their effects on structures cannot be predicted with confidence, using deterministic analyses alone. Structural performance can be predicted only in statistical terms, using established techniques of random vibration analysis (9).

The loads associated with mechanical equipment (e.g., turbines) are much more deterministic, because their operating characteristics are generally known to a high degree of certainty. These loads are neither as random as earthquakes, wind or waves, nor as destructive as blast or missile impact. The design of structures to withstand these loads is therefore straightforward. The structures should be tuned properly against the equipment in order to avoid resonance problems.

The design of nuclear power plants calls for a number of hypothetical accidents, many of which would result in highly dynamic loads, such as high-energy pipe ruptures, jet impingement, blowdown loads associated with the sudden activation of safety relief valves, and internally generated missiles. The analysis and design problems connected with these accidents are amply covered in the pertinent literature. For example, the proceedings of the last International Conference on Structural Mechanics in Reactor Technology, held in Paris in 1981 (10), contain about 870 papers, many of which address this subject.

Problems associated with missile impact span a wide range. For example, nuclear power plant containment buildings have to be designed to withstand the impact of tornado-borne debris such as a 4000 lb passenger vehicle, thrown at the containment wall with 50 mph, or a telephone pole hurled at it with 200 mph. Other cases to be considered are the impact of aircraft or fragments of a fractured turbine, and the loads resulting from high-energy pipe rupture. At the other end of the spectrum are penetrators in military attack, against which certain protective structures have to be designed. The analysis of such problems has to consider not only large displacements, large strains, and highly nonlinear material laws, but also the provision for slide lines, so that parts of the structural model may slide relative to others.

Blast loads due to chemical or nuclear explosions generate shock waves, which subject structures to highly impulsive loads. Once the shock waves hit the ground surface, they also generate ground motions very similar to earthquake ground motions. When studying the effects of weapons on protective structures, the various wave propagation effects have to be taken into account.

Once the dynamic loads have been defined in whatever form was possible or appropriate, the equations of motion have to be solved. For a deterministic analysis, the load histories have to be known precisely. But most loads are not known precisely, therefore probabilistic methods or random vibration analysis methods are needed. These do not require deterministic load input, but only certain statistical descriptions of them, such as the power spectral density, and they provide also the analysis results in terms of such statistical quantities.

Unfortunately, probablistic methods are difficult to apply to nonlinear structures, such as reinforced concrete structures subjected to overloads. In such situations, it has become accepted practice to use numerical simulation, i.e., a number of random functions are selected such that they satisfy the prescribed statistical properties of the random process. Each one of these sample functions is then treated as if it were a deterministic function, for which the nonlinear structural response can be computed. The large number of computed structural response functions can then be evaluated statistically. Such statistical response prediction is much more meaningful than the results of a single deterministic analysis, although also much more expensive, because many complete nonlinear dynamic analyses may have to be performed. But in many situations this is the only way to arrive at rational response predictions at all.

The dynamic analysis of large nonlinear structures may pose other difficulties as well, for example, those associated with excessive element distortions. When parts of the structure slide relative to others, slide lines have to be incorporated (like in missile impact problems, where the missile may push out a plug), which have to maintain equilibrium, compatibility, and the constitutive relations at the interface, including friction. When elements become excessively distorted, the commonly used Lagrangian formulations (wherein strains and stresses are expressed in a fixed global coordinate system) will break down and rezoning may become necessary. In that case, a new regular element mesh is laid out, and the motions and stresses of the old, distorted elements are mapped into the new mesh layout. Eulerian formulations do not have this problem, because here element deformations and stresses are expressed in coordinates which are traveling with the elements. Hydrodynamic analysis programs therefore normally employ Eulerian formulations.

NUMERICAL METHODS

Once a structural analysis problem has been formulated, it has to be solved. If the problem were formulated in the form of differential equations, some closed-form solution would be sought. But in computer-based methods, continuous problems are discretized, resulting in as many algebraic equations as there are degrees of freedom in the structure. The numerical tasks can be classified into three basic groups:

1. Simultaneous solution of linear equations;
2. Solution of eigenvalue problems;
3. Numerical integration of differential equations.

The solution of linear equations has already been discussed in connection with static analysis. The eigenvalue problem arises out of dynamic and buckling analyses. Dropping the loading and damping terms from the equations of motion leads to the free vibration problem, an eigenvalue problem with the structure's frequencies and mode shapes as the solution (11). If the geometric stiffness is included, the solution of the eigenvalue problem consists of the critical load and buckling mode shape.

Even though a structure may be discretized spatially using the finite element method, the discretization in time is normally done by finite differences, and some proper numerical integration method has to be employed to compute the solution. In most widely used computer codes, implicit formulations are used, wherein the equilibrium of the finite element system is enforced at the end of a time step. The resulting algebraic equations have to be solved for the incremental displacements (or accelerations) within this time step (8). Explicit formulations, which enforce equilibrium at the beginning of a time step, do not require the solution of linear equations for each time step during which the effective structure stiffness changes. Therefore it seems that explicit methods are much more efficient than implicit ones, but they are subject to stringent stability criteria, which require much smaller time steps than those necessary for implicit integration. The choice of the most efficient integration scheme therefore depends on whether it is more efficient to take many small time steps, each one requiring relatively little effort, or much fewer larger time steps, each one requiring a lot more computation.

Numerical methods have to be judged on the basis of their accuracy, stability and efficiency. Commercial programs seldom give the user the option of selecting a particular numerical solution method. But in order to avoid pitfalls, the user is advised to independently verify the correctness of the results. For linear elastic (especially static) problems this is almost unnecessary, because most linear equation solvers give acceptable answers, provided the structure is well-conditioned. But problems may arise in dynamic analyses, in particular if nonlinear effects are included. In such cases, the analyst should have complete control over which numerical method to use for a particular problem.

SOFTWARE ENGINEERING

Turning to software engineering, the third discipline of computer analysis of structures, we may offer the following definition: software engineering is the science of programming computers to help engineers achieve better or more economical designs, or both.

Since engineers work in a production-oriented environment, the computer use has to be seen from the viewpoints of productivity and competitiveness. All advanced engineering mechanics, numerical methods, and programming skills ought to serve the ultimate goal of solving real engineering problems. Solving a mechanics problem that has no real engineering application may be a curiosity, or even pure science, but it is definitely not engineering. Devising inefficient solution schemes won't help either. And writing programs which are difficult or impossible to use is also a violation of basic principles.

Software engineering is the science of first identifying those procedures in the engineering design/analysis process, which can be automated, and then developing software which puts the computer to use where it is of most benefit in terms of quality and economy of the final design end product. In spite of tremendous advances in computer science, there will remain many activities of the engineer which will not be automated economically for some time. Examples are pattern recognition, the storage of experience, and heuristic decision making rules. It is only in areas involving the quantitative data processing that the computer is clearly superior. Further advances in artificial intelligence research may possibly modify this assessment in the future, but for some time to come the computer will be used only for a certain share of the whole task, while the experienced engineer will still be needed.

The ingredients of software engineering can be grouped into means (hardware, systems software, data structures, data base management systems), attributes (reliability, modularity, maintainability, portability, upwards compatibility) and the user interface (documentation, user support, development). Without a solid footing in all three, a commercial software developer will not stay in business for long. We shall look at them in some detail, not because we want to outline criteria for software developers, but because the user community ought to be aware of the basic standards and yardsticks by which commercial software should be measured. Software should not be what developers offer to the users, but rather what the users demand from the developers.

1. Hardware. The dizzying development in recent years in the field of microelectronics requires full-time efforts just to stay abreast. But program developers and users obviously have to be aware of what is or may become available. Computers no longer cost millions of dollars. Minis, micros, personal computers, etc., now make computers affordable to all engineering offices. Computer-aided design and manufacturing systems, especially, will change the average engineering office dramatically in the years to come.

2. Systems Software. This serves as the important interface between applications software and hardware. Efficient Fortran coding can reduce storage requirements and execution times, but the systems software can further optimize the execution of a program through optimum use of the computer resources. This is the exclusive domain of computer scientists, but we need effective communication with them, because as users we are also strongly affected by the systems software.

3. Data Structures. Much progress has been made over the years regarding the structuring and handling of large amounts of data, such as may be involved in large finite element analyses. This subject is particularly acute when large amounts of data have to be handled in small computer memories. But disk storage space is still relatively expensive, therefore efficient data structures will save money.

4. Data Base Management Systems (DBMS). This fashionable word is used mostly in non-structural and even non-engineering applications. Aside from business applications such as personnel management, project control, etc., an important engineering application is construction

management. But also in structural analysis programs, efficient data base management techniques can bring numerous benefits.

5. Reliability. A high probability of providing correct answers to a given problem is the most important of all software attributes. We don't want bugs or to allow the salesman to promise more than the program can deliver. Reliability is the opposite of error-proneness, i.e., the chance of getting no answers or (even worse) wrong answers. A system or program abort alerts the user to an obvious problem. Also some wrong answers (displacements of 10^{29} inch) attract the attention of the average user. But the worst errors are only of moderate magnitude, e.g., involving factors such as 2 or 3. It takes an experienced engineer with a critical and courageous mind to question the correctness of the results provided by the computer in such cases.

6. Modularity. This is of primary concern to program developers, because it makes it easier to maintain and extend a program.

7. Maintainability. This quality stands for the degree with which a developer can respond to user requests and complaints and to changing environmental conditions, such as different hardware or systems software. It also stands for the ease with which errors can be isolated and corrected. Some large programs are written so poorly that successive modifications require progressively more effort for coding and checking, until a point is reached at which the program can be said to have suffocated under its own dead weight.

8. Portability. A program may be optimized to run extremely efficiently on your machine. But there may come the

day when you can get a computer twice as fast at half the cost. If it requires $100,000 to convert your program to the new machine, you have a problem. The solution is portability, which makes a program as machine-independent as possible. Unfortunately, system-dependent features can increase the program efficiency so drastically, that we cannot afford to go entirely without them. Therefore, all machine-dependent functions are concentrated in specially designated and easily replacable subroutines.

9. Upwards Compatibility. This quality is invaluable when you wish to run, with some slight changes, a problem which you have analyzed five years ago. You may be able to produce the dusty card deck, but the program developer has meanwhile introduced 1001 changes to his program. If it accepts your card deck anyway, it is said to be upwards compatible.

10. Documentation. Barely ten years ago, this was an unknown word among most programmers. There might exist an 8½ by 11 sheet with the program name, the programmer's name, and a two-paragraph description of what the program can do. Everything else was buried in the master's head and was lost if he quit his job or died. By now it has become apparent that a good program documentation is as important as the program itself; in other words, the commercial success of a program with limited capabilities but good documentation is decidedly better than that of an excellent program with poor documentation. As the most important interface element between user and program, it should consist of a theoretical manual, a programmer's manual, a user's manual, and a verification example manual.

11. User Support. Although the program documentation,

if written properly, should leave nothing to ask, a human interface is also important. I am referring to that helpful chap at the other end of the telephone line, available 24 hours a day, who does not get angry, no matter how stupid the question asked. It is his job to keep the user happy and the royalties rolling in.

12. Development. This is another aspect of the user interface. Because the computing market is dynamic, the user needs keep changing. Code specifications, for example, such as the ACI, ASME and AISC codes, are updated periodically. A program has to undergo constant updating to stay abreast and remain competitive. New features and options have to be incorporated, restrictions relaxed, and user requests accommodated. Many new features may be required just for marketing purposes; the users may never need them, but it does not hurt to know they are there.

In summary, it is obvious that a good, competitive, user-friendly program has to take all of the above items into account to remain competitive and to keep the users happy. For this reason, the initial development cost will be much higher, but this will appreciate or amortize at a considerably higher rate due to reduced maintenance cost. This is a typical example where the developer has to resist the investor mentality: never mind the product quality, as long as I get a quick return on my investment. Barely any other engineered product will pay as much dividend as a software system, prudently designed for maintainability and user-friendliness.

GENERAL PURPOSE ANALYSIS PROGRAMS

Let us now turn to general purpose static and dynamic analysis programs, which enjoy wide usage. These represent investments ranging from hundreds of thousands to tens of millions of dollars. Some of them are in the public domain, i.e., they have been developed with government funding and can be obtained from government agencies such as COSMIC, or universities, for mostly a nominal cost which is small compared to the cost of development plus maintenance. Without service or maintenance backup, such programs are generally of limited utility for the buyer unless he has the means to service them himself.

Other programs are for sale by their private developers. Purchase agreements vary widely and may or may not include the source code. The sale price is usually separate from a maintenance contract, which normally covers updates, error debugging, and limited user support. After purchasing the source, the user will be free to do with it as he pleases, i.e., to make modifications and additions, create stripped-down versions, etc. But for obvious reasons there will be restrictions with regard to non-disclosure to third parties.

The final category contains programs which the developer is not willing to sell, but only to lease. Access is provided through some computer networks. Here the user has no choice but to rely completely on the developer for providing error-free code -- a strong inducement to consider the program as a black box.

In the following, a few comments on the most widely used programs are offered. Objective and complete program evaluations and comparisons are time-consuming and difficult to make.(12-17) The comments below are based mostly on my own experience and therefore likely to be subjective, of limited scope, and open to criticism by users with different experience.

LINEAR STRUCTURAL ANALYSIS PROGRAMS

ASKA (Automatic System for Kinematic Analysis) is a general-purpose program developed by the Institute for Statics and Dynamics of Flight Structures (ISD) at the University of Stuttgart, Germany, under the directorship of Professor Argyris.(18) It is one of the most comprehensive programs available, in sheer volume of code rivaled possibly only by NASTRAN. Originally it was a strictly linear program, but in recent years, nonlinear versions have also been developed to handle geometric nonlinearities as well as plasticity and creep. From a software engineering standpoint, ASKA represents the state of the art. The extensive element library permits the modeling of frames, two- and three-dimensional continua as well as axisymmetric shells and solids.

The program is comparably difficult to use and requires a certain amount of familiarity obtained through formal training on the system. The program is widely used in Europe, but less in the United States.

BERSAFE (Berkeley Structural Analysis by Finite Elements), developed by the Central Electricity Generating Board at the Berkeley Nuclear Laboratory in England, is another system which started out as a linear program and was expanded in later years to treat nonlinear isotropic and anisotropic elasto-plastic problems as well.(19) According to the published literature, it has incorporated many state-of-the-art algorithms. Automatic interactive mesh generation and modification facilities and extensive data checks make it quite user-friendly. In this country, it is not widely used.

EAL (Engineering Analysis Language) is a large-scale data base oriented general purpose software system for engineering analysis, developed by Engineering Information Systems, Inc., of Jose, Calif.(20) Also marketed under the name EISI-EAL, it is the successor to EISI-SPAR, providing a broad spectrum of computational and data management facilities, with primary emphasis on design and analysis functions based on finite element methods. Although originally marketed primarily among the aerospace industry, it has earned a high reputation also among civil engineering users as a reliable proprietary code with good support services.

EASE (Elastic Analysis for Structural Engineering) is a highly successful and widely used proprietary program, developed by the Engineering Analysis Corp. of Redondo Beach, California. Its success is due to its efficient algorithms, adequate element library, user-friendliness and a competent support staff.(21) The currently distributed version is called EASE2.

NASTRAN (NASA STRUCTURAL ANALYSIS) owes its existence to President Kennedy's vow to send a man to the moon. In 1965 NASA awarded a contract to the Computer Science Corporation, with subcontractors McNeal-Schwendler, Martin Baltimore and Bell Aero Systems, to develop a program to solve all structural analysis problems conceivable. Five years later, the first version was released with about 150,000 statements, at a cost of $3 to $4 million. The public domain version is still available from COSMIC, although without support for users in non-government agencies. (22) The McNeal-Schwendler Corp. has since developed the very successful proprietary version MSC-NASTRAN. In spite of the enormous size of the program, it has been installed on minicomputers such as the VAX(23). Original-ly its appeal was limited mostly to the aerospace industry, but in recent years, NASTRAN has gained many satisfied users in other industries as well.

SAP (Structural Analysis Program) originated in the University of California at Berkeley under the guidance of

Professor Wilson (24). The most widely distributed version is SAP4, of 1973, with some updates added in 1974. SAP is distinct from most other widely used programs in the following respects: 1. At the time of the first release, the element library and efficient solution algorithms represented the state of the art; 2. the clear and transparent programming is easy to work with and gave a generation of programmers the opportunity of learning good programming style; 3. a truly public-domain program, it is available from the University of California for very little cost; 4. on the negative side, the university offers no user support whatsoever; and 5. the program is difficult to use because of relatively poor input pre-processing and output post-processing. The program documentation is virtually nonexistent, the manual completely inadequate, and the file structure not state-of-the-art. As a result, many users develop their own proprietary versions, mostly by adding pre- and post-processors, up to the point of completely rewriting the program. Wilson himself has developed a new proprietary version, SAP80, available from Structural Analysis Programs in El Cerrito, Calif., for 16-bit micro-processors.(25)

In 1974, a SAP Users Group was formed at the University of Southern California, to provide limited user support for a membership fee. A program version SAP5 originated at USC, basically SAP4 plus a band-minimizer and a geometric stiffness matrix capability for buckling analysis. More recently, the SAP Users Group has acquired the proprietary version of Babcock and Wilcox, then called FESAP, and distributed it with further additions and modifications as SAP6. This is a rather efficient and modernized vesion of SAP4; the terms of agreement are very similar to those of other proprietary programs.(26)

STARDYNE is one of the oldest proprietary static and dynamic analysis systems, developed by Mechanics Research Inc. in Los Angeles(27). The first public release was 1968, and many new versions, especially with new dynamic capabilities, have been released since. It is now a system of compatible structural analysis programs for static and dynamic loads and small displacements. The program has been very successful. The numerical algorithms seem to be average and the element library somewhat outdated, but what counts most with users is the user-orientation and the support offered by the developers. Although data are input in fixed format, users don't seem to mind, and I have heard praises for the user's manual.

STRUDL (Structural Design Language) was developed at the MIT as a part of the Integrated Civil Engineering System (ICES) Project, a cooperative venture of MIT, IBM and various government agencies.(28) The public domain version is probably still available from MIT, but has a multitude of errors and no support. For this reason, commercial versions are being offered, the most popular ones being the McAUTO Version(29) and GTSTRUDL(30), a version developed and extended by the Georgia Institute of Technology under the direction of Professor Emkin. In its class of user-oriented general-purpose programs, probably no other program is as widely used as STRUDL. It is particularly popular among structural engineers. There exists an ICES User's Group with worldwide membership, newsletters and user conferences. The best feature of STRUDL is a relatively easy-to-learn free-format user-oriented input language which allows the user much flexibility in defining a structure and setting up an analysis. Capabilities and reliability depend very much on the version used and the maintenance support available. The commercial versions are under continuing development. The element library and analysis options are constantly updated, and limited design capabilities are also now available, such as stress checks according to the ACI and AISC specifications.

SUPERB is a general-purpose finite element code developed by the Structural Dynamics Research Corp. of Milford, Ohio.(31,32) It is an efficient integrated system, especially if used together with the advanced interactive pre-processor program called SUPERTAB.

NONLINEAR STRUCTURAL ANALYSIS PROGRAMS

Before turning to nonlinear general-purpose programs, a few preliminary comments are in order. Potential users of such programs are reminded that all such programs are difficult to use, notwithstanding the assurances to the contrary by the various promoters. Such programs require sophisticated users with advanced knowledge of structural mechanics and numerical methods. Black-box usage of such programs without any appreciation of their inner workings is a sure road to disaster. Not only are these programs difficult to use, they are also seldom user-friendly. It could be argued that such an extra barrier against wide usage is rather desirable in order to deter unqualified users. Below, some codes are listed, which were developed specifically for nonlinear applications. As mentioned earlier, to many of the originally linear codes some nonlinear options were added over the years. But the programs listed below were written primarily to solve nonlinear problems. Only codes based on Lagrangian formulations are included, since Eulerian codes are used primarily for hydrodynamic applications and are therefore outside the scope of this survey. Also omitted are finite difference codes, both with Eulerian and Lagrangian formulations, because their use in conventional civil engineering applications is rather limited.(33)

ABAQUS, developed by Hibbitt, Karlsson & Sorenson, Inc. of Providence, Rhode Island, is the most recent addition to nonlinear codes.(34) In spite of its relatively recent release, the program has already earned high marks, especially in the nuclear and oil industries, because of powerful capabilities, good documentation, and many user-friendly features.(35) With solid user support and new developments, the program can be expected to increase its popularity.

ADINA (Automated Dynamic Incremental Nonlinear Analysis) is a modern and efficient code written by Professor Bathe of the MIT.(36) It has a good library of state-of-the-art elements and material models. An ADINA Users Group consisting of a number of industrial users in the US and abroad has supported further development and held periodic users conferences at the MIT. The basic program is available from Professor Bathe, but a somewhat more user-friendly proprietary version is now installed on various computer networks, supported by ADINA Engineering Inc. in Watertown Massachusetts. The program is used primarily in the nuclear power industry and by some defense contractors.(37)

ANSR (Analysis of Nonlinear Structural Response) is a general-purpose program written by Professor Powell and his students at the University of California at Berkeley.(38) The latest version, ANSR-2, is an improvement of an earlier ANSR-1 version and can be considered as a replacement of an even earlier program, DRAIN-2D.(39) ANSR is conceived as an efficient analysis tool, particularly well-suited for research purposes. The user has numerous options available for solution strategies, but in order to make the program more user-oriented, good pre- and post-processors will have to be added. The individual elements are documented in a series of

Berkeley research reports.

ANSYS was developed by Dr. Swanson of Swanson Analysis Systems Inc. of Houston, Pennsylvania.(40) It is probably the most successful commercial nonlinear analysis program, primarily because it can be used without loss of efficiency (and it is in fact heavily used) for linear analysis as well, making the nonlinear option a very attractive feature. Also, the program has a solid reputation for dependable user support and good user-orientation. It is much older than most of the other programs, therefore it may be less efficient in certain cases, but for users this is often of secondary importance. If they are well familiar with the linear analysis portion of the code, the danger of misuse is lessened somewhat if it is used also to investigate certain nonlinear effects.

DYNA, developed by Dr. Hallquist of the Lawrence Livermore National Laboratory, exists in two versions, DYNA-2D and DYNA-3D, which are based on an explicit integration of the equations of motion.(41,42) Highly optimized for computers such as the CRAY and CDC 7600, they are among the most efficient codes available and represent the state of the art in computational mechanics, but they are neither user-friendly nor are there many people knowledgeable enough to use them effectively.

EPIC was developed by the Defense Systems Division of Honeywell Inc. of Hopkins, Minnesota,(43) and has many capabilities to analyze nonlinear effects in complex structures.

MARC, written by Dr. Marcal of Marcal Analysis Research Corporation in Palo Alto, California, was probably the first general-purpose nonlinear analysis program. During the last 15 years it has maintained its position among the most widely used commercial programs, and the user support is good. However, proper use of the advanced features of the program is far from easy.(44)

NIKE, developed by Dr. Hallquist of thw Lawrence Livermore National Laboratory, exists in two versions, NIKE-2D and NIKE-3D. They are very similar to the DYNA codes mentioned above, except that they use implicit integration of the equations of motion(45,46). Highly optimized for advanced mainframe computers, they represent the state of the art with regard to computational efficiency of engineering mechanics. These codes are not at all easy to use, even though graphic packages are available for pre- and post-processing of data.

NONSAP is the nonlinear version of SAP, written by Wilson and Bathe at the University of California at Berkeley and can be considered a predecessor of ADINA. Its advantage is that, as a public domain program, its cost is very low. The disadvantage is its restriction to in-core solutions and the lack of user support. For research and development it can serve good purposes in a similar way as SAP does in the linear domain.(47)

IDEALIZATION OF STRUCTURES

The best and most powerful programs in the world do not mean anything if we don't know how to make good use of them. This means we have to be able to correctly model the structure to be analyzed. This is a problem regularly encountered in engineering practice. After graduation from school, few engineers will be asked to write programs. Most of them will be asked to use programs. But if we look at our libraries, we shall find plenty of books on the theory of dynamic analysis, structural analysis, finite elements, etc., i.e. the theory on which programs are based. There are no books that tell the engineer how to use programs correctly or how to model structures for analysis. The reason may be that the professors who usually write books either have insufficient experience with applications in engineering practice, or no interest, while the practioners are seldom given the time or the opportunity to document their experience. Moreover, mathematical modeling of structures is an art, something you learn mostly by experience, which is not easily taught or described in a book. Below, I will try to give a few guidelines, which could make the sometimes painful process of learning and gaining experience a little easier. More information can be found in Refs. 48 and 49.

Modeling, like designing, is based on the skill of making correct assumptions. Some of these are obvious to everybody, but others appear sometimes to be very daring and will have to be verified. In some cases this is not easy or even possible, because of limitations of the current state of the art. In design, it is always relatively straightforward to come back and check whether the design assumptions were valid or not.The verification of analysis assumptions is much more difficult. The degree to which it is possible is the measure of the confidence that we have in the correctness of the mathematical model and the results obtained with it.

Step 1. The idealization of a structure starts with the study of the engineering drawings. For complicated structures or pieces of equipment, this can be a time-consuming task, requiring the engineer to visualize a structure in three-dimensional space.

Step 2. Abstraction of nonstructural components. Nobody can tell us what is nonstructural and what is not, so we have to make our own assumptions, in line with standard practice. For example, partitions, windows, curtain walls, insulation on piping, etc., are normally regarded as having negligible influence on the structural response to load. But we know very well that this is not necessarily the case. For example, partitions can strongly influence the seismic response of tall buildings.

Step 3. Idealization of structural components. The identification of "beams" in a concrete floor system is somewhat regulated by the ACI Code, but a closer look at the problem will reveal how daring such assumptions are. In complex machinery, we may wish to consider an assemblage of plates, welded into something resembling a box section, as a beam. Cut-outs, bevels, diaphragms, and appendages may be ignored for the time being, but we have to ask ourselves about the justification. If in doubt, we should come back later and model the component in question in more detail.

Step 4. Linearization of nonlinear behavior. For example, it takes courage to analyze reinforced concrete as if it were a linear material. But if designed properly, it is a forgiving material, just like steel, forgiving our ignorance or unwillingness to compute more realistically.

Step 5. Appropriate representation of loading. All loads are subject to uncertainties and randomness in space and time. Even dead load is not as well known as often assumed. The most uncertain loads, such as wind or earthquake ground motions, have to be modeled as random processes in order to permit response predictions that are meaningful.

Step 6. Finite element mesh design. This is a difficult task, although with modern interactive graphics pre-processors, it is much less laborious than it used to be. The objective is to "guess" the response and design the mesh accordingly, especially with regard to the required level of refinement. For example, in areas of expected stress concentrations, a fine mesh should be used. This task may take several trials and errors and experience concerning the approprite level of refinement. Often, a simple stick model, consisting only of beams and lumped masses (for dynamic analysis) suffices. If there is reason to believe that such a crude model is inadequate, we can always come back later and design a more refined model. But the level of refinement has to correspond to the level of knowledge of the materials and loads. It simply is not justified to model each nut and bolt in a complicated piece of equipment, for which the loading is highly uncertain.

Step 7. Boundary conditions. Mathematical boundary conditions should simulate the realistic conditions as closely as possible. Note that clever use of symmetry can reduce the computational effort considerably.

Step 8. Data checking. The various computer graphics packages are invaluable tools, because they can help in revealing incorrect coordinates and improper connectivity between structural members.

Step 9. Static analysis. If the actual loads are static, this may be the final run. But even then, it is advisable to first analyze the structure for some very simple basic loading conditions, for which the answers are either known or easily checked by hand. This will give us confidence in the correctness of the model and the answers it provides later for the actual loading. Even if the actual loads are of a dynamic nature, it pays to make a number of static analysis runs to test the correctness of the external boundary conditions, the internal connectivity, the reactions and material properties. The static analysis verifies the correct stiffness characteristics and is an excellent check of the input data.

Step 10. Eigenvalue analysis. If the loads are dynamic, then an eigenvalue analysis should be performed, whether or not the mode shapes and frequencies are needed subsequently for a modal analysis or response spectrum analysis. This analysis identifies rigid body modes, verifies the correctness of the structure mass and also the stiffness in additional detail. If some mode shapes and frequencies are already known, for example from an experiment, then we can fine-tune the model against these results. We can use this phase to get a better feeling for the structural behavior. Rushing through this phase may mean beating the deadline, but possibly at the expense of obtaining wrong answers without even knowing it. It is quite common that dynamic finite element analysis gives wrong answers, which look reasonable. In design, the results can be checked against code-prescribed stresses or deflections. In analysis, there often are no criteria to check the answers against. The only way to proceed in such cases is to gradually build up our confidence in the model by reproducing known answers. Then we can dare to predict answers to a problem for which the answers cannot be verified.

Step 11. Steady-state vibration analysis. Such an analysis is recommended as a further check, for example, in order to verify the natural frequencies in a frequency sweep.

Step 12. Transient analysis. Before analyzing the structure for the actual transient loads, we may want to choose first a few simple loads such as an initial impulse or step function. Such studies can be used to compare different integration schemes, for example, modal analysis versus direct integration, explicit versus implicit integration. This phase serves also to test not only the model but also the program itself, by executing all options needed in the final run. Besides, it is always nice to get answers which we can check readily.

Step 13. The final production run -- that is, if you haven't been fired yet. The supervisor is very likely to be impatient by now, blaming those Ph.D.s who make a research project out of each job. But in this phase, you can turn out parameter studies, sensitivity studies, analyses of details and design modifications about as fast as the turnaround time permits, provided you have not cut corners earlier. Now comes the time to enjoy the satisfaction of a job well done.

EXAMPLES

A few examples shall illustrate some of the points made earlier. Fig. 2 shows the French-built bulb turbines for the Rock Island Hydroelectric Project on the Columbia River. Each turbine casing is supported by two concrete pedestals and six radial stay vanes anchored in the concrete frame, schematically illustrated in Fig. 3. The designers needed to know the stiffness of the support frame in order to design the turbine casing. Only a three-dimensional finite element analysis was considered adequate for this task. Because of symmetry, only half of a typical unit for two turbines was modeled, Fig. 4. By applying one unit displacement at a time at the various vane support nodes, the required stiffness coefficients could be determined directly. Program STRUDL was used to solve this problem.

Fig. 5 shows an interesting sculpture, entitled "Stairway to Nowhere," situated on the Atlantic Richfield Plaza in downtown Los Angeles. The sculpture is built up with hollow metal boxes, which are bolted together. In order to analyze this structure, it is worthwhile to recall some of the basic steps of the direct stiffness method and the meaning of a finite element. Each box can be considered to be a "finite element," with a finite number of degrees of freedom, which interacts with the neighboring elements through six bolts having three force components each, Fig. 6. Thus, we can build a finite element model of a typical box and analyze it for 18 loading conditions, one displacement component at a time, to obtain the 18 by 18 finite element stiffness. Since all boxes are alike, we can transform the nine freedoms of the upper level to the local coordinate system of the next box, so that the "global" element stiffness has to be computed only once. The structure stiffness is then assembled according to the rules of the direct stiffness method.

The last example is the main propulsion unit of a modern ship. Fig. 7 illustrates the entire unit, including the major equipment, while Fig. 8 shows an abstracted view of the subbase without the equipment, but with the support structure down to the ship's hull. A simple "stick" model is shown in Fig. 9, consisting only of beam elements. For a more detailed study of the complex plate assembly, a more detailed model including plate finite elements was constructed, Fig. 10. Both models were rigorously tested according to the step-by-stp procedure described earlier. Further details can be found in Ref. 47.

FUTURE OUTLOOK

Computer methods have made possible unprecedented progress in structural analysis and design in the last 20 years. Although the future will surely bring similar changes, it is not yet possible to make specific predictions. It can be said, however, that future progress will depend largely on how well the gap between program developers (researchers) and practitioners can be bridged, so that the profession can take full advantage of the electronic hardware yet to come.

A second factor which will have a major impact on the future development is the availability of personal computers. Until now many employers felt fit to endow their secretaries with more capital investment (in the form of typewriters and word processors) than their engineers. In the future, this will not matter, because computers will become so inexpensive that the engineers themselves will buy them if their employers don't. This will completely change their attitudes toward computers, the way they work, the way they set priorities and the way they think.

A third source of change is the emergence of computer graphics, without which computer aided design would not be what it is now and what it promises to become. It greatly enhances user-friendliness of analysis software and improves communication with the computer. With the help of interactive graphic pre- and post-processors, the productivity and effectiveness of the engineer will be largely improved.

I foresee a gradual elevation of the status of the engineer, which will overcome even the traditional inertia of employers: endowed with a personal workstation, he will more and more assume the position of a true professional, relying on his experience and expertise to analyze and design structures. The computer will free him of tedious and time-consuming tasks, reducing the need for specialization and fragmentation of the work force.

In this development education will be instrumental. Our universitites will have to take on the burden of preparing their students for this new working environment. If everything were to continue as it has in the past, we will have large numbers of unqualified people running powerful software and obtaining useless or misleading results. The introduction of computers into school curricula has become standard by now, but a basic Fortran course and possibly a matrix structural analysis course are insufficient. We will have to teach our students all the basics needed to make proper and effective use of software packages offered in engineering practice. There are no ready solutions. In the past it has been proposed that individual users ought to undergo formal training in data processing and automatic calculation, after the successful completion of which they would be licensed to use a particular software system.(50) Some valid criticism has been brought up against such licensing procedures, but so far no better alternatives have been proposed.

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15. ANSYS

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18. MARC

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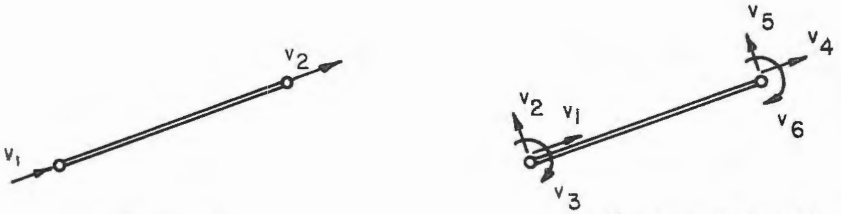
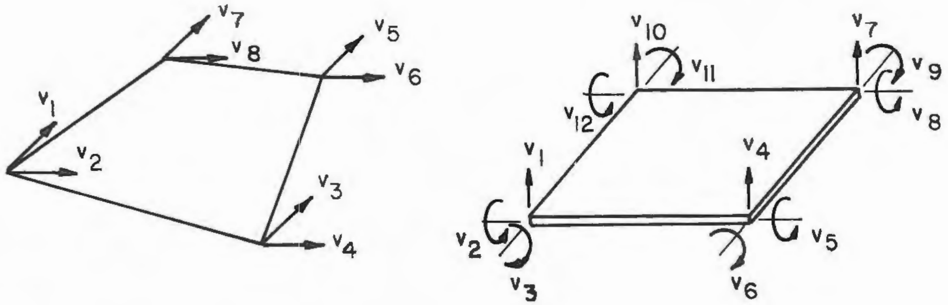
260 Sheridan Avenue, Suite 200
Palo Alto, California 94306
Attn: Dr. P.V. Marcal Phone: (415) 326-7511



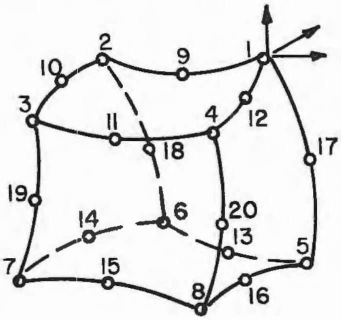
a) Truss

b) Plane Frame Member



c) 2D Plane Stress Element

d) Plate Bending Element



e) 20-Noded 3D Solid Element

Fig. 1 Typical Finite Elements and Their Degrees of Freedom

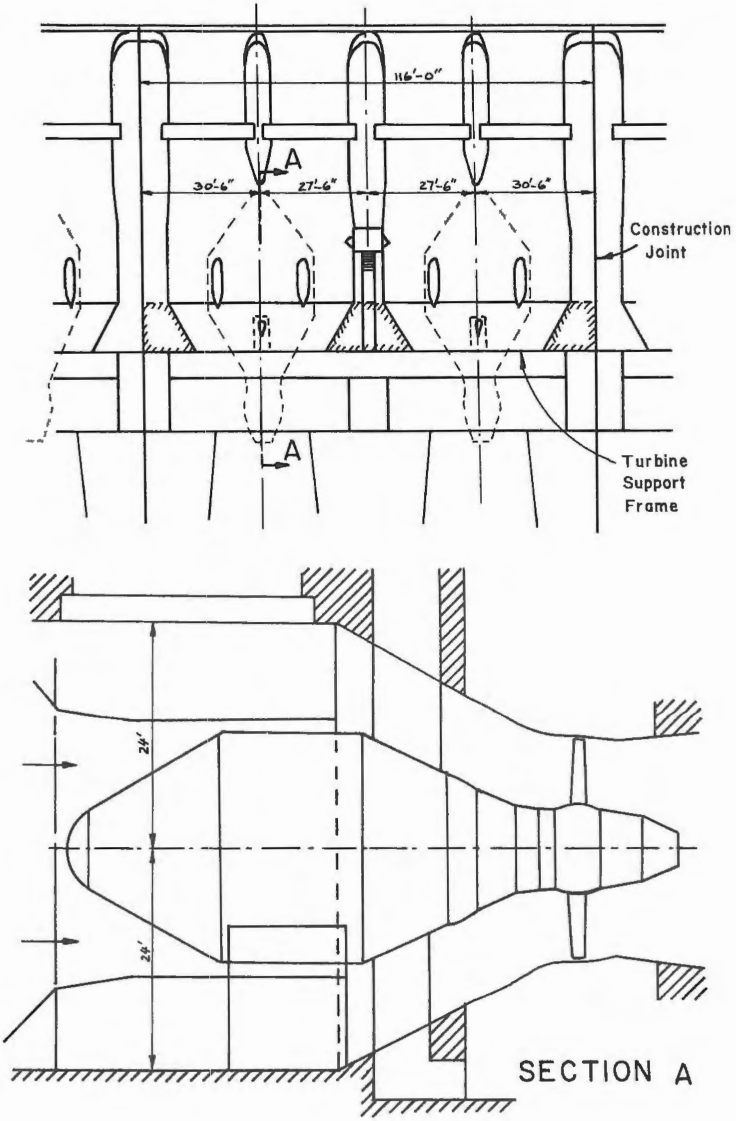


Fig. 2 Plan View and Elevation of Bulb Turbines in Hydroelectric Plant Project

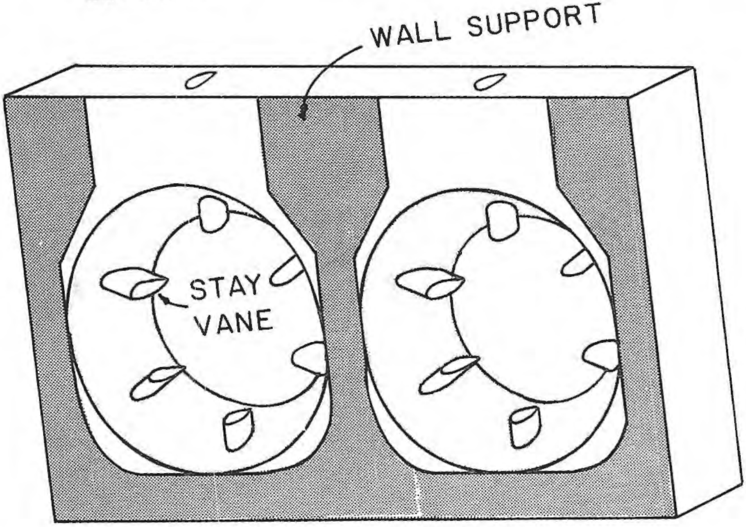


Fig. 3 Rendering of Turbine Support Frames

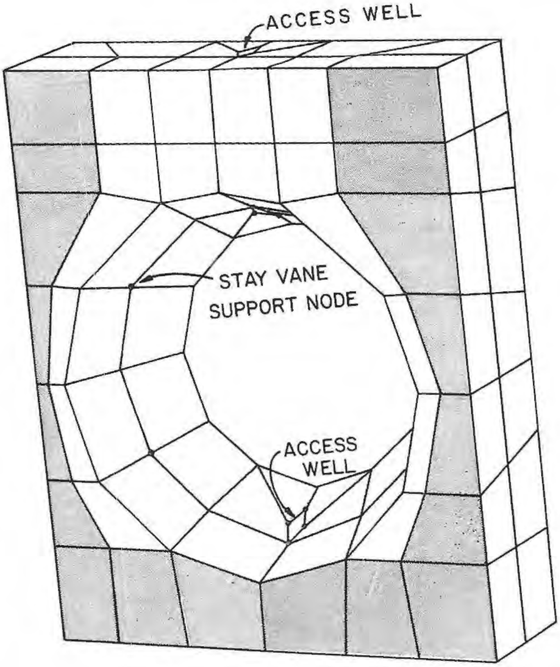


Fig. 4 Three-Dimensional Finite Element Model of Turbine Support Frame

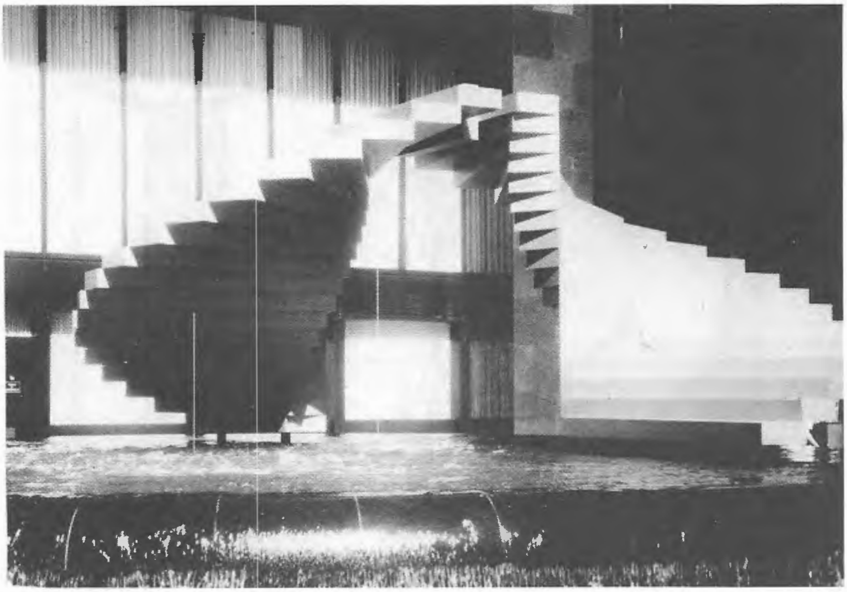
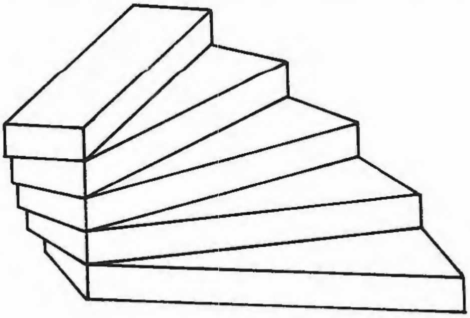


Fig. 5 "Stairway to Nowhere" Sculpture



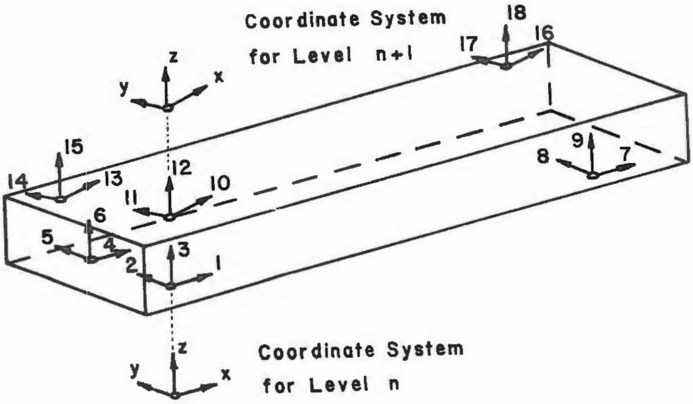


Fig. 6 Degrees of Freedom of Typical Step

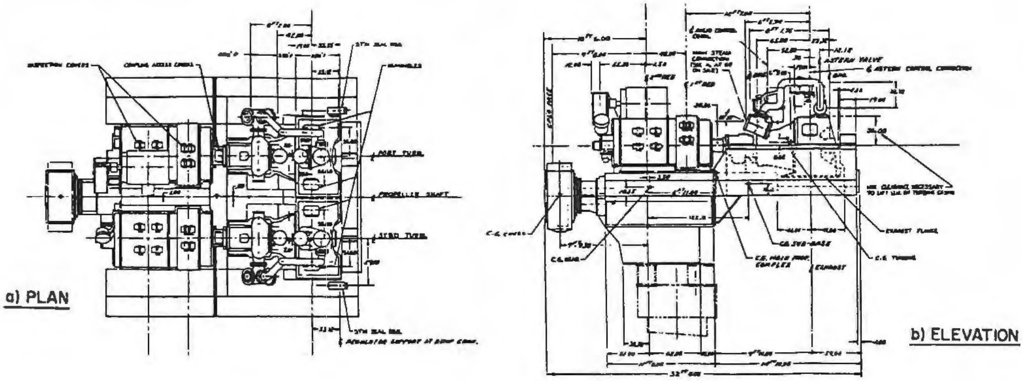


Fig. 7 Ship Main Propulsion Unit - Plan and Elevation

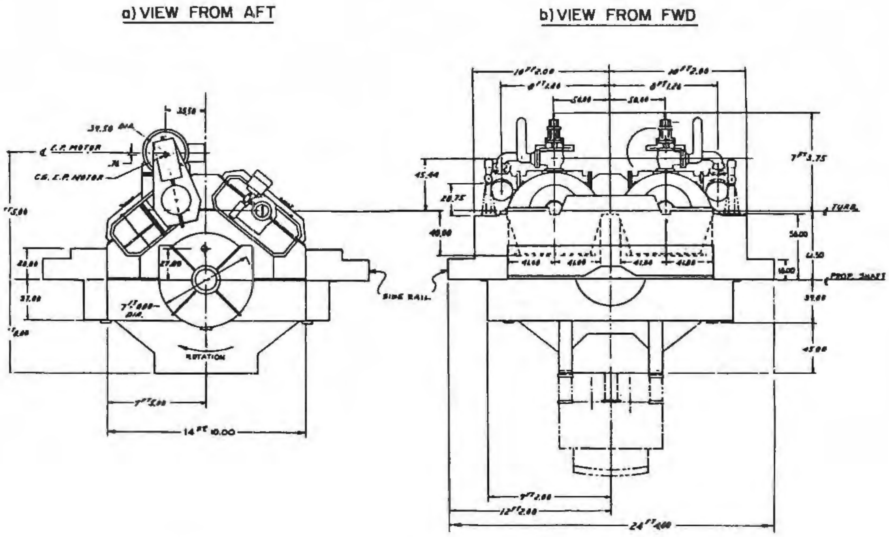


Fig. 8 Ship Main Propulsion Unit - Forward and Aft View

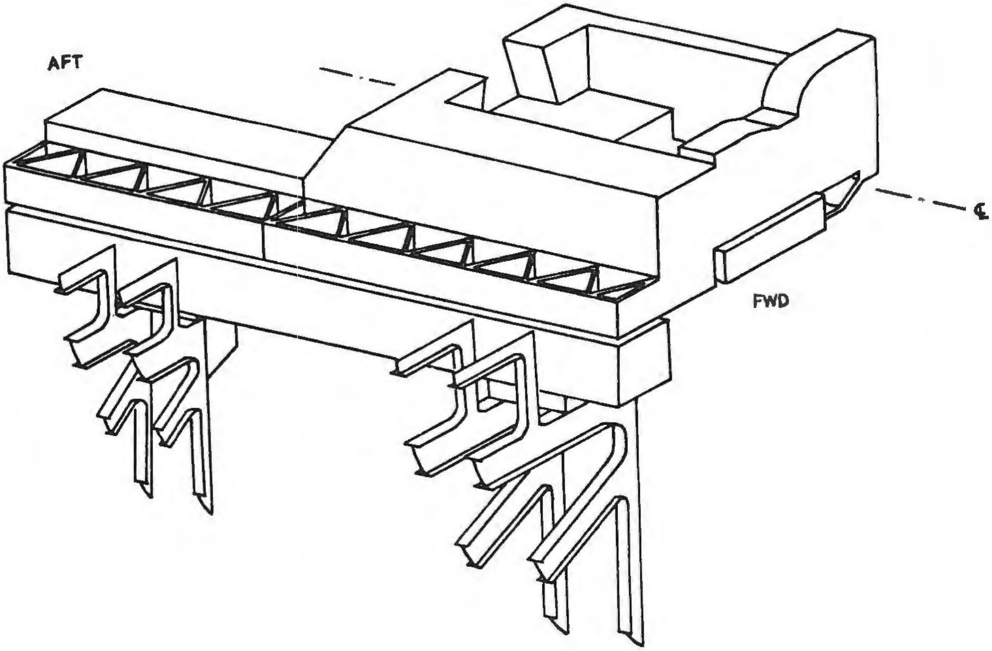


Fig. 9 Rendering of Starboard Main Propulsion Unit Subbase

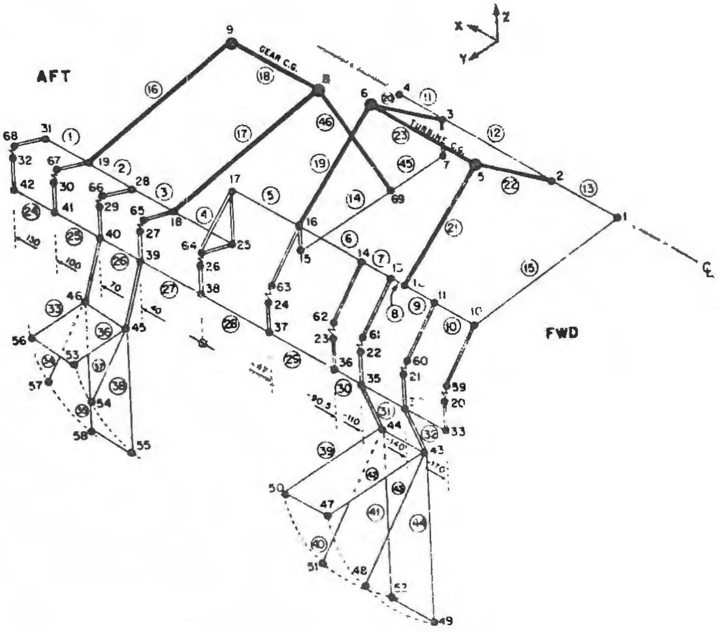


Fig. 10 Model of Main Propulsion Unit Using Beam Elements Only

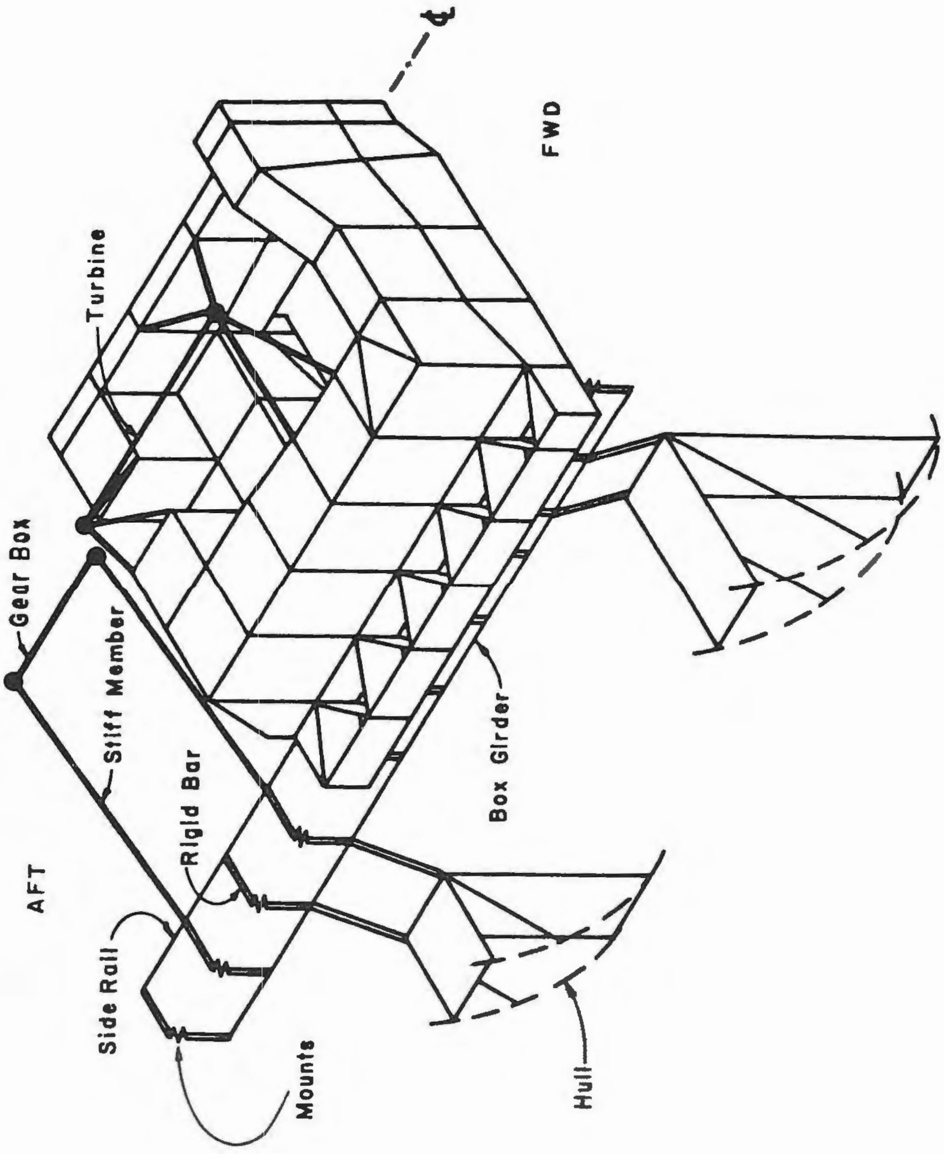


Fig. 11 Model of Main Propulsion Unit Using Beam and Plate Elements

LOW-FLOW FREQUENCY AND FLOW-DURATION ANALYSIS OF NATURAL-FLOW STREAMS IN MASSACHUSETTS

S. William Wandle, Jr.[1]

ABSTRACT

The 7-day low-flow statistics and flow-duration curves were computed for 39 sites. Station records were selected to represent essentially natural conditions (unaffected by regulation or diversion) or consistent regulation patterns. The average length of record at these sites is 25 years, and the daily flow exceeded 90 percent of the time ranged from 0.04 to 0.39 (with a mean of 0.18 and a standard deviation of 0.09) cubic foot per second per square mile. The 7-day 2-year and 7-day 10-year low flows ranged from 0.01 to 0.37 (with a mean of 0.12 and a standard deviation of 0.08) and from 0 to 0.19 (with a mean of 0.06 and a standard deviation of 0.05) cubic foot per second per square mile, respectively. The available guidelines to compute and analyze low-flow frequency and flow-duration curves at sites with sufficient daily flow record are summarized. Techniques to estimate these flow characteristics at other sites are briefly described.

ACKNOWLEDGMENTS

This article describes selected analyses of streamflow data from a program supported cooperatively by the Department of Environmental Quality Engineering, Massachusetts Division of Water Pollution Control, Water Quality and Research Program, and the U.S. Geological Survey. Streamflow data used in these analyses are a subset of the historic streamflow data set available for Massachusetts through agreements with the U.S. Geological Survey and the following agencies:

Commonwealth of Massachusetts
  Water Resources Commission
    Department of Environmental Management
    Division of Water Resources
  Department of Environmental Quality Engineering
    Division of Water Pollution Control
 Department of Public Works
    Research and Materials Section
    Highway Engineering Division

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Metropolitan District Commission
Water Division
Federal Energy Regulatory Commission
U.S. Army, Corps of Engineers
New England Division
North Atlantic Division

New England Power Company, Western Massachusetts Electric Company, and the cities of New Bedford and Taunton aided in the collection of streamflow records.

INTRODUCTION

Streamflow characteristics are needed by government agencies and the engineering and planning communities to meet requirements relative to waste assimilation, fisheries management, hydropower, land-use planning, stream-system analysis, and water-resource development and management. As part of a cooperative program between the Massachusetts Department of Environmental Quality Engineering, Division of Water Pollution Control, Water Quality and Research Program, and the U.S. Geological Survey, a study is underway to provide a gazetteer of streams, including streamflow and river basin data.

Streamflow information, such as the frequency of low flows and the duration of daily flows, is important in the planning and siting of water-related activities. "Duration of daily flows" refers to flow-duration characteristics or the percentage of time daily flows were equaled or exceeded. For example, low-flow frequency and flow-duration data provide indices to assess the impact of drought. The historic streamflow-data base, compiled from the U.S. Geological Survey's nationwide data-collection network, can aid in satisfying the current demand for up-to-date flow characteristics. The purpose of this report is to provide the users of flow-frequency information with a common and current data base for management of Massachusetts streamflow resources. A brief explanation of low-flow frequency and flow-duration analyses is included.

The flow-frequency information in this article is based upon a sample of streamflow records which was not available to Higgins (1967) and the authors of the Hydrologic Investigations Atlas series of major river basins reports listed in appendix I. This sample consists of additional years of streamflow records which include the mid-1960's drought or constant river basin conditions or both. This analysis is primarily limited to streams where the flow regime is essentially natural. In these streams, the daily flows of interest were not significantly altered by the existing regulation or diversion pattern from the flow sequence that would occur without the regulation or diversion (natural stream). Flow-frequency information is also given for streams where the flow regime is influenced by a consistent regulation pattern.

The set of flow characteristics on natural-flow streams can be transferred to an ungaged site or to a site with scant streamflow data where the flow is also natural. The impact of planned regulations or diversions on a stream system can also be determined.

A regulated stream system requires additional data to analyze and the resulting analysis would have little transfer value except to another system with a similar regulation pattern.

STREAMFLOW ANALYSIS

Flow records representing relatively constant river-basin conditions are required for a valid frequency analysis. However, most stream systems in Massachusetts are influenced by reservoirs, diversions, regulation, and withdrawals for municipal supplies. Determinations of flow characteristics of a stream where the flow regime has been altered requires analysis of the longest period of homogeneous records under conditions expected to continue in the future. Homogeneous records for a site are those records representing a constant set conditions that affect the flow-regime within the river basin. A frequency curve based upon the natural and regulated periods combined, or on the partial period reflecting previous conditions, would not be reliable to estimate future flow characteristics under the given regulation pattern. In some situations it may be necessary to model the influence of the regulation on the stream system to determine future flow characteristics.

This frequency analysis utilized discharge records for stations where:

1. The flow is essentially natural (Johnson, 1970);
2. The flow is limited to natural by exclusion of the period of significant regulation; and
3. The flow is influenced by a consistent regulation pattern for at least 10 years.

Following the above criteria, streamflow records for 39 gaging stations shown on the map in figure 1* and listed in table 1* were selected as the data base for this analysis. Only eight of these stations are located in eastern Massachusetts because most discharge records from eastern Massachusetts are influenced by regulation, diversions, or withdrawals for municipal supplies. Information on stream regulation was obtained from the series of water-resources data reports issued annually (see U.S. Geological Survey, 1980, for an example), Knox and Soule (1949), and the station descriptions on file in the New England District office of the U.S. Geological Survey.

*At end of paper.

Low-flow frequency and flow-duration analyses follow procedures recommended by Riggs (1972) and Searcy (1959), respectively. Both techniques are summarized in this article. The reader is referred to these reports included in the references for more detailed explanations of the method. Statistics on low flow and flow duration are available through the U.S. Geologial Survey's National Water Data Storage and Retrieval System (WATSTORE) utilizing computer program A969, Daily Values Statistics (Meeks, 1977). Information on the availability of statistical analyses may be obtained from: U.S. Geological Survey, New England District, 150 Causeway Street, Suite 1001, Boston, MA 02114.

Flow-Duration Analysis

A flow-duration curve indicates the percentage of time a given streamflow was equalled or exceeded at a site, during the time period selected for analysis. Duration tables of daily flows for a gaged site are generated by computer program A969. The number of daily values for each year in each of a maximum of 35 flow-magnitude classes and a summary for the period giving the percentage of all days in which a class limit was equalled or exceeded are provided. A class is an array of daily mean discharges equal to or greater than that class value and less than the next higher class value. An example of the duration table of daily flow values from program A969 is shown in table 2 for the West Branch Westfield River at Huntington. Flow duration curves prepared for the 39 gaging stations using the results from computer program A969 are shown in figures 2-7.

A flow-duration curve can be estimated for sites where several discharge measurements rather than daily discharges are available (Searcy, 1959, p. 17). The relationship between measurements and concurrent daily flows on a nearby gaged stream is used to define an estimated flow-duration curve. The gaged basin is selected with characteristics which most nearly represent the characteristics affecting flow at the site. Measurements during base flow are required to define the low-flow end of the curve because the shape can vary considerably from site to site owing to influence of basin characteristics. At higher flows the relationship is usually a 45-degree line through the coordinates of the drainage area or is parallel to this line. It may be desirable to confirm this with actual data.

A flow-duration curve based upon short-term records can be extended to reflect conditions during a longer period (Searcy, 1959, p. 12). The relationship (correlation) between pairs of discharges at flow-duration points for the common period of record is used to establish the long-term curve. The discharge relationship for the common period of record is assumed to represent the relationship for the long-term period.

Estimation of flow-duration characteristics at ungaged sites has been successful in several regions (Thomas and Benson, 1970; Thomas and Cervione, 1970; and Dingman, 1978). These techniques utilized the regression of measurable basin characteristics on selected points of the daily flow-duration curve. This analysis could be applied to natural flow streams in the Commonwealth with a high likelihood of success.

The duration curve provides a basis for comparing streamflow characteristics of drainage basins. For actual comparisons, flows should be expressed as unit flow. The slope of the curve reflects the amount of storage available to equalize streamflow. At the low-flow end, a steep slope indicates negligible storage (primarily ground-water storage) available to sustain streamflow. A curve with a change in slope from steep to relatively flat during low flow reveals the availability of surface-water or ground-water storage that tends to equalize the flow; that is, maintain low flows at a higher rate than might otherwise be expected. Thus, a comparison of the flow-duration curves 11 (Otter River at Otter River) and 12 (East

Branch Tully River near Athol) in figure 3 provides the following information: The relatively flat slope of the lower portion of curve 11 shows that the flow in Otter River is equalized by a larger relative storage of surface water and ground water than that in the East Branch Tully River basin. Note that curve 12 is for the East Branch Tully River before the construction of Tully Reservoir. The area of lakes, ponds, and swamps, in percentage of drainage area for these two streams, is 14.0 and 2.32, respectively. In figure 7, an example of a regulated stream system is shown by curve 34 (Fall River below Otis Reservoir, near Otis). Maintenance of a fairly constant flow in Fall River by the large storage in Otis Reservoir is reflected in the flat slope of the duration curve during both low and high flows. During high-flow periods, water is stored in Otis Reservoir, reducing steamflows; and, during low-flow periods water is released from storage in Otis Reservoir, increasing low flows.

Flow-duration curves can be used to estimate future streamflows if the factors influencing runoff, including diversions and regulation, remain essentially the same as during the base period. Flow-duration information is useful for basin planning, water power, waste disposal, water supply, navigation, and quality-of-water studies. The impact of man's future activities should be considered before estimating future flows with the duration curve. A flow-duration curve represents an average for the period of record. The chronological sequence of flows is not described by the curve. Expected occurrences of streamflow are estimated from either a high-flow or low-flow frequency curve.

Low-Flow Frequency Analysis

Low-flow frequency curves at sites with at least 10 years of daily flow record may be computed from the annual average minimum flows for 1, 3, 7, 14, 30, 60, 90, 120, 183, and 365 consecutive days each climatic year. Low-flow analyses in the New England region are based upon a climatic year, defined as the 12-month period ending March 31 of the designated year. Division of the record during the normally high-flow period in the spring avoids creating erroneous values that would result from splitting low-flow periods into separate years. Commonly cited statistics are the "7-day 2-year" and "7-day 10-year" low-flow values

The 7-day 10-year low flow (7Q10) is the discharge at the 10-year recurrence interval taken from a frequency curve of annual values. The annual values are the lowest mean discharge for 7 consecutive days in each climatic year of record (7-day low flow). A 7-day 10-year low flow (7Q10) value of 0.9 ft^3/s (cubic foot per second) is interpreted as follows: The 7-day low flow (lowest mean discharge for 7 consecutive days) will be less than 0.9 ft^3/s at intervals averaging 10 years in length. In terms of probability, which may be less misleading than "intervals averaging," the probability is 1 in 10, or a 10 percent chance, that the 7-day low flow in any one year will be less than 0.9 ft^3/s. The definition and interpretation of the 7-day 2-year low flow (7Q2) follow from the above discussion.

Computer program A969 provides the following low-flow analyses for sites with at least 10 years of daily flow record:

1. A tabulation of the lowest mean discharges in each climatic year of record for 9 periods of n consecutive days, where n = 1, 7, 14, 30, 60, 90, 120, and 183. An annual summary is also included.

2. Ranking of each yearly low-flow value according to the magnitude in the n-day set.

3. A discharge/frequency relationship computed by fitting the selected n-day set to the log-Pearson III distribution. This distribution is described in Riggs (1968).

4. Discharge/frequency curves plotted from the observed n-day discharges and the theoretical discharges. Recurrence intervals are calculated using the plotting position formula:

> Recurrence interval = $(n + 1)/m$, where n is the number of events and m is the order number. The annual events are arrayed according to magnitude with the smallest as number 1. The 7-day low-flow computer analysis for West Branch Westfield River at Huntington is shown in table 3.

The fitted log-Pearson III frequency curve should be examined to check the fit of the curve to the observed data. The many factors affecting annual low flows, including precipitation, evapotranspiration, geologic characteristics, and unusual regulation and withdrawals, preclude the use of any distribution to adequately fit annual low-flow data in all cases. Higher annual low flows may not belong to the same population as the smaller ones because of differences in the basin characteristics influencing these events. If the curve fails to fit the data in the lower end, a graphical interpretation should be made. A graphical frequency curve is considered the basic curve for annual low flows according to Riggs (1971 and 1972). The 7-day 2-year and 10-year low flows, determined from frequency curves computed following the described procedures, are given in table 1 for the data base. These frequency curves are shown in figure 8 for selected gaging stations.

Discharge measurements made during periods of base flow, and estimating techniques using basin characteristics, are two methods that provide estimates of 7Q2 and 7Q10 if systematic discharge records are not available or if they are insufficient in length. The preferred estimating technique, because of the many factors affecting low flow and difficulty in providing an index to explain the variability in low flows, is the collection of base-flow measurements to estimate the low-flow characteristics as explained in Riggs (1972). Estimates of the 7-day low-flow characteristics, have been made for 343 sites as a result of a cooperative program between the Massachusetts Division of Water Resources and the U.S. Geological Survey. The Hydrologic Investigations Atlas reports containing these estimates are listed in appendix 1. Reports are in process for the Sudbury-Assabet-Concord and Blackstone River basins as well. This low-flow information may also be used to estimate low-flow characteristics at other sites as indicated in Riggs (1972).

Johnson (1970) estimated low-flow characteristics in central New England from basin parameters by using multiple-regression analysis. Drainage area, mean annual precipitation, minimum January temperature, and snow cover were the significant independent variables. The 7Q10 is estimated for most streams in the Connecticut Valley urban area in Brackley and Thomas (1979). Tasker (1972) utilized a ground-water availability factor and drainage area to estimate low flows in southeastern Massachusetts. Tasker (1975) suggests that a regional estimate be combined with the estimate from base-flow measurements to reduce the number of required field measurements. Male and Ogawa (1982) provide several estimating equations for 7Q10 based upon multiple-regression analysis using 15 independent variables and 28 stations in Massachusetts. The errors from low-flow regionalization techniques are often large because effects of the basin geology on low flow require additional data and analysis to quantify.

Regional storage relationships may be defined by using the 7Q2 value to estimate the reservoir storage required for different draft rates as in Tasker (1977). Facility-siting studies for water supply, hydropower, and wastewater treatment on streams require knowledge of the 7Q10.

SUMMARY

Daily flow statistics, available from computer program A969, are used to estimate low-flow and duration of flow characteristics, assuming the factors affecting streamflow remain the same as during the period of systematic flow records. The impact of regulation and diversions on the observed daily flow is determined, and a flow period is selected for analysis based upon the type of data being analyzed. The 39 station records selected for this analysis represent either essentially natural flow conditions or a fairly constant regulation pattern for several years. The average length of record at these sites is 25 years, and the daily flow exceeded 90 percent of the time ranged from 0.04 to 0.39 cubic foot per second per square mile. The 7-day 2-year, and 7-day 10-year low flows ranged from 0.01 to 0.37 and from 0 to 0.19 cubic foot per second per square mile, respectively. The fit of the observed low-flow data to the log Pearson III curve is examined and, for some streams, a graphical interpretation is preferred.

Guidelines are available to provide estimates of low-flow (7Q2 and 7Q10) and duration characteristics at sites other than those with sufficient daily flow record. Low-flow characteristics estimated from base flow measurements at 343 sites are given in the series of Hydrologic Investigations Atlas reports on water resources of the major river basins in Massachusetts. Techniques to estimate low-flow characteristics from basin parameters are available but generally provide results with large estimating errors if geologic or additional factors are not considered.

CONVERSION FACTORS

The following table may be used to convert inch-pound units to International System of Units (SI).

Multiply inch-pound units	By	To obtain SI Units
square mile (mi2)	2.590	square kilometer (km2)
cubic foot per second (ft^3/s)	.2832	cubic meter per second (m^3/s)
cubic foot per second per square mile ($ft^3/s/mi^2$)	10.93	cubic decimeter per second per square kilometer / (dm3/s)/km2 /

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Thomas, M. P., and Cervione, M. A., Jr., 1970, A proposed streamflow data program for Connecticut: Connecticut Water Resources Commission Bulletin no. 23.

U.S. Geological Survey, 1980, Water resources data for Massachusetts and Rhode Island, water year 1979: U.S. Geological Survey Water-Data Report MA-RI-79-1, 349 p.

Appendix 1.--U.S. Geological Survey Hydrologic Investigations Atlas reports (HA prefix omitted from report number) with flow-duration and low-flow characteristics

275. Water resources of the coastal basins of southeastern Massachusetts, Westport River, Westport to Seekonk, by R. E. Willey, J. R. Williams, and G. D. Tasker, 1978.
276. Water resources of the Nashua and Souhegan River basins, Massachusetts, by R. A. Brackley and B. P. Hansen, 1977.
281. Hydrology and water resources of the Housatonic River basin, Massachusetts, by R. F. Norvitch, D. F. Farrell, F. H. Pauszek, and R. G. Petersen, 1968.
293. Water resources of the Millers River basin, Massachusetts, by M. R. Collings, D. R. Wiesnet, and W. B. Fleck, 1968.
460. Water resources of the Taunton River basin, southeastern Massachusetts, by J. R. Williams, D. F. Farrell, and R. E. Willey, 1973.
481. Hydrology and water resources of the Hoosic River basin, Massachusetts, by B. P. Hansen, L. G. Toler, and F. B. Gay, 1973.
484. Hydrology and water resources of the Neponset and Weymouth River basins, Massachusetts, by R. A. Brackley, W. B. Fleck, and W. R. Meyer, 1973.
504. Water resources of the coastal drainage basins of southeastern Massachusetts, Weir River, Hingham, to Jones River, Kingston, by J. R. Williams and G. D. Tasker, 1974.
506. Hydrology and water resources of the Deerfield River basin, Massachusetts, by F. B. Gay, L. G. Toler, and B. P. Hansen, 1974.
507. Water rescures of the coastal drainage basins of southeastern Massachusetts, Plymouth to Weweantic River, Wareham, by J. R. Williams and G. D. Tasker, 1974.
554. Water resources of the Charles River basin, Massachusetts, by E. H. Walker, S. W. Wandle, Jr., and W. W. Caswell, 1975.
560. Water resources of the coastal drainage basins of southeastern Massachusetts, northwest shore of Buzzard's Bay, by J. R. Williams and G. D. Tasker, 1978.
562. Streamflow and water quality in the Connecticut River Lowlands, Massachusetts, by S. W. Wandle, Jr. and W. W. Caswell, 1977.
589. Hydrology and water resources of the coastal drainage basins of northeastern Massachusetts, from Castle Neck River, Ipswich, to Mystic River, Boston, by David F. Delaney and Frederick B. Gay, 1980.
614. Hydrology and water resources of the Shawsheen River basin, Massachusetts, by Frederick B. Gay and David F. Delaney, 1980.
616. Hydrology and water resources of the lower Merrimack River basin, Massachusetts, from Concord River, Lowell, to Plum Island, Newburyport, by Frederick B. Gay and David F. Delaney, 1980.

Table 1.--Summary of low-flow characteristics, drainage area, and period of record for flow-frequency network

ber n ures 8	Station number from data-collection network of the U.S. Geological Survey	Station name	Period of record, in water years, for analysis	Contributing drainage area	Annual minimum 7-day mean low flow, in ft^3/s at indicated recurrence interval		Remarks
				(mi^2)	2-year	10-year	
	01096000	SQUANNACOOK RIVER NEAR WEST GROTON, MA	1950-79	62.8	12.6	5.4	
	01097300	NASHOBA BROOK NEAR ACTON, MA	1964-79	12.7	.38	.12	Occasional regulation since 1967.
	01100600	SHAWSHEEN RIVER NEAR WILMINGTON, MA	1965-72	36.5	--	--	Less than 10 years of record. Diversions at times since 1973.
	01100700	EAST MEADOW RIVER NEAR HAVERHILL, MA	1963-74	4.93	.38	.11	Discontinued.
	01105557	FURNACE BROOK AT QUINCY, MA	1973-79	3.83	--	--	Less than 10 years of record.
	01105600	OLD SWAMP RIVER NEAR SOUTH WEYMOUTH, MA	1967-79	4.29	.35	.18	
	01106000	ADAMSVILLE BROOK AT ADAMSVILLE, RI	1941-78	7.91	.15	.05	Discontinued.
	01109200	WEST BR PALMER RIVER NEAR REHOBOTH, MA	1962-74	4.34	.05	0	Discontinued.
	01161500	TARBELL BROOK NEAR WINCHENDON, MA	1968-79	18.2	2.4	1.2	Regulation greater prior to 1967.
	01162500	PRIEST BROOK NEAR WINCHENDON, MA	1917-79	19.4	1.7	.37	Regulation at low flow prior to 1953.
	01163200	OTTER RIVER AT OTTER RIVER, MA	1966-79	34.2	7.0	4.5	
	01165000	EAST BRANCH TULLY RIVER NEAR ATHOL, MA	1917-48	50.4	3.3	2.1	Regulated by Tully Reservoir since 1948.
	01165500	MOSS BROOK AT WENDELL DEPOT, MA	1917-79	12.3	1.3	.55	
	01169000	NORTH RIVER AT SHATTUCKVILLE, MA	1950-79	88.4	12.9	8.1	Regulation greater prior to 1950.
	01169900	SOUTH RIVER NEAR CONWAY, MA	1967-79	24.0	5.6	4.1	
	01170100	GREEN RIVER NEAR COLRAIN, MA	1968-79	41.4	7.9	4.5	
	01171500	MILL RIVER AT NORTHAMPTON, MA	1940-79	54.0	10.0	6.2	Regulation prior to 1956.
	01171800	BASSET BROOK NEAR NORTHAMPTON, MA	1964-74	5.56	.89	.46	Discontinued.
	01172500	WARE RIVER NEAR BARRE, MA	1947-57	55.0	4.2	1.4	Regulated by Barre Falls Reservoir since 1958.
	01173260	MOOSE BROOK NEAR BARRE, MA	1963-74	4.54	.07	0	Discontinued.
	01173500	WARE RIVER AT GIBBS CROSSING, MA	1913-30	199	48.9	27.3	Diversions since 1931.
	01174000	HOP BROOK NEAR NEW SALEM, MA	1949-79	3.39	.12	0	
	01174500	EAST BRANCH SWIFT RIVER NR HARDWICK, MA	1938-79	43.7	4.2	.09	
	01174600	CADWELL CREEK NEAR PELHAM, MA	1962-79	.63	.02	0	
	01174900	CADWELL CREEK NEAR BELCHERTOWN, MA	1962-79	2.81	.16	.09	
	01175500	SWIFT RIVER AT WEST WARE, MA	1913-39	188	68.7	35.6	Regulated by Quabbin Reservoir since 1939.
	01175670	SEVENMILE RIVER NEAR SPENCER, MA	1962-79	8.58	.48	.21	Occasional regulation since 1971.
	01176000	QUABOAG RIVER AT WEST BRIMFIELD, MA	1939-79	151	26.4	13.0	Regulation greater prior to 1938.
	01179500	WESTFIELD RIVER AT KNIGHTVILLE, MA	1910-40	162	24.2	13.8	Regulated by Knightville Reservoir since 1941.
	01180000	SYKES BROOK AT KNIGHTVILLE, MA	1946-73	1.64	.11	.06	Discontinued.
	01180500	MIDDLE BR WESTFIELD R AT GOSS HEIGHTS, MA	1911-64	52.6	4.6	2.1	Regulated by Littleville Lake since 1965.
	01180800	WALKER BROOK NEAR BECKET CENTER, MA	1964-77	3.01	.34	.21	Discontinued.
	01181000	WEST BR WESTFIELD RIVER AT HUNTINGTON, MA	1936-79	93.7	10.5	5.6	
	01185100	FALL R BL OTIS RESERVOIR NR OTIS, MA	1970-79	16.5	--	--	Regulated by Otis Reservoir.
	01197300	MARSH BROOK AT LENOX, MA	1964-74	2.19	.06	0	Discontinued.
	01198000	GREEN RIVER NEAR GREAT BARRINGTON, MA	1952-71	51.0	5.3	3.3	Discontinued.
	01331400	DRY BROOK NEAR ADAMS, MA	1963-74	7.53	.90	0	Discontinued.
	01332000	NORTH BR HOOSIC RIVER AT NORTH ADAMS, MA	1932-79	39.0	7.7	5.1	Diurnal fluctuation prior to 1948.
	01333000	GREEN RIVER AT WILLIAMSTOWN, MA	1950-79	42.6	8.5	4.5	Slight diurnal fluctuation at times.

Table 2.--Duration table from computer program A969

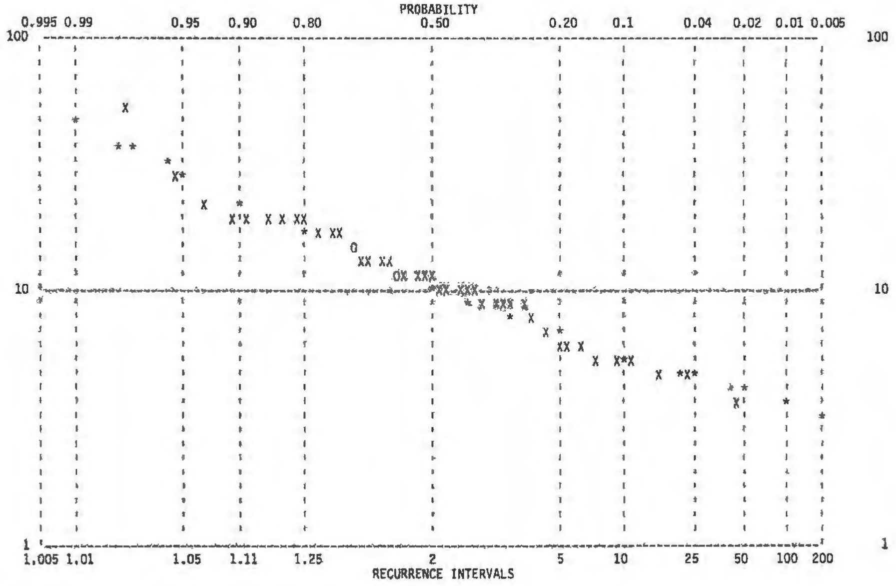
```
                                               STATION NUMBER  01181000
                                   DURATION TABLE OF DAILY VALUES FOR YEAR ENDING SEPTEMBER 30
DISCHARGE-(CFS)
MEAN
WEST BRANCH WESTFIELD RIVER AT HUNTINGTON, MA
CLASS     0  1  2  3  4  5  6  7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26 27 28 29 30 31 32 33 34
YEAR                                            NUMBER OF DAYS IN CLASS
1936                 10 24 24 20  35  15  23  16  25  22  39  21  29   8   5   9   7   7   8   4   5   3   2  2     1  1        1
1937                           3  16  22  11  19  23  25  24  23  45  25  36  27  14  17  12  11   7   2   1  1     1
1938                               1   7   8  16  12  24  20  46  55  33  38  37  24  10   8   9   7   3   1  4        1     1
1939                     5 25 21   8  11  21   8  22  30  27  34  44  30  12  11  15  12  12   9   3   1   2  2
1940                     4 25 31  15  11  37  46  43  23  20  20  13  14  11   8   6   5   9   3   8   5   5  2  1  1

1941                     9 25 26  19  13  24  30  37  31  43  24  31  12  12   5   8   8   7               1
1942                        1  4  18  25  19  19  35  41  43  38  35  15  12   9  20  11   4   9   2   3      2
1943                        1  2  25  12  23  21  15  11  21  49  33  23  23  19  27  18  19   8   9   5         1
1944                  3  4 13 19  20  27  28  47  21  28  20  17  27  20  20   7  16  10   6   8   3   1         1
1945                               3  17  13   9  14  41  42  29  40  20  26  18  27  18  19  11   9   3   1  4  1

1946                        8 13  19  18  17   9   9  24  54  47  45  21  15  20  13  15   5   6   3   1   2  1
1947                  5  6 13 10  11  27  52  44  20  22  27  12  24  12  11  14  17  10   9   9   4   2   3     1
1948                    14 31 16  14   8  11  13  28  28  27  30  27  20  20  17  20  11  10   8   6   1   3  1  1  1
1949            4  3 10 11 25 33  26  25  16  24  19  14   8  15  31  28  18  13  12  12   9   2   1   2      2  1              1
1950                    10 39 28  24  30  17  11  10  13  23  24  28  20  21  21  20  10   6   6   1   1   1  1

1951                     9    14  24  23  27  1/  13  20  22  26  27  26  22  30  28  14   7   8   4       1     1  2
1952                        4  4  14  17  21  14  11  13  23  15  44  35  37  22  31  20  18   8   5   2   4  2  1  1
1953           17 11 12 11  9 10   7  46  18  12  10   9  20   9  26  18  15  20  18  26  12  11   5   4   4  4  1
1954            3  2  8 11  8 16  13  13  17  23  26  26  20  21  29  26  26  26  20  12   4   6   6   1   1  1
1955         6  4  9  3  3  6  2   7  17  16  17  26  26  20  22  27  32  29  18  26  11  16   5   7   5   1  2  1                 1

1956               1  7 21  7  6  12  13  14  24  15  29  22  32  30  20  13  16  14  12  20  16  10   2   1  4  3           1  1
1957            4  9 21 22 13 14  15   8  10  13  14  29  33  32  40  24  21  18  15   4   3   2              1
1958               5  7  2 11 19  23  12  23  20  21  24  43  22  35  22  13  11  15   6   8   9   6   2   4  2
1959                     7 15 18  12  11  17  29  26  36  29  26  41  22  16  16  14  10   9   6   1   3      1
1960                        3  6  11  15  15  17  17  12  32  30  53  37  27  24  17  12  10   7   9   6   2  2     1  1

1961                     6 14 11  12  12  10  10  41  49  31  22  21  27  15  13  17  23  11  14   1   4   1
1962               6 15 18 23 23  20  21  15  22  51  30  19  20  23  10   9   9   9   7   6   2   1   3   2     1
1963            1  8 15  8 17 15  12  20  10  18  23  52  39  21  33  19  19   9   8   2   4   3   4   3   2
1964            7 10 26 17 24 23  14  21  11   9   8  21  29  33  18  15  13  13  15  18   8   9   3   1
1965            1 10 24 16 39 20  22  30  38  26  14  20  30  23  12  12   8   2   6   8   1   2   1

1966            2  7 13 13 13 31  30  17  41  32  14  19  19  14  20  21  17  18  17   4   2       1
1967                     6  9  7  16   9   9  14  10  34  66  43  38  23  18  16  13  12  11   4   4   1   1  1
1968                     2 11 19  23  10  10   9   9  38  34  44  50  22  23  16  13   8  11       4   7   2  1
1969                     3  1  2  10  26  29  20  15  18  65  40  39  19  15  10  12  12   8   4   6   4   3  1  2     1
1970            2  3  5 11 12 16   9  16  16  17  17  18  18  37  47  25  21  21   8  11   9  12   6   3   2  3

1971                     4 15 19  20  19  11  13  17  29  50  29  44  18  16   7  12  13   9   9   5   4   2
1972                           2  23   6   9  15  10  16  16  33  52  29  30  28  30  16  19  10   5   5   7  1  1  2  1
1973                           2  11  11  21  27  22  16  13  14  38  29  33  37  25  16  12  13  12   5   4  2  2
1974                        8  8  20  15  11  18  27  22  14  23  31  40  33  31  20  14  12   7   4   3   2  1           1
1975                               3   6  12  18  19  19  27  35  60  42  27  30  18  19   9   4   6   2   4  2  1  1     1

1976                        3  7  17  19  14  17  10  11   6  20  53  44  41  32  24  11  12  13   5   2   2     1  2
1977                           3  12 [illegible] [illegible]  46  33  37  36  17  34  18  18  15   9   9   5   5   6   5      3  2     1  1
1978                          18  16  20  14  10   9   5  21  15  38  47  34  34  23  19  18  10   6   5      2     1
1979                           6  25  38  34  25  18  22  23  15  29  17  19  18  19  15  14   9   4   6   5        3  1

CLASS   VALUE   TOTAL   ACCUM    PERCT         CLASS   VALUE   TOTAL   ACCUM    PERCT         CLASS   VALUE   TOTAL   ACCUM    PERCT
  0       0.0       0   16071    100.0          12      47.0     879   11200     69.7          24     840.0     205     520      3.2
  1       3.2       6   16071    100.0          13      59.0    1077   10321     64.2          25    1100.0     121     315      1.9
  2       4.2      45   16065    100.0          14      75.0    1258    9244     57.5          26    1400.0      79     194      1.2
  3       5.3      84   16020     99.7          15      96.0    1162    7986     49.7          27    1700.0      58     115       .7
  4       6.8     184   15936     99.2          16     120.0    1539    6824     42.5          28    2200.0      24      57       .3
  5       8.6     277   15752     98.0          17     160.0    1040    5285     32.9          29    2800.0      17      33       .2
  6      11.0     495   15475     96.3          18     200.0     908    4245     26.4          30    3500.0       7      16
  7      14.0     573   14980     93.2          19     250.0     795    3337     20.8          31    4500.0       3       9
  8      18.0     707   14407     89.6          20     320.0     742    2542     15.8          32    5700.0       2       6
  9      23.0     768   13700     85.2          21     410.0     538    1800     11.2          33    7300.0               4
 10      29.0     848   12932     80.5          22     520.0     431    1262      7.9          34    9300.0       1       1
 11      37.0     884   12084     75.2          23     660.0     311     831      5.2

VALUE EXCEEDED 'P' PERCENT OF TIME

V95 =       12.0
V90 =       18.0
V75 =       37.0
V70 =       46.0
V50 =       95.0
V25 =      210.0
V10 =      450.0
```

Table 3.--Low-flow frequency analysis from computer program A969

```
                                                  STATION NUMBER  01181000
                    LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS·IN YEAR ENDING MARCH 31
DISCHARGE-(CFS)
MEAN
WEST BRANCH WESTFIELD RIVER AT HUNTINGTON, MA
YEAR        1           3           7          14          30          60          90         120         183
1937     7.60 12     7.70 12     8.50 12     9.20 12    10.00 10    11.00  5    16.00  9    20.00  9    38.00  7
1938    15.00 35    16.00 35    20.00 40    22.00 35    24.00 32    55.00 40    82.00 40    94.00 39   159.00 39
1939    20.00 42    23.00 42    27.00 42    29.00 42    48.00 41   112.00 43   164.00 43   180.00 43   195.00 41
1940    10.00 25    11.00 25    11.00 24    13.00 24    18.00 24    20.00 16    21.00 14    23.00 12    39.00  8

1941     9.60 20     9.80 21    10.00 20    12.00 22    14.00 16    15.00 12    16.00 10    22.00 10    42.00 11
1942     9.50 21     9.60 19     9.80 17    11.00 19    19.00 27    27.00 27    29.00 20    33.00 19    50.00 17
1943    16.00 37    18.00 40    18.00 36    22.00 36    41.00 40    46.00 38    52.00 35    64.00 32    95.00 31
1944    13.00 31    14.00 34    16.00 34    19.00 33    23.00 30    23.00 22    39.00 27    42.00 25    93.00 29
1945     8.10 15     8.30 14     9.30 16    10.00 15    13.00 14    23.00 23    31.00 21    33.00 20    44.00 14

1946    43.00 43    47.00 43    55.00 43    67.00 43    73.00 43    86.00 41    37.00 41   108.00 40   135.00 36
1947    11.00 26    11.00 26    13.00 27    17.00 31    18.00 25    24.00 24    34.00 22    37.00 22    40.00  9
1948     7.90 13     7.90 13     8.70 13     9.80 14    13.00 15    14.00 10    18.00 12    26.00 13    62.00 21
1949     9.80 23     9.80 20    10.00 21    11.00 16    15.00 17    17.00 13    22.00 15    27.00 14    46.00 15
1950     4.20  2     4.50  3     5.20  4     6.80  6    10.00 11    13.00  7    14.00  6    16.00  6    21.00  2

1951     8.60 16     8.70 16     9.00 14     9.50 13    11.00 12    15.00 11    17.00 11    19.00  7    58.00 20
1952    16.00 38    17.00 36    19.00 37    23.00 38    26.00 33    40.00 34    61.00 37    67.00 33    91.00 28
1953    11.00 27    12.00 28    13.00 28    22.00 37    26.00 34    30.00 31    42.00 31    41.00 24    69.00 22
1954     4.30  3     4.30  2     4.40  2     4.50  1     5.80  1     8.80  1     9.70  1    14.00  3    28.00  5
1955     8.00 14     8.40 15     9.10 15    11.00 17    17.00 20    22.00 19    51.00 32    89.00 37   140.00 37

1956     3.30  1     3.50  1     3.80  1     4.50  2     5.90  3    20.00 17    36.00 24   123.00 41   222.00 43
1957     6.70 11     7.00 11     7.90 11     8.40 10     9.40  7    17.00 14    24.00 17    34.00 21    56.00 19
1958     4.60  6     4.70  6     5.50  5     6.40  5     7.80  4     9.70  2    10.00  2    11.00  1    22.00  3
1959    13.00 32    13.00 31    13.00 29    15.00 28    27.00 35    34.00 32    40.00 28    52.00 26    89.00 27
1960     9.40 19     9.50 17     9.90 18    12.00 20    18.00 21    27.00 28    35.00 23    40.00 23    74.00 23

1961    11.00 28    12.00 29    13.00 30    16.00 29    31.00 39    46.00 39    59.00 36    83.00 36   104.00 35
1962     9.60 22    10.00 22    11.00 22    12.00 21    18.00 22    22.00 18    22.00 16    32.00 17    43.00 12
1963     5.90 10     6.00 10     6.40 10     8.60 11     9.40  8    14.00  8    15.00  7    19.00  8    38.00  6
1964     4.80  9     5.20  8     5.90  7     7.00  7     9.20  6    11.00  3    13.00  4    16.00  4    42.00 10
1965     4.40  5     4.60  4     4.80  3     5.30  3     5.80  2    11.00  4    11.00  3    13.00  2    17.00  1

1966     4.70  7     5.20  9     6.00  8     6.40  4    10.00  9    12.00  6    14.00  5    16.00  5    22.00  4
1967     4.30  4     4.70  5     5.50  6     7.10  8     8.90  5    14.00  9    16.00  8    22.00 11    55.00 18
1968     9.30 17     9.60 18    10.00 19    11.00 18    16.00 18    25.00 25    39.00 25    54.00 28    80.00 26
1969     9.90 24    10.00 23    11.00 23    13.00 23    18.00 23    26.00 26    27.00 19    33.00 18    94.00 30
1970    17.00 39    17.00 37    19.00 38    24.00 39    30.00 38    45.00 37    63.00 38    93.00 38    97.00 33

1971     4.70  8     5.10  7     6.00  9     7.60  9    13.00 13    19.00 15    21.00 13    27.00 15    49.00 16
1972     9.30 18    10.00 24    12.00 25    14.00 25    17.00 19    23.00 20    39.00 26    57.00 29    78.00 25
1973    15.00 36    17.00 38    18.00 35    19.00 34    21.00 29    30.00 29    41.00 29    61.00 30   180.00 40
1974    17.00 40    18.00 39    20.00 39    24.00 40    27.00 36    30.00 30    51.00 33    64.00 31   100.00 34
1975    11.00 29    11.00 27    12.00 26    14.00 26    20.00 28    40.00 35    52.00 34    70.00 34    96.00 32

1976    20.00 41    21.00 41    22.00 41    28.00 41    56.00 42   104.00 42   111.00 42   135.00 42   209.00 42
1977    12.00 30    13.00 30    14.00 31    15.00 27    24.00 31    41.00 36    65.00 39    75.00 35    74.00 24
1978    14.00 33    14.00 32    16.00 32    18.00 32    29.00 37    36.00 33    42.00 30    53.00 27   147.00 38
1979    14.00 34    14.00 33    16.00 33    17.00 30    19.00 26    23.00 21    25.00 18    30.00 16    44.00 13
```

Table 3.--Low-flow frequency analysis from computer program A969 (Continued)

```
WEST BRANCH WESTFIELD RIVER AT HUNTINGTON, MA              N =     43                          STATION  01181000

1937-1979,  12 MON PERIOD ENDING MARCH 31
  7  DAY LOW VALUE


INPUT DATA (ZERO VALUES OMITTED)

      8.500        20.000        27.000        11.000        10.000         9.800        18.000        16.000         9.300        55.000
     13.000         8.700        10.000         5.200         9.000        19.000        13.000         4.400         9.100         3.800
      7.900         5.500        13.000         9.900        13.000        11.000         6.400         5.900         4.800         6.000
      5.500        10.000        11.000        19.000         6.000        12.000        18.000        20.000        12.000        22.000
     14.000        16.000        16.000
MEAN =        12.667                                                       MEAN LOGS =          1.036
VARIANCE =        72.521                                                   VARIANCE LOGS =          0.055
STANDARD DEVIATION =          8.516                                        STANDARD DEVIATION LOGS =          0.235
SKEWNESS =        3.105                                                    SKEWNESS LOGS =          0.364
STANDARD ERROR OF SKEWNESS =          0.361                                STANDARD ERROR OF SKEWNESS LOGS =          0.361
SERIAL CORRELATION COEFFICIENT =          0.107                            SERIAL CORRELATION COEFFICIENT LOGS =          0.296
COEFFICIENT OF VARIATION =          0.672                                  COEFFICIENT OF VARIATION LOGS =          0.226

NON EXCEED PROB     RECURRENCE INTERVAL    PARAMETER VALUE

     0.0100              100.00                 3.578
     0.0200               50.00                 3.992
     0.0500               20.00                 4.742
     0.1000               10.00                 5.572
     0.2000                5.00                 6.849
     0.5000                2.00                10.516
     0.8000                1.25                16.913
     0.9000                1.11                22.098
     0.9600                1.04                29.826
     0.9800                1.02                36.502
     0.9900                1.01                44.019
WEST BRANCH WESTFIELD RIVER AT HUNTINGTON, MA              N =     43                          STATION  01181000

1937-1979,  12 MON PERIOD ENDING MARCH 31
  7  DAY LOW VALUE
```



```
THE FOLLOWING SYMBOLS MAY APPEAR IN THE PLOT
X - AN INPUT DATA VALUE
* - A CALCULATED VALUE
0 - A CALCULATED VALUE AND ONE DATA VALUE AT SAME POSITION
2 - TWO INPUT DATA VALUES PLOTTED AT SAME POSITION
3 - THREE INPUT DATA VALUES PLOTTED AT SAME POSITION
A - A CALCULATED VALUE AND TWO DATA VALUES AT SAME POSITION
B - A CALCULATED VALUE AND THREE DATA VALUES AT SAME POSITION
```

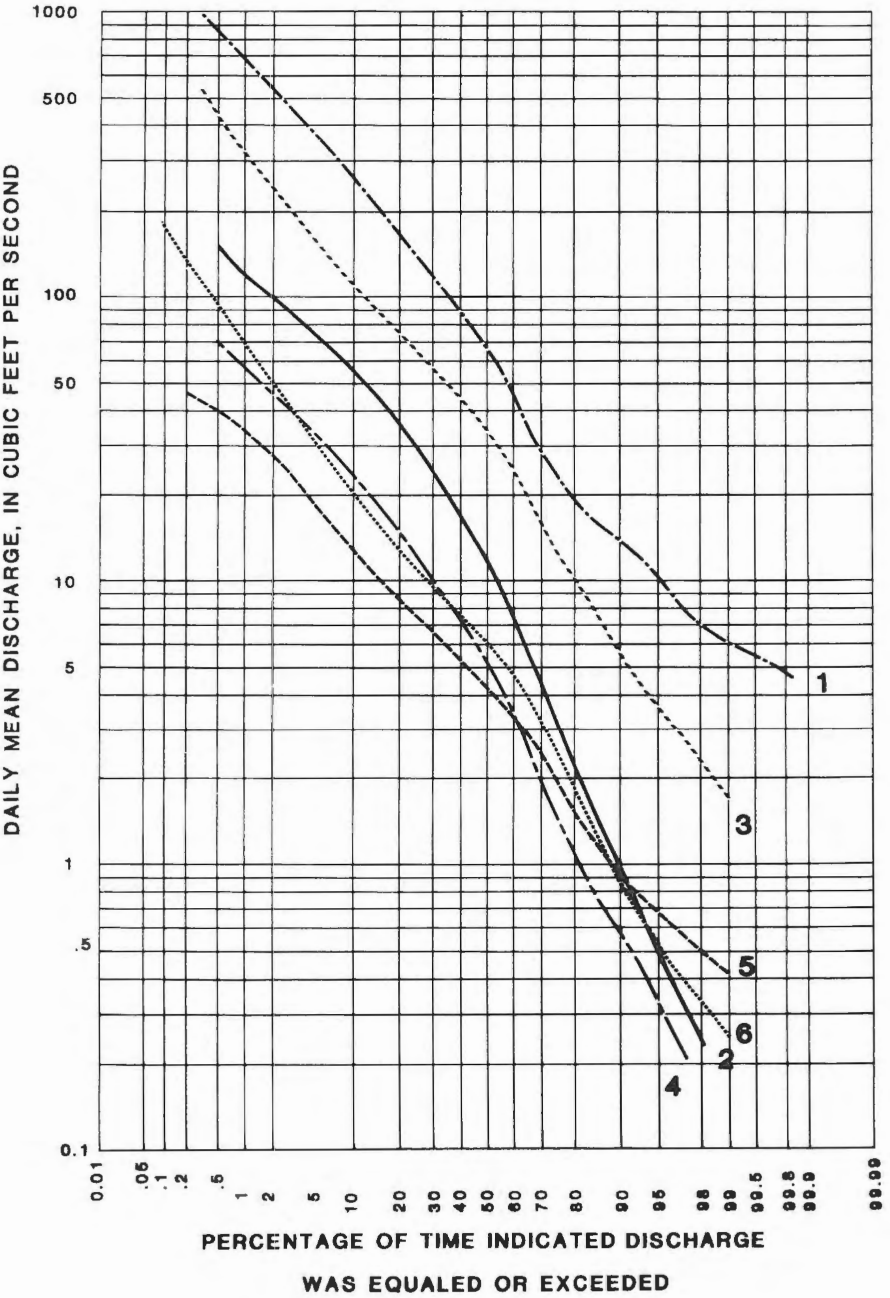
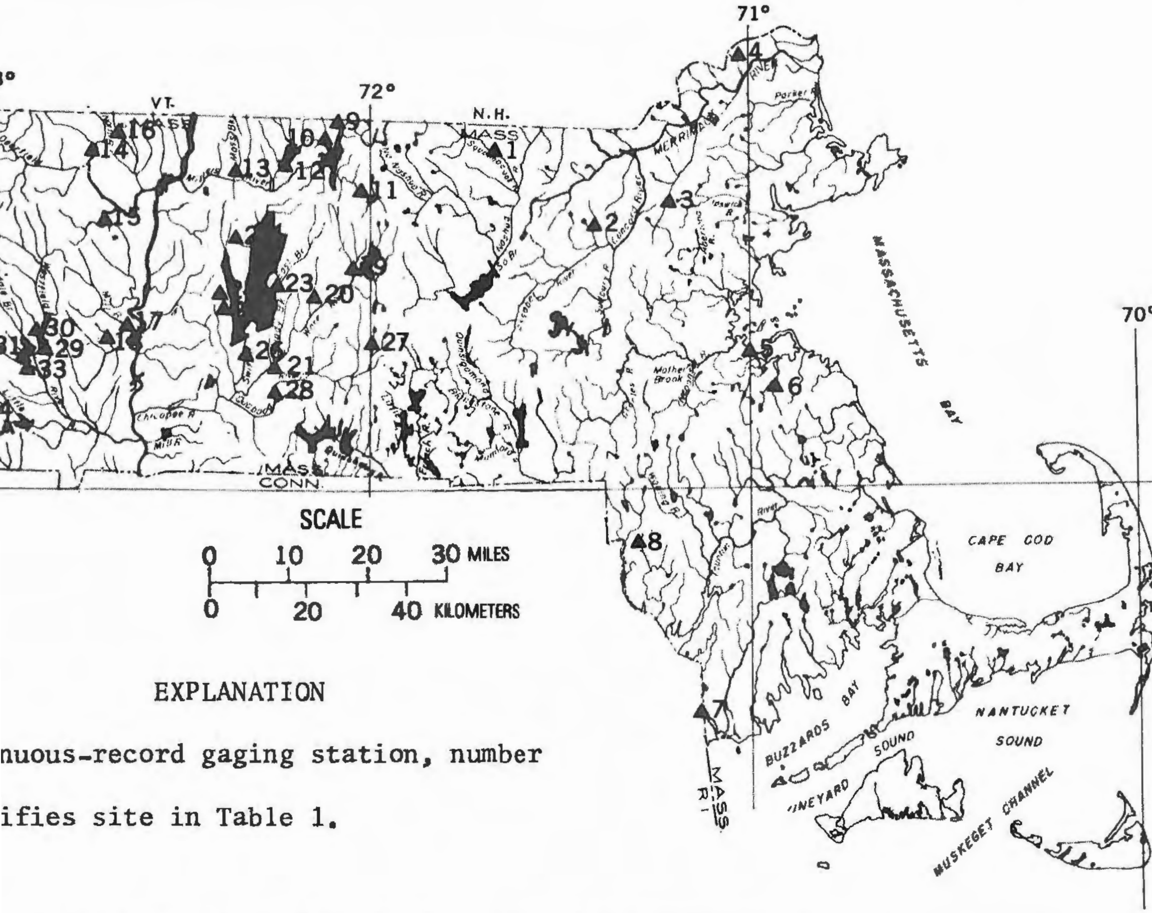


Figure 2.--Flow-duration curves for stations 1 to 6 in table 1.



EXPLANATION

nuous-record gaging station, number

ifies site in Table 1.

.--Location of gaging stations for flow-frequency network.

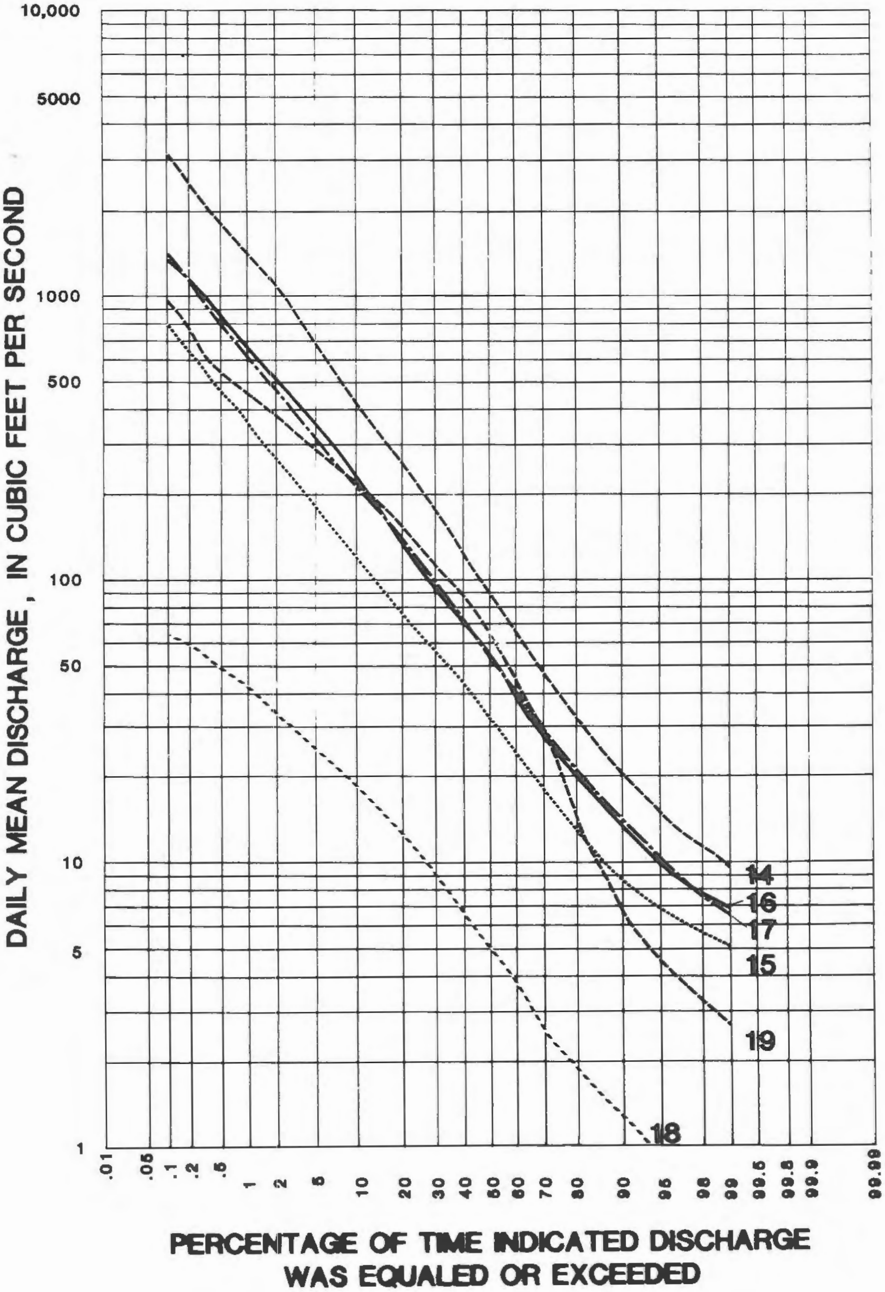


Figure 4.--Flow-duration curves for stations 14 to 19 in table 1.

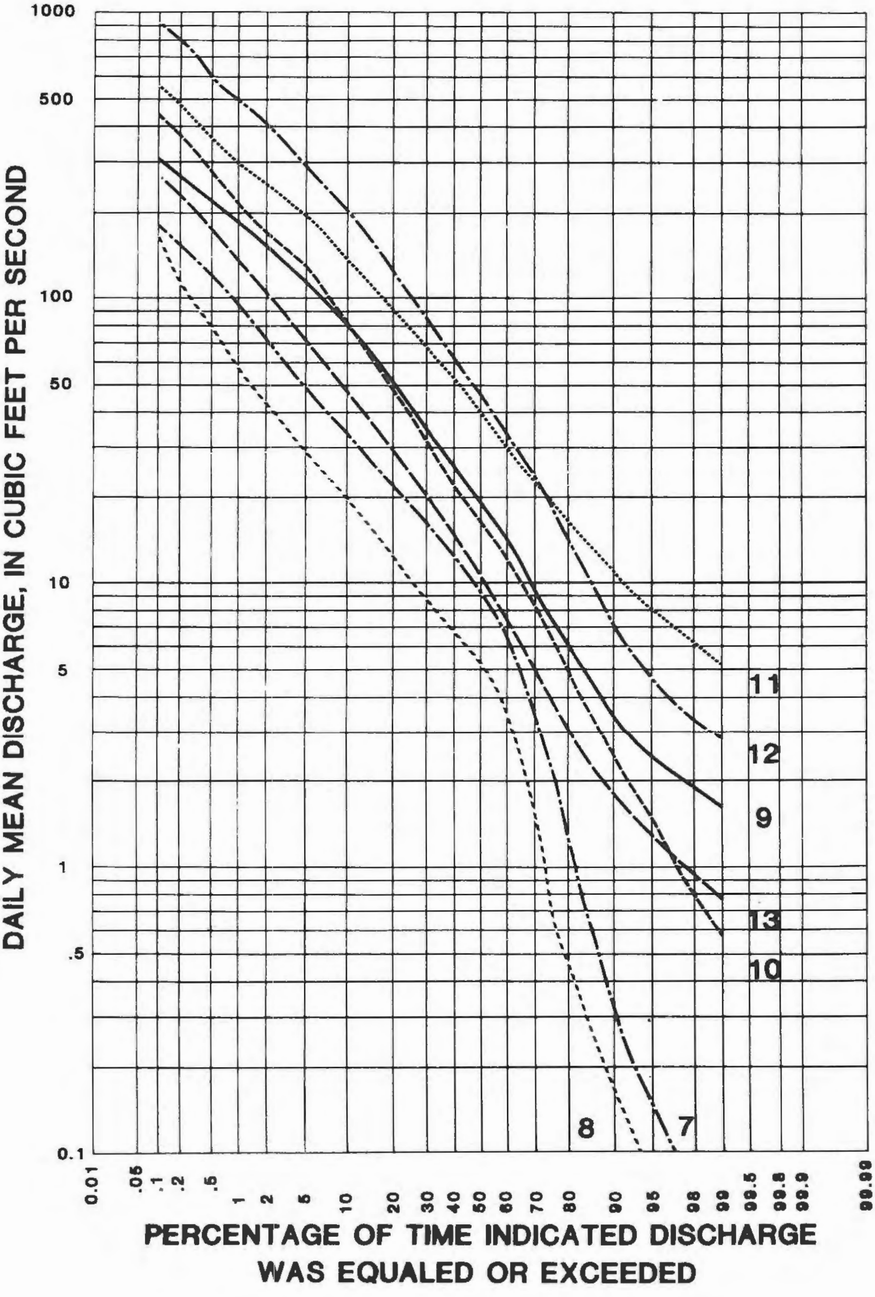


Figure 3.--Flow-duration curves for stations 7 to 13 in table 1.

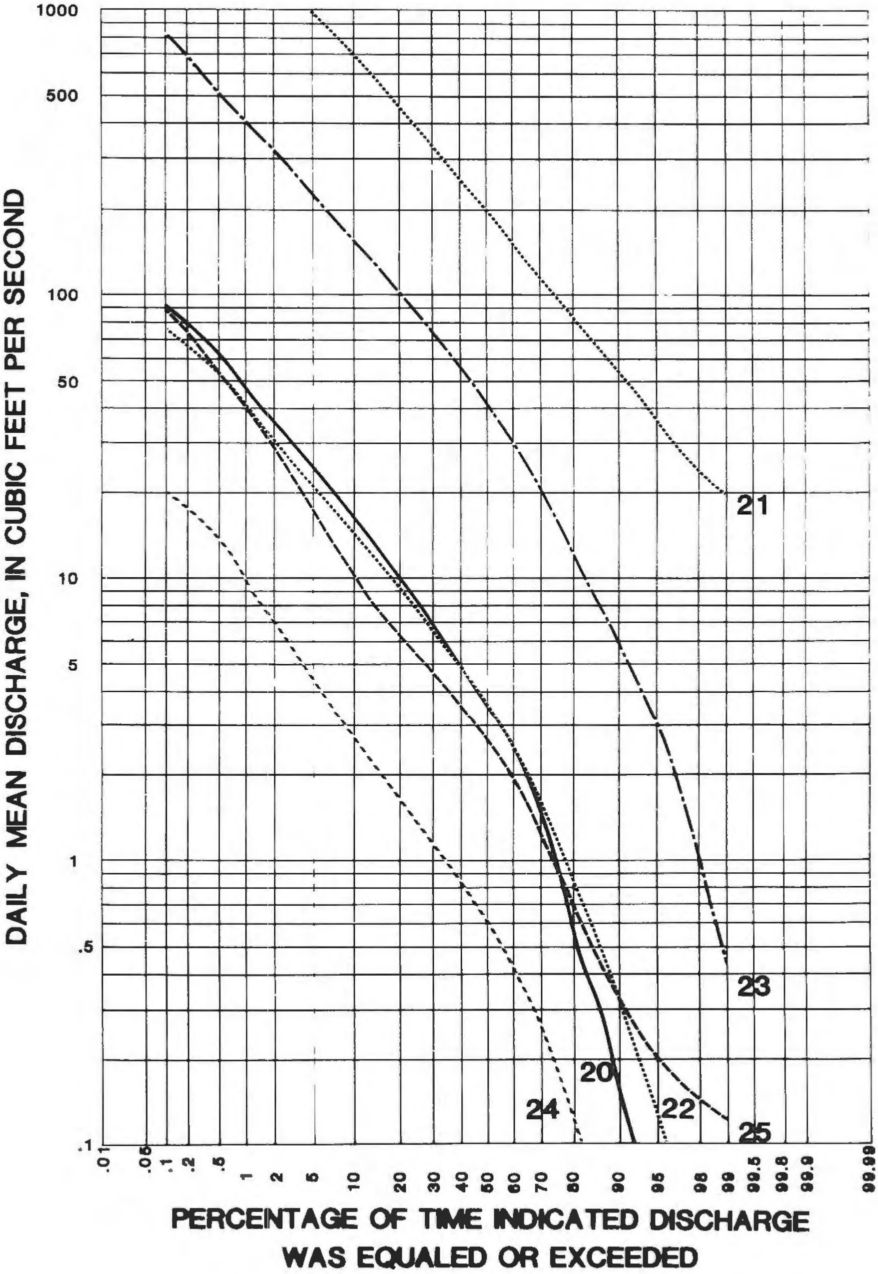


Figure 5. --Flow-duration curves for stations 20 to 25 in table 1.

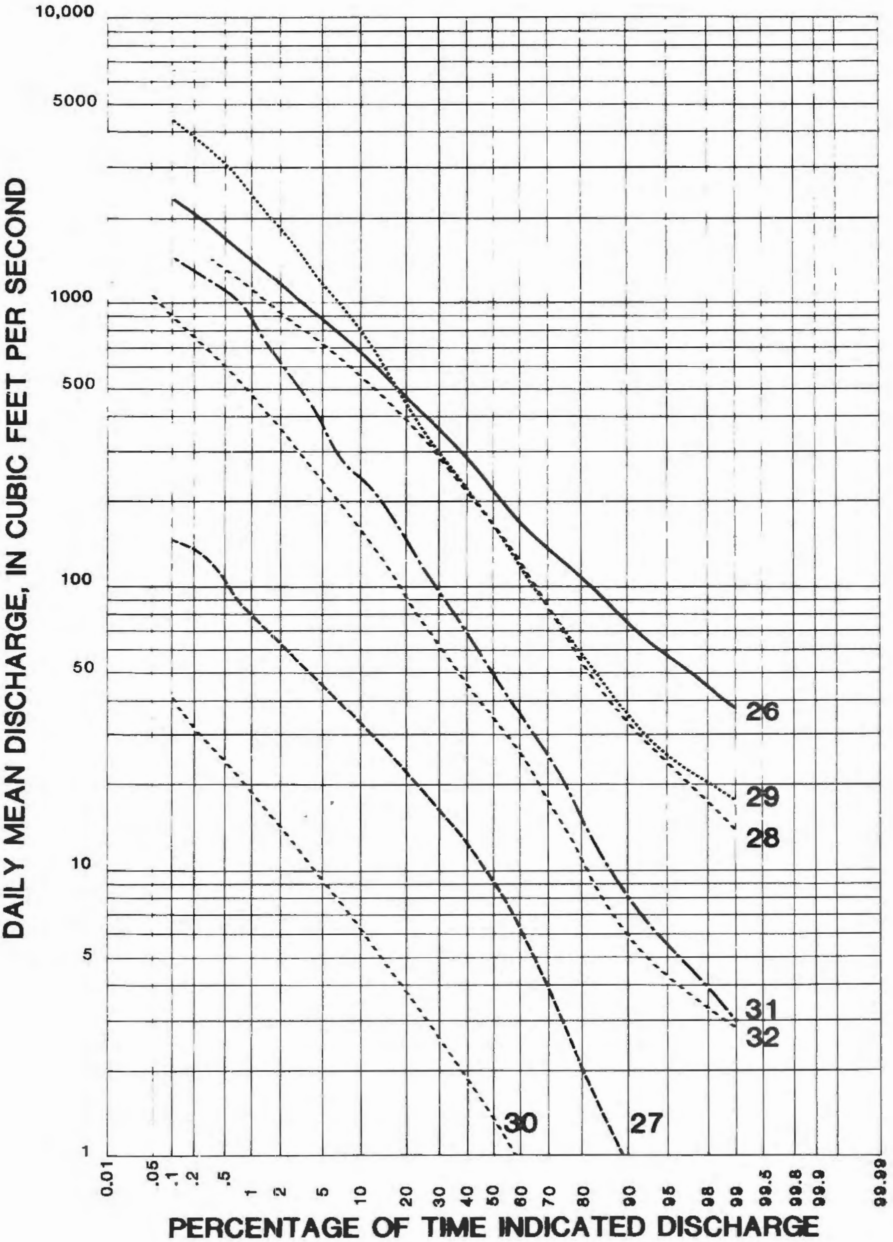


Figure 6.--Flow-duration curves for stations 26 to 32 in table 1.

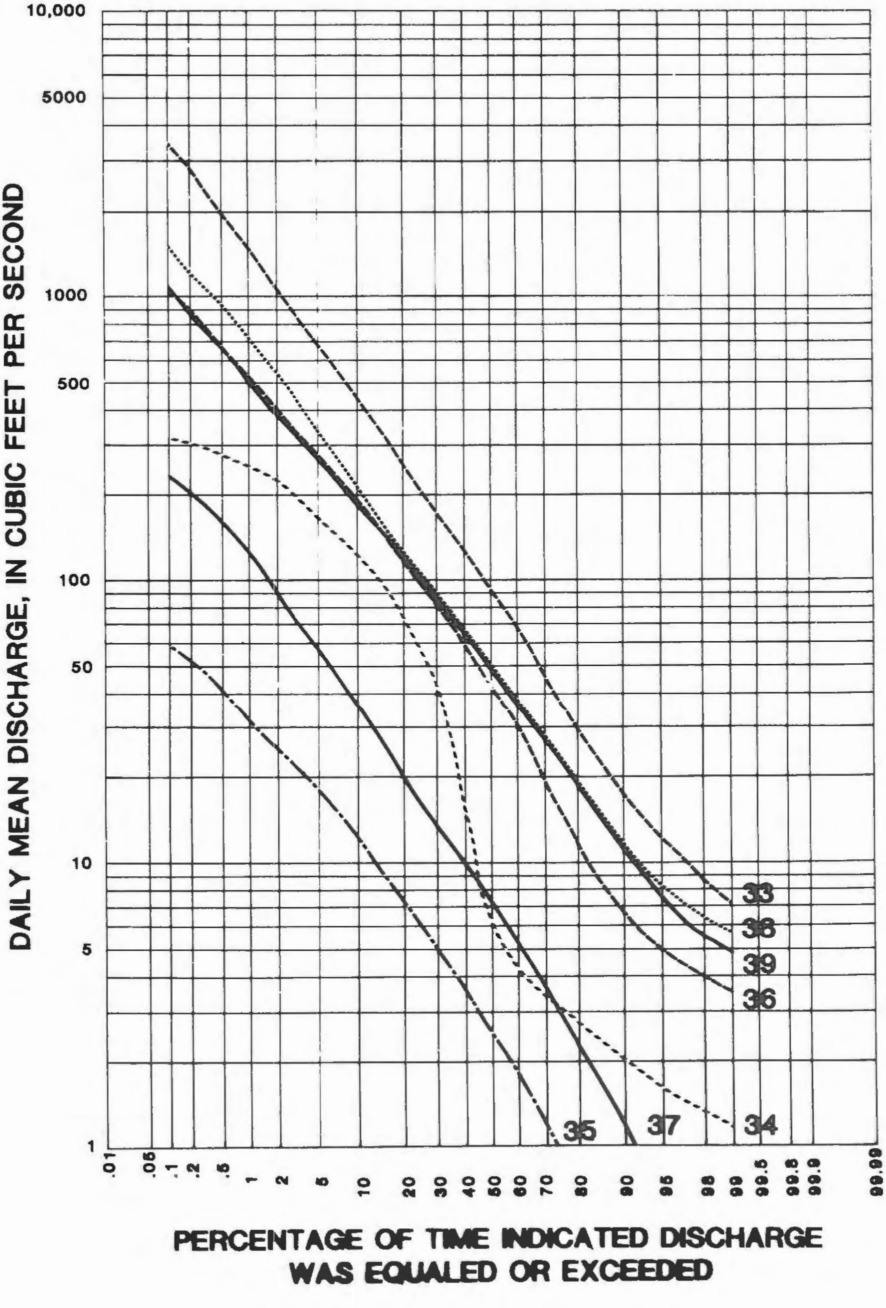


Figure 7.--Flow-duration curves for stations 33 to 39 in table 1.

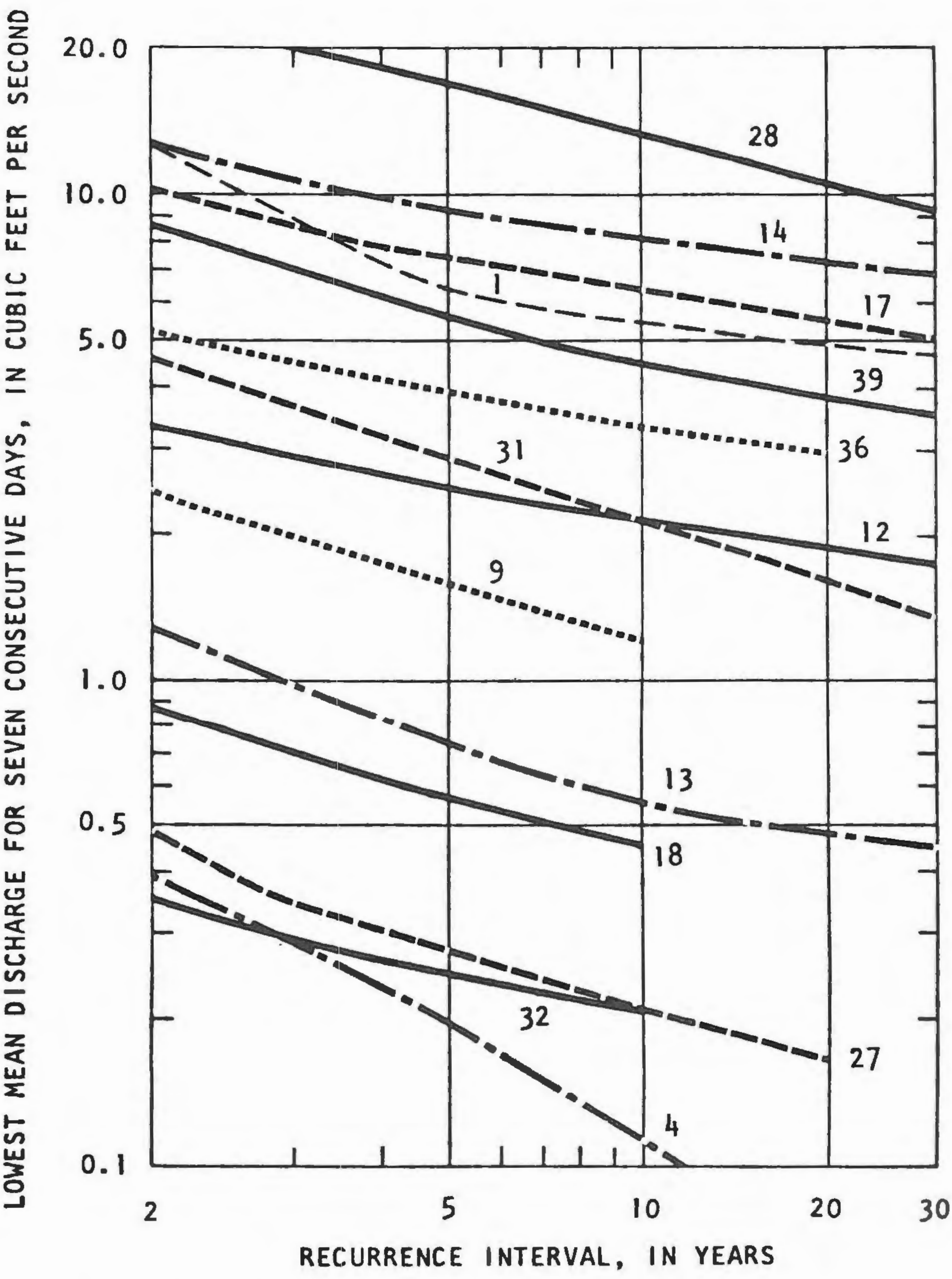


Figure 8.--Seven-day low-flow frequency curves for selected stations in table 1

MEMOIRE

Joseph C. Lawler

1920 - 1982

Joseph Christopher Lawler, son of Joseph C. and Clara M. (Emerson) Lawler, was born in Lynn, Massachusetts, on May 3, 1920. He received a B.S. degree in civil engineering from Northeastern University in 1943, immediately entered the Navy as an ensign in the Civil Engineer corps and spent the rest of the war with a construction battalion in the South Pacific. Discharged in 1946, he entered Harvard that fall to study sanitary engineering under Gordon Fair. He was granted an M.S. in 1947 and joined the small, newly formed Boston consulting engineering partnership of Camp Dresser & McKee, an association that was to continue for the remainder of his life. The firm then comprised at most eight persons in addition to the partners, Dr. Thomas R. Camp, Herman G. Dresser and Dr. Jack E. McKee.

Mr. Lawler's technical competence, appetite for hard work, limitless energy and instinctive business sense soon made themselves felt. He became a partner in the firm in 1952, was named President when the partnership was incorporated in 1970, and was Chairman of the Board and Chief Executive Officer at the time of his death. Under his leadership Camp Dresser & McKee Inc. had become an internationally known organization employing mroe than 1200 engineers, scientists and supporting staff, with offices in fifteen states and seven foreign countries and consistently among the top 20 on the Engineering News-Record's "500" list.

While not a prolific writer – his engineering and management activities absorbed most of his time – Mr. Lawler authored more than 25 published papers and technical articles and collaborated with Dr. Camp on three chapters in Davis' Handbook of Hydraulics. He was also a member of the committee that prepared the first edition of ASCE's Manual 37, "Design and Construction of Sanitary Sewers."

He was a registered Professional Engineer in California, Massachusetts, New York, and six other states. He joined ASCE as a student in 1939 and continued his association with the Society throughout his life. He was also an active member of the Engineering Societies of New England (President 1962-1963), a Diplomate of the American Academy of Environmental Engineers, a member of the Water Pollution Control Federation (Director, 1972-1975; member of the Executive Committee, 1972-1973), a member of the New England Water Pollution Control Association (President 1970), a member of the American Water Works Association, a Fellow of the American Consulting Engineers Council, and a member of the National Society of Professional Engineers. He belonged to the British "Institution of Water Engineers and Scientists" and was its United States correspondent. He was elected to The National Academy of Engineering in 1973.

Mr. Lawler was a staunch supporter of Northeastern University, serving as a member of the corporation from 1965, as a Trustee from 1977, and as a Director of the Alumni Association. Northeastern awarded him an honorary Doctor of Engineering degree in 1972, named him Alumni Man of the Year, also in 1972, and cited him as its Outstanding Civil Engineering Alumnus in 1979. Other Northeastern University honors included membership in Tau Beta Pi and Chapter Honor Member of Chi Epsilon.

The Engineering Societies of New England gave him the New England Award as engineer of the year in 1972. He received the NSPE Professional Engineers in Private Practice Award in 1977, the Gordon Maskew Fair Award of the American Academy of Environmental Engineers in 1979 and ASCE's Parcel-Sverdrup Civil Engineering Management Award in 1982. His Parcel-Sverdrup Management Lecture, delivered at the Society's 1982 spring meeting, was published in the October 1982 edition of Civil Engineering.

Mr. Lawler's interests and activities were not confined to his office and his University. He served his community as a member of its school building committee and as an elected member of the school board. He participated actively in the work of the National Conference of Christians and Jews, the Greater Boston Council, Boy Scouts of America, and in the Greater Boston United Way annual campaign. A dedicated outdoor sportsman, he was a founding member and a driving force in the New England Chapter of Safari Club International, the Safari Club Conservation Fund, and the American Wilderness Leadership School. He helped organize and chaired the National Academy of Engineering's "Roundtable on Engineering Contributions to the National Clean Water Program" in 1981. Recommendations developed by it for amendment of the Clean Water Act were well received by both the Environmental Protection Agency and the U.S. Senate and are expected to influence future environmental legislation.

Joe Lawler, as he signed himself and was widely known, as a man for all seasons and conditions of man, equally at home with partrician or peon, engineer, banker, or cleric. He died as he lived, active to his final hour, early in the morning on November 18, 1982.

Prepared by Oscar S. Bray

ANNUAL REPORT OF THE BOARD OF GOVERNMENT, 1982-1983

The Boston Society of Civil Engineers Section,
The American Society of Civil Engineers

Pursuant to the requirements of the Bylaws, the Board of Government presents its report for the year ending April 28, 1983.

A. MEMBERSHIP:

The following is a statement of membership in the Section:

Honorary	3
Assigned ASCE Members (as of 3/83)	2368
Subscribers:	
Members	1062
Associates	387
Affiliates	45
Student Chapters	9

Summary of Additions:

New Members	15
New Associates	42
New Affiliates	6

Summary of Losses:

Deaths	10
Resignations	41
Dropped	83

Summary of Life Members:

Prior years	206
Eligible 28 April 1983	12

Honorary Membership is as follows:

John B. Babcock III	elected	January 2, 1969
Albert G.H. Dietz	elected	January 19, 1981
John A. Volpe	elected	January 29, 1968

The Following Members have been Lost Through Death:

Antonino Baglione	January 1983
Dean B. Fraser	November 1982
Kenneth V. Hill	August 1980
Joseph C. Lawler	November 1982
John H. Manning	1982
George E. Meyers	1982
George W. Saunders	April 1982
William E. Stanley	September 1982
Nelson Stone	May 1982
Richard L. Woodward	1982

B. MEETINGS OF THE SECTION AND ITS TECHNICAL GROUPS:

The Section held meetings on the following dates:

September 14, 1982	Joint Meeting with Geotechnical and Computer Groups
October 20, 1982	Joint Meeting with the Environmental Group and Hazardous Waste Committee
November 18, 1982	Joint Meeting with the Computer Group
December 1, 1982	Joint Meeting with the Structural Group
January 11, 1983	Joint Meeting with the Geotechnical Group
February 2, 1983	Joint Meeting with the Structural Group
March 16, 1983	Joint Meeting with the Waterways, Port, Coastal and Ocean Committee
March 22, 1983	Joint Meeting with the Hazardous Waste Committee
April 19, 1983	Joint Meeting with the Hazardous Waste Committee

In addition to the above combined meetings with the Section, the Technical Groups held many other meetings and sponsored many lecture series. The details of the combined meetings with the Section, other meetings and lecture series are contained in the respective Annual Report of the Technical Groups.

C. MEETINGS OF THE BOARD OF GOVERNMENT:

The Board met on the following dates:

May 17, 1982	at the Engineers Club
June 21, 1982	at the Section's office
September 20, 1982	at the Section's office
October 18, 1982	at the Section's office
November 15, 1982	at the Section's office
December 20, 1982	at the Section's office
January 17, 1983	at the Section's office
February 14, 1983	at the Section's office
March 21, 1983	at the Section's office

For significant actions of the Board of Government, see Appendix A.

D. COMMITTEES:

Committees were appointed to deal with the activities and conduct of the Section. Except for the Nominating Committee (as provided in the Bylaws) these committees were under the general direction of the Board of Government, and reported to the Board of Government. The activities of the committees are described in the respective Annual Report of the Committees.

E. Awards:

The Board of Government voted a number of awards at its February 14th and March 21st meetings. See Appendix A, under these dates for a complete listing.

F. Funds:

The operating fund of the Section is called the CURRENT FUND. The endowment of the Section is contained in the PERMANENT FUND. The principal of the PERMANENT FUND is invested, and the annual income so derived is used either to increase the principal or, at the discretion of the Board of Government, transferred to the CURRENT FUND to help defray operating expenses. All entrance fees are income to the PERMANENT FUND.

In addition, there are special funds established by gifts or bequests and special funds established by the Board of Government. A listing of each of the special funds, together with a description of each, is given in Appendix B.

The Treasurer's Annual Report gives the status and details of the transactions for all the funds.

Respectfully submitted,
Stanley C. Rossier
President

Rodney P. Plourde
Secretary

APPENDIX A - ACTIONS OF THE BOARD OF GOVERNMENT

VOTED 4/26/82: 1. Upon the recommendation of the Investment Committee, to remove Section funds from the Boston Safe Deposit and Trust Company and to instruct the Investment Committee to make other recommendations to the Board of Government relative to other investment vehicles.

VOTED 5/17/82: 2. To reinvest the Section funds as follows: 30% in Fidelity Equity-Income, 20% in Vanguard-Windsor Fund, 20% in Source Capital and 30% in Capital Preservation Fund II.

VOTED 6/21/82: 3. Revisions to the Operations Manual relative to the Awards and Action Program-Professional Practice Committees were approved.

4. To support the concept of a LESTER GAYNOR AWARD and to instruct the Awards Committee to make final recommendations regarding this award to the Board of Government.

VOTED 9/20/82: 5. To establish a continuing memorial in honor of Bertram Berger in recognition of his contributions to ASCE and the Section, and that a permanent memorial committee be established to raise the necessary funds and to make recommendations annually to the Board of Government for an appropriate award, with the final decision on any award remaining with the Board.

6. To designate the Senior Vice President of the Section and the President-Elect of the Western Branch as delegates to the ASCE Management Conference.

VOTED 9/28/82: 7. To accept the proposed budget for fiscal 1982-1983, as prepared by the Budget Committee.

VOTED 10/18/82: 8. To endorse the nomination of Charles L. Guild for the ASCE MARTIN S. KAPP AWARD.

VOTED 11/15/82: 9. That District 2 not put up a candidate for the office of Zone I Vice President this year, but wait until the rotation process gives priority to District 2.

10. To endorse the nominations of John P. Sullivan, Jr. for the ASCE YOUNG GOVERNMENT CIVIL ENGINEER OF THE YEAR AWARD; to endorse the nomination of George D. Gustafson for the ASCE CAN-AM CIVIL ENGINEER AMITY AWARD.

11. That the Monthly Luncheon series be reduced to three functions a year: in June, September, and January.

VOTED 12/20/82: 12. To amend Article 4, Sections 3 and 4, and Article 5, Section 4 of the BSCES Bylaws, as recommended by the Constitution and Bylaws Committee.

13. That the Section continue its policy of having students attend all Section functions for one-half the cost per ticket with the Section absorbing any loss, and that all Groups holding meetings shall plan and be responsible for the cost of student attendance up to 10% of the total attendance. Anything incurred above this amount will be charged against the Student Affairs Committee's budget.

14. To establish the LESTER GAYNOR AWARD.

VOTED 1/17/83: 15. To nominate the following for ASCE Professional Division Committees: Jack D. Bryant, Committee on Minority Programs; Kevin K. Egan, Employment Conditions; Rubin M. Zallen, Public Affairs, and Legislation; Michael Kupferman, Committee on Curricula and Accreditation.

16. To accept a lecture series policy as follows: that profits and losses be shared on a 50/50 basis until a particular Technical Group accumulates $10,000.00 in reserve. When a Technical Group accumulates $10,000.00 in reserves, all future profits will be transferred to the BSCES general treasury. That the term "50/50" means 50% of the profit or 50% of the losses is held by the Technical Group, and 50% of the profit or 50% of the losses is transferred to the BSCES general treasury. Losses are not shared if a lecture series is purposely operated to generate a loss.

VOTED 2/14/83: 17. That a BSCES Certificate of Appreciation be award to Oscar Bray at the April 28th BSCES Annual Meeting.

18. To establish the ARTHUR CASAGRANDE FUND.

19. To present the HOWE-WALKER STUDENT AWARDS to the following:

M.I.T.	Eftychi Nestorides
Merrimack College	Michael J. Carter
Northeastern University (Division A)	Jeffrey S. Ferriss
Northeastern University (Division B)	Bob A. Scherpf
Southeastern Mass.	Rose Castro
Tufts University	Michael Cantalupa
University of Lowell	Mark. P. Braconnier
UMass	David J. Chambers

Wentworth Institute	William J. Goggins
Worcester Polytechnic	Guy Busa

20. To present the DESMOND FITZGERALD AWARD of $500.00 to Mark E. Bordne (Northeastern University).

21. To present the WILLIAM P. MORSE AWARD of $500.00 to Christy French (Tufts University).

22. To award $1,000.00 Student Loans to Gerald Jannetti of the University of Lowell and Denis Beique of Northeastern University.

23. To amend Article 2 of the BSCES Constitution, as recommended by the Constitution and Bylaws Committee.

24. That the Section not transfer to the CURRENT FUND $4,000.00 of the money accumulated by the GEOTECHNICAL LECTURE SERIES FUND prior to October 1, 1982, nor transfer to the CURRENT FUND $900.00 of the money accumulated by the STRUCTURAL LECTURE SERIES FUND prior to October 1, 1982; and that the Geotechnical Group will absorb 50% of the deficit realized by the ENGINEERING GEOLOGY LECTURE SERIES.

25. To discuss with Camp, Dresser & McKee, Inc. the possibility of establishing the JOSEPH C. LAWLER ENGINEERING MANAGEMENT LECTURE SERIES FUND.

VOTED 3/21/83: 26. To present $500.00 each from the STUDENT AFFAIRS COMMITTEE'S PROJECT FUNDS to Northeastern University's and Southeastern Mass. University's Student Chapters for their Chapter projects.

27. To establish the Waterways, Port, Coastal and Ocean Committee as another Technical Group of the Section.

28. To allocate $1,200.00 from the CAMP FUND to be paid as an honorarium to the speaker at the March 24, 1983 Camp Lecture.

29. To co-sponsor the ASCE Hydraulics Division Specialty Conference to be held at M.I.T. in August 1983.

30. Not to award the one remaining Desmond Fitzgerald medal but to consider whether additional medals should be cast.

31. To present the DESMOND FITZGERALD AWARD to Harl P. Aldrich, Jr. and Karl A. Seeler for their joint paper published in Volume 68, No. 2 of the BSCES Journal, and that the Award this year consist of a book and certificate.

32. To present the CLEMENS HERSCHEL AWARD to Gerhard H. Jirka for his paper published in Volume 68, No. 1 of the BSCES Journal.

33. To present the 1983 RALPH W. HORNE AWARD to Ronald C. Hirschfeld.

34. Changes in the Operations Manual relative to the Student Affairs and Awards Committees were approved.

APPENDIX B - SPECIAL FUNDS

1. Invested Funds

The following funds are invested by the Section. The income from each fund is used to increase the principal of the fund, or is expended in a manner described for each fund below. All investments and expenditures are subject to the approval of the Board of Government.

LEROY G. BRACKETT FUND This Fund was established on January 30, 1978 from a small bequest made by Donald F. Brackett. No formal recommendation for the use of the Fund has as yet been voted by the Board of Government.

THOMAS R. CAMP FUND This Fund, a bequest of $10,000.00, was received January 15, 1971 from the Directors of Camp, Dresser & McKee, Inc. to establish the THOMAS R. CAMP FUND, the income to be used to support an annual Thomas R. Camp Lecture or lectures on outstanding recent developments or proposed or completed research in the sanitary engineering field. The income from the Fund, over and above that needed to support the annual lecture, should be added to the Fund, but could be used otherwise at the discretion of the Board of Government of the Boston Society of Civil Engineers Section of the American Society of Civil Engineers.

ARTHUR CASAGRANDE FUND On February 14, 1983, acting on the recommendation of the Geotechnical Group Executive Committee, the Board of Government voted to establish the ARTHUR CASAGRANDE FUND: $5,000.00 to be allocated from the GEOTECHNICAL GROUP LECTURE SERIES FUND, the income from which is to be used to support a lecture given by an eminent engineer with longstanding achievements in practice, teaching, and/or research in geotechnical engineering. The income from the CASAGRANDE FUND may on occasion be used to support other suitable activities as approved by the Board of Government.

CONVENTION FUND This Fund was established by the Board of Government on November 17, 1980 with an initial principal amount of $2,000.00 from the surplus realized by the 1979 ASCE Convention Committee. This Fund will be used for the planning of the next ASCE National Convention in Boston in 1986.

DESMOND FITZGERALD FUND THE DESMOND FITZGERALD FUND, established in 1910 by a bequest of $2,000.00 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."

On April 13, 1964, the Board of Government voted to establish a Boston Society of Civil Engineers Scholarship in memory of Desmond Fitzgerald to be funded by the income of this Fund, and to be given to a student studying Civil Engineering at Northeastern University. On September 21, 1981, the Board of Government redesignated the gift to the student as an AWARD and stipulated that the amount of the Award be determined annually.

JOHN R. FREEMAN FUND In 1925 the late John R. Freeman, a Past President and Honorary Member of the Boston Society of Civil Engineers, made a gift to the Society of securities which were established as the JOHN R. FREEMAN FUND. The income from the 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 the hydraulic science or art; or a portion to be devoted to a yearly prize for the most useful hydraulics-related paper contributed to the Society; or every third year establishing a traveling scholarship open to members of the Society for visiting engineering works, a report of which would be presented to the Society.

ALEXIS H. FRENCH FUND A bequest of $1,000.00 was received in 1931 from the late Alexis H. French, a Past President of BSCE. The income from the Fund is "to be devoted to the Library of the Society."

LESTER GAYNOR FUND On December 20, 1982 Lester Gaynor made a gift to the Section equal to $1,500.00 for the establishment of the LESTER GAYNOR FUND, the income from which shall be used for a wall plaque and certificate to be awarded annually to a BSCES member or, second consideration, a registered professional engineer engaged in the practice of Civil Engineering. The recipient designated by the Board of Government shall be an individual who has been outstanding as a part-time elected or appointed city or town official and whose reimbursement for this service has been, but has not been more than, an honorarium.

CLEMENS HERSCHEL FUND This Fund was established in 1931 by a bequest of $1,000.00 from the late Clemens Herschel, a Past President and Honorary Member of BSCE. The income from the Fund "is to be used for the presentation of prizes for papers which have been particularly useful and commendable and worthy of grateful acknowledgement."

RALPH W. HORNE FUND This Fund, a bequest of $3,000.00, was received June 29, 1964, from the Directors of Fay, Spofford & Thorndike, Inc., the income from which shall be devoted to a prize or certificate to be awarded annually to a BSCES member designated by the Board of Government to have been outstanding in unpaid public service in municipal, state, or federal elective or appointed post; or in philanthropic activity in the public interest.

HOWE-WALKER FUND A bequest of $1,000.00 was received December 2, 1933, from the late Edward W. Howe, a Past President of BSCE. No restrictions were placed upon the use of the money but it was decided at that time to keep the bequest intact in a separate fund, called the EDWARD W. HOWE FUND, and that the income be used for the benefit of the BSCE or its members.

A bequest of $1,000.00 was received in 1961 from Mary H. Walker, wife of Frank B. Walker, a former Past President of BSCE. No restrictions were placed upon the use of this money but it was decided at that time to keep the bequest intact in a separate fund, called the FRANK B. WALKER FUND, and that the income be used for the benefit of BSCE or its members.

On January 30, 1978, the Board of Government voted to combine the two funds into the HOWE-WALKER FUND, with income from this joint Fund being used to provide prizes, called the HOWE-WALKER AWARDS, to members of student chapters. The Awards are made annually at Student Night.

KARL R. KENNISON FUND This Fund is derived from two irrevocable trusts established on behalf of BSCE by the late Karl R. Kennison, a Past President (1938-1939) and Honorary Member of BSCE. The trusts were established on August 29, 1960 and January 17, 1961. The trusts consisted of shares in the Massachusetts Fund, with the Massachusetts Company, Inc. as trustee. The total original market value of the trusts was $8,171.09. Three conditions of the trusts were that after Mr. Kinnison's death: 1) the net income from the trusts should be paid to BSCE for a HYDRAULICS LECTURE FUND to be used for various public lectures on this subject; 2) the Board of Government could withdraw the principal of the trusts on written demand; and 3) the Board of Government may make changes in the use of the trust as it may determine are warranted.

Mr. Kennison died in April 1977. The principal was withdrawn from the trusts by the Board of Government in 1978 and placed in the KARL R. KENNISON FUND, said Fund being established for that purpose by the Board of Government.

JOSEPH C. LAWLER FUND This Fund, a bequest of $15,000.00, was received April 26, 1983 from the Directors of Camp, Dresser & McKee, Inc. to establish the JOSEPH C. LAWLER ENGINEERING MANAGEMENT LECTURE FUND, the income from which is to be used to support an annual lecture on the general subject of management of complex engineering projects, engineering firms, or people, by a speaker of national reputation. If the yearly income from the Fund exceeds the cost of the annual lecture, the balance may be used for the support of other suitable engineering management educational activities, as approved by the BSCES Board of Government, with suitable credit given to the JOSEPH C. LAWLER ENGINEERING MANAGEMENT LECTURE FUND.

LECTURES FUND This Fund was established in December 1968 by the Board of Government by combining the TRANSPORTATION LECTURES FUND, the STRUCTURAL LECTURES FUND and the previous LECTURES FUND into a single LECTURES FUND. The purpose of the Fund is to provide money for special lectures sponsored by the Society.

The STRUCTURAL LECTURES FUND was established in March 1954.

The TRANSPORTATION LECTURES FUND was established in 1961 by the Board of Government, with an initial appropriation of $125.00 from the DESMOND FITZGERALD FUND and $125.00 from the WILLIAM P. MORSE FUND.

The original LECTURES FUND was established by the Board of Government in 1967 to receive attendance fees and disburse expenses for a series of 14 lectures entitled "The Use of Computers in Civil Engineering".

WILLIAM P. MORSE FUND A bequest of $2,000.00 was received in 1949 from the late William P. Morse, a former member of BSCE. No restrictions were placed upon the use of the Fund, but it was decided at that time to keep the bequest intact in a separate fund and that the income be used for the benefit of the Society and its members. On April 5, 1954, the Board of Government voted "to appropriate from the income of this Fund a scholarship to be known as the BOSTON SOCIETY OF CIVIL ENGINEERS SCHOLARSHIP in memory of William P. Morse, and that it be given to a civil engineering student at Tufts University."

On September 21, 1981 the Board of Government redesignated the gift to the student as an AWARD and stipulated that the amount of the award be determined annually.

ROGER GARDNER MEMORIAL FUND This Fund was established at the request of the Student Affairs Committee. At the December 17, 1979 meeting of the Board of Government it was voted to present a certificate and a sum of money to be later determined to a deserving student. Funds for the certificate and cash award to be raised by solicitations made to BSCES members-at-large and area firms.

STUDENT AFFAIRS FUND This Fund was established by the Board of Government on November 17, 1980 with an initial principal amount of $4,000.00 from the surplus realized by the 1979 ASCE Convention Committee. The annual income from this Fund will be at the disposal of the Student Affairs committee, with its use subject to the approval of the Board of Government.

EDMUND K. TURNER FUND In 1916, the Society received a bequest of $1,000.00 from Edmund K. Turner, a former member, the income of which is to be used for Library purposes.

2. Non-Invested Funds

The following funds are under the control of the Treasurer. Any income that may be derived from the (short term) investment of these funds is credited to the CURRENT FUND.

BORING DATA FUND THE BORING DATA FUND was originally established in November 1958 by the Board of Government with an initial appropriation of $1,000.00 for the purpose of collating into one comprehensive edition all of the boring data published in various BSCE Journals prior to that time. This report was published in 1961.

In 1968, the Board of Government appropriated $3,000.00 for publication of a supplement to the 1961 Report, and 46 consulting firms and contractors donated $6,355.00 to help pay the expenses of collecting and compiling the data. On May 21, 1969, the Board of Government voted to transfer $1,000.00 from the FRANK B. WALKER FUND to this Fund, to insure continuation of the work. Further donations of $2,525.00 were obtained during the 1970-1971 year. The supplement was published in four editions of the BSCE Journal from 1969 to 1971.

The remaining assets of the Fund have been kept intact for the future publication of boring data.

CONTINUING EDUCATION FUND The CONTINUING EDUCATION FUND is a special reserve fund established for accounting purposes to set aside profits from Continuing Education Lecture Series. This account is credited with amounts received as tuition and charged with honorariums and expenses paid.

GROUP LECTURE FUNDS Established by vote of the Board of Government in 1976. Each lecture series organized by a BSCES technical group is assigned a special fund for accounting purposes; 50% of the surplus from a lecture series is transferred to the CURRENT FUND to help defray the Section operating expenses. The other 50% of the surplus is made available to the sponsoring technical group to defray expenses for other meetings, lecture series, technical and educational functions, subject to the aproval of the Board of Government. Two years after completion of a lecture series, its fund is terminated and the remaining balance is transferred to the CURRENT FUND.

STUDENT LOAD FUND The STUDENT LOAN FUND was established in 1965-1966. The assets of the Fund are derived from donations solicited by the Student Affairs Committee from area firms.

The assets are used to make loans to deserving members of Student Chapters or clubs in the Section area, as approved by the Board of Government. The loans are interest free and repayable in four years following graduation.

MINUTES OF THE ANNUAL MEETING OF THE SECTION

Part I

April 26, 1983. Part I of the 135th Annual Meeting of the Boston Society of Civil Engineers (the ninth meeting of the Boston Society of Civil Engineers Section following the merger of the BSCE with the Massachusetts Section of ASCE) was held at the offices of Camp, Dresser & McKee, Inc. in Boston. The meeting was called to order at 2:00 by President Stanley C. Rossier.

Executive Director Susan Albert distributed the Annual Report of the Board of Government.

Richard F. Murdock presented the Annual Report of the Treasurer, as well as a brief mid-year report on the financial status of the Section.

Secretary Rodney P. Plourde called for reports from the following Committees: Action Program, Advertising, Annual Meeting, Auditing, Awards, Bertram Berger Memorial, Budget, Constitution & Bylaws, Thomas R. Camp Fund, Continuing Education, Employment Conditions, Energy, John R. Freeman Fund, Hazardous Waste, History & Heritage, Investment, Key Man, Lecture Series, Membership, Minority Affairs, Luncheon, Nominating, Operations Manual, Program, Public Relations, Publications, Retired Engineers Service Program, Social Functions, Student Affairs, Subsoils, Technical Advisory Committees on the Building Code: Foundations, Loads and Seismic Design Sub-Committees. Also the reports of the Technical Groups: Computer, Construction, Environmental, Geotechnical, Hydraulics, Structural, Transportation, Waterways, Port, Coastal and Ocean.

The reports of the Computer Technical Group, Loads Sub-Committee and the Western Branch were not available for reading at this time. The report of the Nominating Committee was not read at this time as it had been previously distributed to the membership.

Secretary Plourde moved that the Committee and Technical Group reports be accepted and placed on file. It was seconded and so VOTED.

The results of the election of the Nominating Committee Members were announced. They are Jack Bryant, Robert J. Dunn, Jr. and Richard M. Simon.

Charles Parthum, of Camp, Dresser & McKee, Inc., on behalf of the Board of Directors of CDM, presented to President Rossier a check for $15,000.00 for the establishment of the JOSEPH C. LAWLER ENGINEERING MANAGEMENT LECTURE FUND as a permanent memorial to the late CDM Chairman of the Board and Chief Executive Officer.

President Rossier concluded the meeting by presenting his retiring address, which is to be printed in the BSCES Journal.

Part II

April 28, 1983. Part II of the 1983 BSCES Annual Meeting was held at the New England Aquarium in Boston. President Rossier convened the meeting at 9:20 p.m., following dinner in the main room of the Aquarium. President Rossier called upon Secretary Rodney Plourde to assist him in the awarding of prizes and certificates to Life Members.

Secretary Plourde announced the awarding of Certificates of Appreciation to Richard F. Murdock for serving as Treasurer from 1981 to 1983; Mathew A. DiPilato who served as Chairman of the Social Functions Committee from 1981 to 1983; Oscar S. Bray for his many years of service to the Society and the Section.

Awards for technical papers were presented as follows:

CLEMENS HERSCHEL AWARD

Recipient: Gerhard H. Jirka

Paper: "Multiport Diffusers for Heat Disposal - A Summary"

DESMOND FITZGERALD AWARD

Recipients: Harl P. Aldrich and Karl A. Seeler

Paper: "The New Technology"

President Rossier presented the 1983 RALPH W. HORNE AWARD to Dr. Ronald C. Hirschfeld.

Brief biographies of newly elected ASCE and BSCE Section Life Members were distributed, and President Rossier presented certificates to those BSCES Life Members who were present. New BSCES Life Members were as follows: Joseph Capone, Jr. and John W. Ireland.

Ronald C. Hirschfeld, District II member of the ASCE National Board of Direction, presented ASCE Life Member certificates to those ASCE Life Members present. New ASCE Life Members were as follows: Robert R. Campbell, Stephen E. Dore, Jr., Harry J. Keefe, Ernest R. Goodwin, Robert J. Hansen, Robert H. Lubker, George B. McGuire, Maurice A. Reidy, Edmund C. Sheahan, and Alfred M. Toy.

President Rossier read the names of those members who had died during the past year: Antonio Baglione, Dean B. Fraser, Kenneth V. Hill, Joseph C. Lawler, John H. Manning, George E. Meyers, George W. Saunders, William E. Stanley, Nelson Stone, and Richard L. Woodward.

President Rossier presented Certificates of Appreciation to the 1982-1983 BSCES Technical Group Chairmen as follows: Computer Group - Mukti Das, Construction Group - Mark Tedeschi, Environmental Group - James O'Shaughnessy, Geotechnical Group - Lewis Edgers, Hydraulics Group - Paul Shiers, Structural Group - Maurice Reidy, Transportation Group - Paul Levy, Waterways, Port, Coastal and Ocean Group - Ken Childs.

President Rossier introduced ASCE President-Elect, S. Russell Stearns

President Rossier announced that Charles Parthum, of Camp, Dresser & McKee, Inc., has agreed to serve as Chairman of the 1986 ASCE National Convention Committee.

President Rossier then turned over the gavel to incoming President Richard J. Scranton, who presented a plaque and past president's pin to retiring President Rossier commemorating his year as president. President Scranton made a few brief remarks and introduced the 1983-1984 officers and directors: Vice Presidents John P. Sullivan and Rodney P. Plourde, Secretary Judith Nitsch, Treasurer Warren H. Ringer and Directors David E. Thompson, Rubin M. Zallen, Steven L. Bernstein and Dominic E. D'Eramo.

President Scranton then introduced the guest speaker, Mr. Steven R. Karp, Senior Partner and Treasurer of State Properties of New England, who spoke on the development and management of industrial and office parks, condominiums and shopping malls.

One hundred and forty-three members and guests attended the dinner and evening meeting.

ANNUAL REPORT OF THE TREASURER October 1, 1982
For Fiscal Year October 1, 1981 to September 30, 1982

FISCAL STANDING

The Fiscal Standing of the Section is summarized in the four tables which accompany this report:

Table I - Condensed Statement of Condition
Table II - Condensed Statement of Income and Expenditures
Table III - Detailed Statement of Income and Expenditures and Funds in the Putnam Daily Dividend Trust
Table IV - Detailed Statement of Income and Expenditures

SECTION INVESTMENTS

The Boston Safe Deposit and Trust Company was terminated as custodian of our portfolio of securities effective 1982. The portfolio was sold and the resulting cash was invested in a money market fund, Fidelity Daily Income Trust, until the following investment vehicles can be purchased in the following percentages: Fidelity Equity - Income (30%), Vanguard Windsor (20%), Source Capital (20%), and Capital Preservation (30%).

SECTION BANK DEPOSITS

All non-invested cash is deposited into the Mutual Bank NOW Account and a Putnam Daily Dividend Trust. Both are interest-bearing accounts. The fiscal record was:

	Debit	Credit	Balance
MUTUAL BANK **NOW** ACCOUNT -			
Balance, 10/1/81			$ 10,175
Deposits (10/1/81-9/30/82)		$148,974	
Interest		1,193	
Disbursements	$142,364		
	$142,364	$150,167	$ 17,978
PUTNAM DAILY DIVIDEND TRUST -			
Balance, October 1, 1981			$ 33,754

PERMANENT FUND

The Permanent Fund receives its prorated portion of investment income and all entrance fees for the local Section membership. A prorated portion of all custodial service charges is debited.

	Debit	Credit	Balance
Balance, October 1, 1981			$114,856
Custodian Service	$ 1,381		
Interest, dividends		$ 10,625	
Gain on sales of investments		12,889	
Transfer to CURRENT FUND	11,720		
TOTALS	$ 13,101	$ 23,514	$125,098

TECHNICAL GROUP LECTURE SERIES FUNDS 1982

Environmental Group -

Beginning Balance		$ 1,216	
*Reduction of principal		300	
Available for 1982-1983			$ 916

Structural Group -

Beginning Balance			$ 1,788	
Income - building cladding		$ 21,612		
Expenses		11,333		
		10,279		
50% available for approved exp.		5,140		
Deficit 1981-1982		1,004		
Balance		$ 4,136		
Less - due from current fund	$ 1,225			
*Reduction of principal	800	$ 2,025		
			$ 2,111	
Available for 1982-1983				$ 3,899

Geotechnical Group -

Beginning Balance		$ 14,874	
*Reduction of principal		1,516	
Available for 1982-1983			$ 13,358

*Per Board of Government vote January 18, 1982

TECHNICAL GROUP FISCAL OPERATIONS 1981-1982

	Income	Expenses	Surplus	Deficit
Computer	$ 327	$ 172	$155	
Construction	983	1,356		$ 373
Environmental	938	1,125		187
Geotechnical	4,549	4,955		406
Hydraulics	381	321	60	
Structural	357	1,361		1,004
Transportation	208	0	208	
Waterways	6	6		
	$7,749	$9,296	$423	$1,970

Respectfully submitted,
Richard F. Murdock
Treasurer

TABLE 1-CONDENSED STATEMENT OF CONDITION
Assets, Liabilities, and Funds - September 10, 1982

			BOOK VALUE*	
ASSETS:			9-30-82	9-30-81
Mutual Bank NOW Account			$ 17,978	$ 10,175
Putnam Daily Dividend Trust	(Table III)		33,754	20,649
Fidelity Daily Income Trust	(Table II)		310,266	0
Boston Safe Deposit:	(Table II)			
Bonds	$ 0	$114,681		
Stocks	0	146,283		
Principal cash and short term investments	0	31,054		
Income cash	1,269	3,682		
Total, Boston Safe Deposit			$ 1,269	$295,700
TOTAL ASSETS			$363,267	$326,524
TOTAL FUNDS AND LIABILITIES (Schedule 1)			$345,289	$331,430
NET WORTH (DEFICIT)**			$ 17,978	$ (4,906)
TOTAL FUNDS AND NET WORTH			$363,267	$326,524

*As of September 30, 1982, all funds are in cash accounts; therefore, book and market value are the same.

**$1,095.00 due to Permanent Fund
$1,225.00 due to Environmental Group Lecture Series

SCHEDULE 1 - SCHEDULE OF FUNDS LIABILITIES
September 30, 1982

	BOOK VALUE	
	9-30-82	9-30-81
Camp Fund	$ 21,204	$ 18,513
Permanent Fund	125,098	114,685
Freeman Fund	93,117	91,653
Turner Fund	5,924	5,260
Fitzgerald Fund	8,917	7,813
French Fund	5,855	5,198
Herschel Fund	3,956	3,286
Howe-Walker Fund	9,468	8,054
Morse Fund	8,122	7,140
Horne Fund	7,965	6,821
Lecture Fund	7,308	6,349
Bracket Fund	369	363
Kennison Fund	14,204	11,967
Invested Current Fund	0	8,570
Roger Gardner Fund	28	28
Continuing Education Fund	5,524	9,419
Boring Data Fund	1,596	1,596
Student Load Fund	3,368	1,744
Group Lectures	17,266	16,971
Convention Fund	2,000	2,000
Student Affairs Fund	4,000	4,000
TOTAL FUNDS LIABILITIES	$345,289	$331,430

ONDENSED STATEMENT OF FUNDS INCOME AND EXPENDITURES
/1/81 - 9/30/82

	BOOK VALUE 10/1/180	INTEREST DIVIDENDS TRANSACTIONS	RECEIPTS	TRANSFERS TO CURRENT FUND (EXPENDITURES)	CUSTODIAN CHARGES	GAIN ON SALE OF INVESTMENTS	TRANSFER TO PUTNAM	BALANCE		E V 9/
								FIDELITY	BOSTON SAFE	
	$114,685	$10,625	$ 0	$11,720	$1,381	$12,889		$124,573	$ 525	$1
	91,653	8,012	1,917	17,144	1,041	9,720		92,722	395	
	5,260	458	110	400	59	555		5,901	23	
	7,813	697	153	500	91	845		8,883	34	
	5,198	452	115	400	59	549		5,833	22	
	3,286	285	76	0	37	346		3,942	14	
	8,054	691	153	180	90	840		9,434	34	
	7,140	638	153	500	83	774		8,091	31	
	6,821	620	153	300	81	752		7,934	31	
	6,349	579	153	400	75	702		7,279	29	
	18,513	1,612	382	1,050	209	1,956		21,124	80	
	363	3	0	0	0	3		369	0	
	11,967	1,041	268	200	135	1,263		14,153	51	1
urrent	8,570	0	191	191	0	0	$8,570	0	0	
	28	0	0	0	0	0		28	0	
	$295,700	$25,713	$3,824	$32,985	$3,341	$31,194	$8,570	$310,266	$1,269	$31

NDENSED STATEMENT OF INCOME AND EXPENDITURES
THE PUTNAM DAILY DIVIDEND TRUST
-81 to 9-30-82

	BOOK VALUE 10-1-81	UNFUNDED BALANCE 10-1-81	RECEIPTS	DIVIDENDS	SEE NOTE REALLOCATION	TRANSFERS TO CURRENT FUND	BC VA 9-30
					1,716		
ation Fund	$ 9,419	$ 3,975	$ 2,259	$1,030	$-3,895	$1,030	$
d	1,596	674	383	175	291	175	
nd	1,744	736	2,042	191	318	191	
					3,091		
eries*	16,971	7,161	6,981	1,856	-2,616	1,856	17
d	2,000	845	480	219	365	219	
Fund	4,000	1,690	960	437	730	437	
	$35,730	$15,081	$13,105	$3,908	$ 0	$3,908	$33

RE SERIES*	10-1-81	RECEIPTS	TRANSFERS TO CURRENT FUND	TOTAL
	$14,874		$1,516	$13,358
	1,788	$2,911	800	3,899
	(907)			(907)
	1,216		300	916
	0			
	0			
	0			
	0			
	$16,971	$2,911	$2,616	$17,266

ning unfunded balance, the Executive Committee of the CONTINUING EDUCATION FUND and the GROUP LECTURE SERIES FUND voted, wit
the Board of Government, to transfer from their cash up to Five Thousand Seven Hundred Dollars ($5,700.00) from the CONTINUING EDUCATION
Thousand Eight Hundred Dollars ($3,800.00) from the GROUP LECTURE SERIES FUND.

TABLE IV-DETAILED STATEMENT OF INCOME AND EXPENDITURES
Fiscal Year 10-1-81 to 9-30-82

		EXPENDITURES	INCOME
TOTAL INCOME	(Schedule 2)		$150,167
TRANSFERS	(Schedule 3)	$ 7,648	
OFFICE AND ADMINISTRATION	(Schedule 3)	38,318	
PRINTING AND ADVERTISING	(Schedule 3)	22,974	
SOCIAL	(Schedule 3)	10,466	
SOCIETY BUSINESS	(Schedule 4)	1,260	
TECHNICAL GROUPS	(Schedule 4)	9,410	
LECTURE SERIES	(Schedule 4)	20,492	
STUDENT AFFAIRS	(Schedule 4)	7,362	
COMMITTEES	(Schedule 5)	4,750	
GENERAL	(Schedule 5)	610	
FUNDS	(Schedule 5)	19,074	
TOTAL		$142,364	$150,167

SCHEDULE 2 - SCHEDULE OF INCOME
Fiscal Year 10/1/81-9/30/82

DUES		$ 28,273
ALLOTMENT		2,979
ACEC/NE REINBURSEMENT		16,593
BANK INTEREST - NOW ACCOUNT		1,193
DIVIDED INCOME - PUTNAM FUND		3,908
ENTRANCE FEES		306
CONTRIBUTIONS		1,651
TRANSFERS FROM INVESTMENTS		36,809
OFFICE AND ADMINISTRATIVE:		
Postage	$ 421	
Supplies	60	$ 481
PRINTING AND ADVERTISING:		
Advertising	$2,641	
Publication sales	2,182	$ 4,823
SOCIAL:		
Annual meeting	$4,013	
Clambake	4,771	
Dinner dance	960	$ 9,744
TECHNICAL GROUPS:		
Computer	$ 327	
Construction	983	
Environmental	938	
Geotechnical	4,394	
Hydraulics	181	
Structural	357	
Transportation	208	
Waterways	6	$ 7,394

SCHEDULE 2 (Cont.)

LECTURE SERIES:		
Camp	$ 123	
Geotechnical	480	
Structural	21,612	
Hydraulics	1,770	$ 23,985
STUDENT AFFAIRS:		
Loans	$ 3,720	
Student night	566	$ 4,286
COMMITTEES:		
Continuing education	$ 4,961	
Monthly luncheon	856	
Energy	689	
Convention	526	$ 7,032
GENERAL:		
Journal sales - Freeman Fund		$ 710
TOTAL		$150,167

SCHEDULE 3 - SCHEDULE OF TRANSFERS, OFFICE AND ADMINISTRATIVE, PRINTING AND ADVERTISING, AND SOCIAL EXPENDITURES

Fiscal Year 10-1-81 to 9-30-82

TRANSFERS TO INVESTMENTS	$ 7,648
OFFICE AND ADMINISTRATIVE:	
Salaries	$22,830
Secretarial	974
Taxes	1,952
Professional services	2,375
Insurance	343
Rent	1,862
Telephone	706
Postage	2,636
Office services	1,930
Staff insurance	820
Office copier	1,890
TOTAL	$38,318
PRINTING AND ADVERTISING:	
Journal	$15,492
Monthly notices	7,482
TOTAL	$22,974

SCHEDULE 3 (Cont.)

SOCIAL:

Annual meeting	$ 4,067
Dinner dance	1,417
Clambake	4,921
Awards	61
TOTAL	$10,466

SCHEDULE 4 - SCHEDULE OF SOCIETY BUSINESS, TECHNICAL GROUPS, LECTURE SERIES AND STUDENT AFFAIRS EXPENDITURES

Fiscal Year 10-1-81 to 9-30-82

SOCIETY BUSINESS:

Local society	$ 100
Western branch	1,000
ASCE conference	160
TOTAL	$ 1,260

TECHNICAL GROUPS:

Computer	$ 172
Construction	1,471
Environmental	1,125
Geotechnical	4,954
Hydraulics	321
Structural	1,361
Waterways	6
TOTAL	$ 9,410

LECTURE SERIES:

Camp Lecture series		$ 1,000
Continuing education		4,132
Geotechnical		349
Structural - expenses	$11,332	
Transferred to S.L.S.F. (Putnam)	2,911	$ 14,243
Hydraulics		768
TOTAL		$ 20,492

STUDENT AFFAIRS:

Summer institute	$ 1,175
Loans	2,000
Student night	1,193
Leadership training	498
Student activities	227
Project funds	555
Miscellaneous loan expenses	90
Transferred to STUDENT LOAN FUND (Putnam)	1,624
TOTAL	$ 7,362

SCHEDULE 5 - SCHEDULE OF COMMITTEES, GENERAL AND FUNDS EXPENDITURES
Fiscal Year 10-1-81 to 9-30-81

COMMITTEES:	
Legislative affairs	$ 2,400
Membership	346
Monthly luncheon	610
Energy	1,118
Investment	65
History and heritage	211
TOTAL	$ 4,750
GENERAL:	
General contingency	$ 610
TOTAL	$ 610
FUNDS:	
Freeman Fund	$ 17,144
Lecture Fund	400
Horne Fund	300
Morse Fund	500
Fitzgerald Fund	500
Howe-Walker Fund	180
Camp Fund	50
TOTAL	$ 19,074
TOTAL DISBURSEMENTS	$142,364

Report of Action Program-Professional Practice Committee, 1982-83

The Committee made investigations and recommended action to the Board of Directors on several issues of concern to the profession this year. Included were: efforts to remove the requirement that a registered professional engineer obtain a permit from the Massachusetts Department of Public Safety in order to be able to supervise construction of small buildings (volume less than 30,000 cu ft); joining efforts with other professional and building industry groups to restore the Massachusetts Building Code Commission; support for creation and funding of the position of executive secretary, Massachusetts Board of Registration of Civil Engineers and of Land Surveyors; and calling for legislation by the General Court of Massachusetts to repeal Chapter 58 of the Acts of 1982 (The Frederick A. Hass Engineering Registration Act).

Many of these issues will require follow-on action by the Professional Practice Committee in the Section's 1983-84 operating year. To assure continuity in the Committee's actions on these issues and to increase the probability of the Section's success in achieving its objectives in the area of professional practice, the following measures are recommended: a. new technical group chairmen ask their present representatives to remain on the Committee; and b. call for greater action and support from the Design Professional Government Affairs Council.

Respectfully submitted,
Richard J. Di Buono
Chairman

Report of Advertisement Committee, 1982-1983

The activities of the Advertising Committee during the past year were devoted to the pursuit of new advertisers for the BSCES JOURNAL. It was determined early on that the best way to contact a large volume of potential advertisers was by mail and, accordingly, an extensive mailing campaign was undertaken. Potential advertisers included both consulting engineers and contractors.

The results of the mailing to date are encouraging and we are hopeful for future gains. We also intend to canvas potential equipment suppliers who may also be interested in promoting their services.

Volunteers for participation on this Committee are sought and will be very welcome.

Respectfully submitted,
Benjamin J. Fehan
Chairman

Interim Report of Auditing Committee

An interim audit of the Section's financial records to April 26, 1983 was conducted. The audit included discussions with the Treasurer. The books of the Section were found to be in order.

Respectfully submitted,
Warren H. Ringer
Rubin M. Zallen
Chairman

Report of the Auditing Committee, 1982-1983

The annual audit of the Section's financial records was conducted on January 28 and February 23, 1983 for the fiscal year October 1, 1981 through September 30, 1982. The audit included discussions with the Treasurer and Executive Director as to accounting procedures. Payment vouchers were checked against disbursements and total receipts and disbursements were checked for each month and were found to balance.

As a result of the audit and an evaluation of the various funds, we make the following observations and recommendations:

1. Concur with Treasurer's decision to set up separate bank accounts for each technical group lecture series. At completion of a lecture the account will be closed and 50% profits will be credited to the CURRENT FUND and 50% will be credited to the respective technical group lecture fund (as voted by the Board of Government).

2. Recommend that the various technical group lecture funds be redesignated as technical group reserve funds. These funds no longer will be used for lectures (see Item 1 above). The seed money for lecture series can come from either the assets of the "reserve fund" assigned to the technical group or from the assets of the CURRENT FUND, as determined by the Board of Government.

3. The CONVENTION and STUDENT AFFAIRS FUNDS are required to be invested with interest being added to the principal. Present practice has been to add the interest to the CURRENT FUND. The Treasurer will take appropriate action.

4. Transactions in the ledger for the various funds should be kept up to date except for distribution of interest from investments. Distribution of interest should be made at least 4 times per year. Consideration should be given to use of a ledger sheet that would make it easier to determine current balance in a fund at any time.

5. The STUDENT LOAN FUND is currently considered a "non-invested fund". Any interest accrued is credited to CURRENT FUND. We recommend that the STUDENT LOAD FUND become an "invested fund" with interest added to the principal.

6. Currently the BORING DATA FUND is a "non-invested fund" with interest going to the CURRENT FUND. We recommend that one of the following actions be taken relative to this Fund:

   a. Make the BORING DATA FUND an "invested fund" with interest accrued to principal, or
   b. Eliminate the BORING DATA FUND and finance further boring data research from the geotechnical group "reserve fund"

7. The CONTINUING EDUCATION FUND is a special reserve fund established for bookkeeping purposes to set aside profits from Continuing Education Lectures Series. For many years this Fund has accumulated money without a specific use for it. We recommend that the assets of this fund be transferred to the CURRENT FUND and that further profits (or losses) from Continuing Education Lecture Series be added (or deducted) from the CURRENT FUND.

8. There is an invested fund called the LECTURES FUND (not to be confused with technical group lecture funds). This is not an endowed fund and was set up by the Board of Government to provide money for special lectures. With the advent of the Technical Group Lectures, this Fund is unnecessary. We recommend that this Fund be terminated and the assets transferred to the CURRENT FUND.

9. Due to low principal amounts, and no active purposes, we recommend that the BRACKETT FUND ($369.00 principal on 9-30-82) and the ROGER GARDNER FUND ($28.00 principal on 9-30-82) be terminated and the assets transferred to the CURRENT FUND.

10. THE KENNISEN FUND has a principal of $14,204.00 as of 9-30-82. This Fund is not used, but was intended for a hydraulics lecture. The Board of Government can revise its use.

    The ALEXIS H. FRENCH FUND and the EDMUND K. TURNER FUND have principals of $5,855.00 and $5,924.00 respectively, as of 9-30-82. These Funds are intended to support a library (which no longer exists).

    We recommend that the President appoint a committee to make recommendations for the proper uses of these three funds.

Respectfully submitted,
Warren H. Ringer
Rubin M. Zallen
Chairman

Report of Awards Committee, 1982-1983

The Committee reviewed applicable Journal articles and presentations made at the Section's meetings for the purpose of making nominations for the annual FITZGERALD, HERSCHEL, and TECHNICAL GROUP AWARDS. The following award nominations were made:

DESMOND FITZGERALD AWARD - Dr. Harl P. Alrich, Jr. and Karl A. Seeler - for their paper "The New Technology"

CLEMENS HERSHEL AWARD - Gerald H. Jirka - for his paper "Multiport Diffusers for Heat Disposal - A Summary"

The Committee also considered nominations for the RALPH W. HORNE AWARD, for recognition of Section members who have been outstanding either in unpaid public service in municipal, State or federally elected or appointed posts or in philanthropic activities in the public interest. The Committee recommended Dr. Ronald C. Hirschfeld for the HORNE AWARD on the basis of his public service and philanthropic work.

This year the Awards Committee was given the task of nominating individuals for ASCE awards. Nominations were made for the YOUNG GOVERNMENT CIVIL ENGINEER OF THE YEAR AWARD, CAN-AM AWARD and the MARTIN S. KAPP AWARD. John Sullivan, Jr. was awarded the YOUNG GOVERNMENT CIVIL ENGINEER OF THE YEAR AWARD.

Respectively submitted,
Brendan Harley, Peter Majeski, Mark Tedeschi, Richard A. Foley
Gonzalo Castro, Nuri Georges, Sarah Simon, Paul Shiers, Paul Levy,
Warren H. Ringer
Chairman

Bertram Berger Memorial Committee, 1982-1983

Bertram Berger, an outstanding engineer in Boston until his sudden death in April, 1982, was honored at the Bertram Berger Memorial Seminar at Pier 4 in Boston on January 27, 1983.

Senator Paul E. Tsongas and Massachusetts' Secretary of Transportation & Construction Frederick P. Salvucci joined with more than 200 Massachusetts engineering leaders to participate in the "Bertram Berger Memorial Seminar." The theme of the Seminar was "The Future of Transportation," the field in which Mr. Berger was most active.

Also attending the Seminar were Mr. Berger's wife, Frances, and their four daughters: Beth (Mrs. Marvin Lew), Robin (Mrs. Michael Rubinstein), Gwen and Lynne, and Mrs. Berger's father, Mr. Samuel Forman.

President Stanley C. Rossier, of the Boston Society of Civil Engineers Section, said the proceeds of the Seminar and other activities would be placed in a Memorial Fund to support the professional development of young engineers. Bert Berger, in addition to his engineering accomplishments and his professional society activities at the State and national level, was well known for encouraging young engineering technicians to complete their college education and become registered professional engineers.

At the Seminar, Senator Tsongas spoke of the need for Congress to enact a capital budget for public works as well as the current operating budget. Engineers at the Seminar agreed this would bring order out of the approaching chaos that could be caused by the country's deteriorating transportation, water, sewer, and other public works.

Secretary Salvucci, a friend of Bert Berger's, recalled early meetings with Bert and the respect with which he was held by his colleagues. Secretary Salvucci outlined some of the transportation needs in Massachusetts and the programs the Dukakis Administration is planning. Other speakers included David W. Davis, Executive Director of the Massachusetts Port Authority; Norman J. Van Ness, Federal Highway Administrator for Massachusetts; and John A. Clements, Commissioner of Public Works & Highways in New Hampshire and Immediate Past President of the American Association of State Highway & Transportation Officials (AASHTO).

President Rossier, of the Boston Society of Civil Engineers Section, read an eulogy prepared by Edward C. Keane.

Respectfully submitted,
Bruce Campbell
Chairman

Report of the Budget Committee, 1982-1983

The first year of operation for the Budget Committee was 1982-1983. Activities during the year included:

Obtaining proposed budgets from all Section committees and technical groups during the Summer of 1982.

Preparation of a proposed budget for fiscal year 1982-1983 for consideration by the Board of Government in September 1982.

Monitoring actual expenses and income and suggesting appropriate cost-saving or revenue-producing actions during 1982-1983.

The Committee wishes to express its gratitude to retiring BSCES Treasurer Richard Murdock whose detailed and efficient accounting of the Section's financial transactions has made our work possible.

Respectfully submitted,
Richard J. Scranton
Chairman

Report of the Thomas R. Camp Committee, 1982-1983

The 1983 Thomas R. Camp Lecture was held on March 24, 1983, at the Northeastern University Faculty Center. Dr. Perry L. McCarty, Chairman, Department of Civil Engineering, Stanford University, was the lecturer, and the subject of the talk was "The Movement and Biodegradation of Hazardous Materials in Groundwater". Attendance for the lecture was 130.

Respectfully submitted,
James C. O'Shaughnessy
Chairman

Report of Constitution and Bylaws Committee, 1982-1983

The Constitution and Bylaws Committee continued to work on preparation and review of proposed amendments to the Constitution and Bylaws in three areas.

1. The Constitution needs to be revised to reflect requirements of the Internal Revenue Service to justify our tax-exempt status.
2. The new student member grade requires changes to reflect the treatment of student members in terms of fees, dues, and rights to vote and hold office.
3. To facilitate the recruiting of Affiliate Members, the rules were simplified.

All these changes were assembled by President Rossier for submittal to membership and national headquarters.

Respectfully submitted,
Saul Namyet
Chairman

Report of BSCES Continuing Education Committee, 1982-1983

The Continuing Education Committee presented a series of eleven lectures in the Fall of 1982 and the Spring of 1983 to assist practicing engineers preparing for the state registration examination. Total enrollment was 63. Based on the response of questionnaires that have been received from students taking the state examinations over the last few years, all class lecturers are currently in the process of revising and updating their notes. It is anticipated that the revised notes will be available for student use and nationwide sale by the Fall of 1983.

Annual Report of the Employment Conditions Committee, 1982-1983

The Committee's membership for this year was as follows:

Kevin K. Egan, Chairman

The Committee worked on a questionnaire that will help it to develop a guide for employment conditions for local use.

The Committee was not able to accomplish as much as it hoped to due to lack of members. The Committee would welcome additional members and support from all levels of the Section's membership.

Respectfully submitted,
Kevin K. Egan
Chairman

Report of Energy Committee, 1982-1983

Members of the Committee during 1982-1983 were:

R. P. Barry, Chairman
T. O. Keller
A. Stanley Lucks
Daniel W. Miles
Robert H. Stewart
P. K. Taylor

The Committee co-sponsored three meetings during the Fall of 1982 and Spring of 1983. These meetings were as follows:

SEPTEMBER 29, 1982 - "Tour of Alden Research Laboratory", presented by George E. Hecker, Director Alden Research Lab (co-sponsored with the Hydraulic Group and Western Branch)

NOVEMBER 23, 1982 - "Energy Management at Water Pollution Control Facilities" presented by Allan Jacobs, of Metcalf and Eddy (co-sponsored with the Environmental Group)

MARCH 10, 1983 - "Emphasizing Energy Considerations in the Design Process" presented by Paul Pimental, of Pequod Associates (co-sponsored with the Construction Group)

A fourth meeting is scheduled:

MAY 3, 1983 - Co-sponsored with the Geotechnical Group

The cooperation and assistance of the technical groups in sustaining and furthering the emphasis upon engineering/energy related issues is appreciated.

Respectfully submitted,
Richard P. Barry
Chairman

Report of John R. Freeman Fund Committee, 1982-1983

Professor Gerhard H. Jirka, Cornell University, delivered his Freeman Hydraulics Prize winning paper as the Eleventh Freeman Memorial Lecture, on April 21, 1982 at MIT's Bush Room, at a meeting of the Hydraulics Group, co-sponsored with the MIT ASCE Student Chapter. The paper, "Multiport Diffusors for Heat Disposal - A Summary" was published in the Spring 1982 issue of the BSCES JOURNAL and in the Journal of the Hydraulics Division, ASCE, December 1982.

The Committee, on April 30, 1982, awarded Ms. Leslie J. Blythe a Fellowship Grant to aid in pursuing work towards a graduate degree at MIT. The award was made in consideration of her application which established that she would pursue thesis work acceptable to the Committee and would publish the thesis, or a condensation thereof (if that would be more appropriate), in the BSCES JOURNAL.

The JOHN R. FREEMAN MEMORIAL FUND underwrote the travel expenses of Professor Robert R. Faddick, Colorado School of Mines, who addressed a Joint Meeting of the Hydraulics Group and the Boston Chapter of ASME on January 26, 1983 at the MIT Faculty Club. Dr. Faddick's subject was "Technology of Movement of Solids and Slurries in Pipelines - State of the Art (Past Experiences - Present Design Practices/Applications - New Developments". He submitted a paper on this subject for publication in the JOURNAL.

Dr. Edward B. Kinner, the most recent Past President of BSCES, was appointed to the FREEMAN FUND Committee.

A March 2, 1981 FREEMAN FUND Committee request to the Treasurer of BSCES that the FREEMAN FUND be reinvested was substantially satisfied when the Section reinvested all of its pooled funds (including the FREEMAN FUND).

Approximately one hundred copies of the special Summer 1981 issue of the BSCES JOURNAL - "Boston's Charles River Basin - An Engineering Landmark" were sold.

Submitted by:
The FREEMAN FUND Committee
L. Kinsel, Lawrence C. Neale,
R. F. Harleman, Edward B. Kinner,
Marc G. Wolman, Chairman

Report of Hazardous Waste Management Committee, 1982-1983

This is a new Committee which was formed following action by the Board of Government on February 16, 1983 approving the Committee.

Members of the Executive Committee for 1982-1983 are:

Brendan M. Harley, Chairman
Thomas L. Neff, Secretary
Robert C. Faro
John L. Splendore
Wesley Stimpson

The Committee's role is to act as a catalyst to bring together the diverse groups currently involved with hazardous waste. To this end, it ran a number of coordinated meetings with the goal of expanding the knowledge of the many facets of hazardous waste management to the wide range of professionals who must deal with this increasingly important problem. The meetings were as follows:

JUNE 23, 1981 - Organizational meeting at the MIT Faculty Club. The topic was "Current State and Federal Regulations Involving Hazardous Waste Management."

Speakers were Mr. Ilyas Bhatti, of Massachusetts DEQE, and Mr. Jeffrey Cassis, Camp Dresser & McKee Inc., who discussed the EPA Superfund and its implementation.

OCTOBER 20, 1983 - Joint meeting at the MIT Faculty Club with the Environmental Group. Mr. David Doyle, of Camp Dresser & McKee, spoke on the implementation of hazardous waste site clean-up operations at the PAS Oswego site. The talk covered the problems inherent in waste removal and transportation and the method of contracting best suited to handling complex site clean-up.

JANUARY 20, 1983 - Meeting at the MIT Faculty Clb. The speaker was Anne Marie Desmarais, of Yankee Environmental Engineering and Research Services, who addressed the issue of "Health and Safety for Chemical Waste Investigations." Topics covered included effective on-site monitoring, worker safety, protective clothing, and the role of the toxicologist as an integral member of a site team.

FEBRUARY 8, 1983 - Joint dinner meeting with the Geotechnical Group at Tufts University. The topic was "The construction of the slurry wall containment at the Gilsen Road Site, Nashua, N.H."

Meetings scheduled to be held in the remainder of this session include:

MARCH 17, 1983 - Meeting at the MIT Faculty Club. Don Muldoon, of Camp Dresser & McKee, together with Charles Lindburgh and Garry Williams, of Goldberg Zoino & Associates, will discuss "Practical Guidelines for Sampling and Analysis of Contaminated Waste"

APRIL 19, 1983 - Meeting at the Parsons Laboratory, MIT. Prof. L. W. Gelher and Mr. Peter Riordan will present papers on "Contaminant Transport Processes and Their Simulation"

MAY 17, 1983 - Meeting at MIT to address the industrial view of "Treatment and Disposal" of hazardous wastes.

The Committee has reviewed whether a lecture series integrating the various disciplines involved in Hazardous Waste Management would be viable. A decision as to whether to request a lecture series for late Spring 1984 will be made in April.

Respectfully submitted,
Brendan M. Harley
Chairman

Report of the History and Heritage Committee 1982-1983

As reported last year, the Borden Base Line has been designated as a National Historic Civil Engineering Landmark. The Western Branch is working with the Committee on arrangements for the dedication being planned for this Spring.

This year the Watertown Arsenal has been designated as a National Historic Civil Engineering Landmark in recognition of the construction materials testing programs carried out there. The dedication is tentatively arranged for late May.

Mr. Potamis is working on the Canton Viaduct for national or Massachusetts designation.

Mr. Battles is working on power generation break-through and the industrial revolution, with specific attention to the Francis turbine installation at Lowell.

Mr. Kraemer is working on the Brockton Railroad Viaducts and Bridges for Massachusetts or possibly national recognition.

During the past year, the Committee has started compiling an inventory of engineering plans and related documents of historical value. This inventory will be a valuable resource for researchers. Eventually, it is hoped that a repository for this historical material may be established in our area.

Mr. Holly is again serving as a member of the ASCE Committee on the History and Heritage of American Civil Engineering.

Respectfully submitted,
Richard F. Battles
Steven R. Kraemer
Gerald C. Potamis
H. Hobart Holly, Chairman

Report of Investment Committee, 1982-1983

The Committee has met quarterly and recommended to the Board of Government that the Boston Safe Deposit and Trust Company be terminated as custodian of our portfolio of securities. The Board of Government voted to follow the recommendations of the Committee and to invest the funds of the Section in the following investment vehicles and associated percentages: Fidelity Equity Income (30%), Vanguard Windsor (20%), Source Capital (20%), Capital Preservation (30%). The Committee monitors these investments and provides periodic reports on the individual performances to the Board of Government.

The members of the Committee are:

Richard F. Murdock, Chairman
Stanley C. Rossier
Edward B. Kinner
Max Sorota
Lee M. G. Wolman
Robert Culver
Michael Hewitt, Financial Advisor

Respectfully submitted,
Richard F. Murdock
Chairman

Report of Key Man Committee, 1982-1983

The Key Man Committee acts as a line of rapid communication between the Section and its members in local engineering firms or agencies. Its primary purpose is to serve as a means of alerting or reminding members of coming meetings or events of the Section.

In 1982 the key man list was revised and the number of firms or agencies represented on the Committee was increased from 79 to 85. The Committee was activated for social events, as well as for some noon luncheon meetings and dinner meetings.

Respectfully submitted,
Wayne E. Kilker
Chairman

Report of Lecture Series Committee, 1982-1983

The Lecture Series Committee met several times during the year to coordinate the planning, scheduling and execution of Lecture Series among the Technical Groups. Telephone polling of the members of the Committee was made from time to time for updating the schedule.

The status of the various series is as follows:

STRUCTURAL GROUP: Series on "Structural Details in Steel and Concrete Buildings" scheduled between 27 September 1983 to 1 November 1983.

COMPUTER GROUP: Series on "Computer Aided Design" scheduled between 28 February 1984 to 10 April 1984.

WATERWAYS, PORT, COASTAL, AND OCEAN COMMITTEE: This Committee is planning a one-day seminar in the Spring of 1984 on the subject of "Coastal Engineering".

CONSTRUCTION GROUP: Planning a short course on "Planning" in late 1983.

GEOTECHNICAL GROUP: Series on "Engineering Geology" was completed in the Fall of 1982 with cost exceeding revenue. Nothing further is planned prior to the Fall of 1984.

TRANSPORTATION GROUP: Nothing planned.

ENVIRONMENTAL GROUP: Nothing planned.

HYDRAULICS GROUP: No lecture series planned. However, group is participating in a specialty conference in August 1983 at MIT.

BSCES/ASCE Special Lecture Series is scheduled for July 9-11, 1984. This is a special fund raising activitiy for the International Conference on Soil Mechanics and Foundation Engineering.

Respectfully submitted,
John P. Sullivan
Chairman

Report of Loads Committee 1982-1983

The Loads Committee did not hold meetings this year, pending clarification of whether recommendations for changes would be considered by the state officials who are responsible for the State Building Code. The Committee now plans to become active in developing recommendations for initial review by the entire membership and for eventual presentation to responsible state officials. Members are encouraged to contact Frank J. Heger, Chairman of the Committee, with suggestions for changes or to report inadequacies in existing code criteria with respect to loads.

Respectfully submitted,
Frank J. Heger
Chairman

Report of Luncheon Committee, 1982-1983

This year no luncheon/dinner meetings were held while the Board of Government and the Committee reviewed the purpose and direction of the functions proposed by the Committee. As a result of several meetings, the following course of action was recommended and approved:

1. That the meeting topics be general in scope to attract the largest possible attendance; however, Section business be conducted at the function.

2. That three functions be held each year:

    a. The first function would be in June, and would be a luncheon meeting. A possible speaker would be the President-elect of the Section. The newly elected local Section president could use the function to announce Committee assignments or program objectives for the coming year.

    b. The second function would be held in September, and would be a dinner meeting. Local leaders associated with civil engineering or the Section would be invited to speak and local Section business would be conducted.

    c. The third function would be held in January and would be a luncheon meeting. Speakers related to the construction industry would be invited to speak and local Section business would be conducted.

3. That the two luncheon meetings be held at any one of the new hotels in Boston, and the dinner meeting be held at the Engineer's Club. As the meeting is the event, and not the subject matter, it is my opinion that the place the meeting is held becomes significant. This will reflect in the cost of the function.

4. The above changes the purpose of the functions. Originally, a rather informal luncheon series was planned, so the membership could meet on a monthly basis. The functions, as recommended above, will involve a longer time commitment and will be more expensive.

    However, the functions could become milestones in the Section year at which Section business is conducted, awards announced, and activity reports presented.

Plans are being made for the June meeting.

Respectfully submitted,
Brian R. Hogan,
Chairman

Reports of the Membership Committee, 1982-1983

The Membership Committee this year consisted of George Bollier, Thomas Carabine, James Errico, Vernon LeBlanc, Paul Ozarowski, and Stanley Lucks, Chairman.

The Committee has the following goals to assist in increasing the membership and ensure the continued vitality of the Section:

1. Contacting members who have failed to pay their membership dues in an effort to maintain the existing membership.

2. Study how the Section can increase its membership from the roll of ASCE members that have been assigned to the Section. About only 1400 of 2500 assigned ASCE members are members of the Section.

3. Determining the most effective way of increasing the Affiliate Membership.

4. Determining the most effective method of encouraging nonmember attendees of Technical Group meetings to join the Section. Prior to the start of the 1983-1984 meetings, information packages will be distributed to the Technical Group Chairmen.

The Committee would appreciate help from the membership in these efforts.

Respectfully submitted,
A. Stanley Lucks
Chairman

Reports of Minority Affairs Committee, 1982-1983

The Committee Membership for this year was as follows:

Jack D. Bryant, Chairman
Jacques A. Borges

The Committee continued active research of existing programs for minority persons who are interested in an engineering career, particularly in technical careers and training courses which lead to a degree in engineering.

The Committee prepared a draft statement of goals with recommendation for the attainment of these objectives. Complimentary subscriptions were obtained of "Minority Engineer" and "Woman Engineer" and given to two students, one university library and one technical society.

The Chairman has been active in miscellaneous activities pertaining to minorities in engineering, participated in the Minority Affairs Seminar at the ASCE Annual Convention, and served as Role Model on Career Day for grade nine at the Randolph High School.

Respectfully submitted,
Jack D. Bryant
Chairman

Report of the Nominating Committee, 1982-1983

The following list includes those members who have been selected by the Nominating Committee to be nominees for the BSCES/ASCE Board of Government for 1983. These members have been contacted and have agreed to the nominations.

Richard Scranton, President
Rodney Plourde, Vice President
Warren Ringer, Treasurer
Judy Nitsch, Secretary
Steven Bornstein, Director (Two Positions)
Domenic D'Eramo, Director
Jack Bryant, Nominating Committee
Robert Dunn, Nominating Committee
Rocco Mancini, Nominating Committee (Six Positions)
Ronald Sharpin, Nominating Committee (Three to be Elected)
Richard Simon, Nominating Committee
Kenneth Weisner, Nominating Committee

Although the Board's approval on these nominees is not required, we would appreciate your support for these nominees.

Our Committee is also responsible to nominate members for National Professional Committees. The following members were selected by the Nominating Committee and your approval is required prior to submitting their names to National Headquarters:

National Professional Committee	BSCES/ASCE Nominee
Curricula and Accreditation (CC&A)	Michael Kupferman
Engineering Management at the Individual Level (EMIL)	(Nominee to be selected by Frank Perkins)
Engineering Management Activities (EMAC)	No Nominee
Minority Programs (COMP)	Jack Bryant
Public Affairs & Legislation (CPA&L)	Rubin Zallen
Employment Conditions (COEC)	Kevin Egan

By copy of this letter to members of the Nominating Committee listed below, I wish to extend my personal thanks for their work on behalf of the Section.

Frank Perkins
Ed Kinner
Saul Namyet
Dick Foley
Domenic D'Eramo
Steve Bernstein
Bob Snowber
Charles Roselli

Respectfully submitted,
William S. Zoino
Chairman

Report of the Operations Manual Committee, 1982-1983

This Committee is charged with keeping the BSCES Operations Manual current. With regard to the Manual the following actions were taken:

1. Revisions concerning the duties of Elected Officers and Executive Director, the AUDITING COMMITTEE, establishment of a BUDGET COMMITTEE,

responsibilities of the AWARDS COMMITTEE and ACTION PROGRAM-PROFESSIONAL PRACTICE COMMITTEE proposed by the 1981-1982 OPERATIONS MANUAL COMMITTEE were voted by the Board of Government during March of 1982.

2. Revisions to the LECTURE SERIES COMMITTEE sections redefining the distribution of income or loss were voted by the Board of Government in January of 1983.

3. Revisions to the STUDENT AFFAIRS COMMITTEE sections renaming the DESMOND FITZGERALD and WILLIAM P. MORSE SCHOLARSHIPS as awards and allowing the Board of Government to set the amount of these awards were voted by the Board of Government during March of 1983.

4. Further revisions to the AWARDS COMMITTEE sections concerning the selection of a recipient for the newly established LESTER GAYNOR AWARD for service as a part-time elected or appointed city or town official were voted by the Board of Government in March of 1983.

The revised Operations Manual will be ready for circulation in May of this year.

Respectfully submitted,
Richard J. Scranton
Chairman

Report of Program Committee, 1982-1983

The Program Committee coordinated the scheduling of all meetings to which the general membership was invited, including:

Functions sponsored by Technical Groups
Functions sponsored by Committees
Functions sponsored by BSCE Section

Dates were allocated to Committees and Groups during a formal meeting in early 1982. Changes were made upon request during the year. All changes were coordinated through the Chairman with special care taken to avoid conflicts with other previously scheduled events and holidays.

Emphasis was given to joint sponsoring of events by two or more technical groups.

Respectfully submitted,
John P. Sullivan
Chairman

Report of the Public Relations Committee, 1982-1983

The Committee this year was composed of the following members:

Robert J. Dunn, Jr.
Douglas F. Reed
Burt B. Jamison

The Public Relations Committee acts as the primary link between the Section, its members and the general public. Its purpose is not only to provide continued awareness within both ASCE and the BSCE Section, but more importantly to enhance the public's awareness, understanding and appreciation of civil engineering as a "People-Serving Profession".

It has been said that "people can only understand you and appreciate what you do if they know you and what you do." As civil engineers, you are those members of that people-serving profession who have the opportunity to provide the community with the awareness, understanding and appreciation of our involvement.

We hope that our efforts will not end with just those of the Committee, but that they will continue through those efforts of its members as well.

Respectfully submitted,
Robert J. Dunn, Jr.
Chairman

Report of the Publications Committee, 1982-1983

During the past year, Section publications have included two issues of the BSCES JOURNAL, published as Volume 68, Numbers 1 and 2, and ten issues of the Newsletter. The BSCES JOURNAL has had approximately 2,000 subscribers including about 400 non-members, mostly libraries.

Both JOURNAL Editor Henry Irwig and Associate Editor Lincoln Ryder are to be congratulated for accomplishing the difficult task of publishing the JOURNAL in a timely and efficient manner.

In an effort to keep production costs to a minimum, the JOURNAL is now being printed almost totally from camera-ready copy. To assure uniformity, a new set of guidelines for authors has been developed.

Respectfully submitted,
Richard J. Scranton
Chairman

Report of Committee for Retired Engineers Service Corps, 1982-1983

The Committee was established by the Board of Government in May 1981 to develop a program which would identify opportunities in public service for retired Civil Engineers.

The Committee is composed of Robert A. Snowber (Chairman), Bruce Campbell and Peter Dyson. It was determined to use the International Executive Service Corps (IESC), established in 1965, as a framework to see whether there was interest in BSCES for such a program.

A luncheon program at Quincy Market was arranged with a representative of the IESC as speaker in May 1982. Due in part to a late mailing, the response was so poor that the meeting was cancelled.

The Chairman has suggested to the Luncheon Committee Chairman that another meeting be arranged, but to date nothing has moved forward.

It is believed, but not confirmed, that there is a need for such a program. The need to continue the Committee should be discussed by the Board of Government.

Respectfully submitted,
Robert A. Snowber
Chairman

Report of the Social Affairs Committee, 1982-1983

The Committee sponsored the 1982 BSCES Clambake on July 29th at the Concord Rod & Gun Club. Over 275 members and guests enjoyed chicken and lobster, and the raffling off of door prizes.

The Clambake continues to be a great summer success, and this Committee recommends that it be continued.

Because of the marked lack of interest expressed by the membership, there was no Winter dance held this year.

Respectfully submitted,
Mathew A. DiPilato
Chairman

Report of Student Affairs Committee, 1982-1983

The Committee this year consisted of: Steven Bernstein, Chairman; Joe Allegro, Assistant Chairman; Adrienne Dill, Secretary; Michael Kupferman, Richard Scranton, Michael Gaa, Thomas Taddeo, Charles Button.

The Committee met throughout the year with the following activities:

PROJECT FUNDS: SAC presented this project, which includes funding up to $500.00 for any student chapter project (except socials).

FREE LUNCH: This program was modified this year to allow up to 2 student members of each chapter/club to attend Technical Meetings free of charge.

STUDENT LOANS: Two $1000.00 interest-free loans were awarded this year to:

Gerald S. Janetti - University of Lowell
Denis Beique - Northeastern University

HOWE-WALKER AND OTHER AWARDS:

The following awards were made at Student Night:

DESMOND FITZGERALD AWARD -	Mark E. Bordne, Northeastern University
WILLIAM P. MORSE AWARD -	Christy French, Tufts University
HOWE-WALKER AWARD	
MIT	Eftychi Nestorides
Merrimack College -	Michael J. Carter
Northeastern University -	Jeffrey S. Ferriss
Northeastern University -	Bob A. Scherpf
Southeastern Mass. -	Rose Castro
Tufts University -	Michael Cantalupa
University of Lowell -	Mark P. Braconnier
UMass	David J. Chambers
Wentworth Institute -	William J. Goggins
Worcester Polytechnic -	Guy Busa

STUDENT NIGHT: This year, Student Night was held on Monday, February 28, 1983 at NU; 105 persons were in attendance. The speakers were from the Corps of Engineers where they presented a dual image slide show on the "Cape Cod Canal Story." Awards were presented.

The SAC assisted the nine (9) Massachusetts engineering schools with information on Student Membership Grade, and providing Contact Members and help wherever necessary.

In 1983-1984, the SAC is planning a special Student Night on "Careers in Engineering" with another engineering society, and it is hopeful that our efforts will bring the Student members closer to the BSCES organization.

Respectfully submitted,
Steven L. Bernstein
Chairman

Report of Geotechnical/Foundations Advisory Committee, 1982-1983

The Committee has met monthly and has voted to make several changes in the code. One of the more important changes is a substantial revision of the pile load test procedure. The time of loading will be reduced and instrumentation will be required for most pile load tests. This proposed procedure will be circulated to the community for comment and a Geotechnical Section meeting will be held to discuss it.

The next major topic to be undertaken by the Committee will be improvement of Table 720.

The Massachusetts Building Code Commission no longer exists. Therefore, no formal procedure currently is available for making changes in the code.

The members of the Committee are:

Steve J. Poulos	Chairman
Edmund G. Johnson	Vice-Chairman
Paul Donahue	
M.W.C. Emerson	
William Langrill	
Asaf Qazilbash	
Peter Riordan	
Richard Simon	
Roy Stiffler	
Peter Taylor	

Respectfully submitted,
Steve J. Poulos
Chairman

Report of Seismic Design Advisory Committee, 1982-1983

The Seismic Design Advisory Committee this year consisted of the following members:

Rene W. Luft	Chairman
Gonzalo Castro	Vice Chairman
Norton S. Remmer	Secretary
James A. Becker	Member
Myle J. Holley, Jr.	Member

Edward B. Kinner	Member
Thomas M. Payette	Member
Maurice A. Reidy, Jr.	Member
Kentaro Tsutsumi	Member
Robert V. Whitman	Member
Kenneth B. Wiesner	Member

The Committee has held two regular meetings: one on 13 December 1982, and the other on 7 March 1983. Highlights of discussion items are given below.

The seismic zone factor of the current State Building Code was reviewed and found consistent with the latest available earthquake risk estimates. A peak ground acceleration of 10-20% of gravity, as given in the Code, has a 90% certainty of not being exceeded in 50 years.

The required lateral force level or base shear in the current State Building Code was reviewed and found to be smaller than expert opinion thinks is reasonable for design against a 10-12% of gravity acceleration; the Committee, however, still endorses the continued use of the base shear formula given in the Code.

The Committee reviewed the soil factor, the response spectrum, and the liquefaction provisions of the current State Building Code, and arrived at new tentative recommendations which will be published shortly.

The Committee is in the process of reviewing the code provisions for anchor bolts and for forces on connections of precast concrete panels.

The Committee invites comments on the Earthquake Load Section of the State Building Code.

Respectfully submitted,
Rene W. Luft
Chairman

Report of the Committee on the Subsoils of Boston, 1982-1983

The Committee on the Subsoils of Boston was reactivated this year after a hiatus of about 10 years. Members of the Committee during 1982-1983 were:

Joseph Engels, Chairman
Steen Christensen
Deborah Gevalt
Donald Hunt
Richard Simon
James Strangenberg
William Walton
Denise Wilton
R. Lee Wooten

The Committee met on September 16, November 9, December 7, January 26, and February 7.

The operating budget for the Committee for 1982-1983 was $3,800.00. This budget consisted of $1,596.00 which remained in the BORING DATA FUND since the last Committee was organized in 1972 and $2,204.00 contributed by the BSCES Geotechnical Group this year.

The Committee concentrated its efforts this year on collecting and compiling boring data from the City of Cambridge. The boring data for Cambridge was last compiled by BSCES in 1952.

Letters requesting Cambridge boring data were sent to over 60 Boston area architectural, engineering and construction firms and government agencies. The approximately 1,500 logs collected are being compiled and condensed by five senior civil engineering students from Tufts University under the supervision of the Committee and Dr. Lewis Edgers, from Tufts. The five students assisting in this work were:

Lissa Clifford
Diego Espinosa
Teresa Murphy
Stephen Sullivan
James Tiampo

It is currently planned to publish the Cambridge data in the Fall of 1983.

Respectfully submitted,
Joseph G. Engels
Chairman

Report of Computer Group, 1982-1983

The Computer Group had the following evening lectures/meetings:

NOVEMBER 18, 1982

Topic:	From Programming to Software Engineering
Speaker:	Dr. Richard F. Vidale
Attendees:	26. There was no admission fee. Coffee and doughnuts were served. The total cost was $63.00 which was reimbursed by BSCES/ASCE.

JANUARY 13, 1983

Topic:	Micro Computers in Civil Engineering
Panelists:	Glen Orenstein (Moderator), David Leavitt, Steve Lerman, John Lupien, Betsey Schumacker
Attendees:	126 for the talk and 94 attended for dinner. This included 2 students under "free-student" program. Students in excess of 10%. Cost per dinner was $7.95; students paid $5.00. We are entitled to be reimbursed $80.80 from the Student Affairs Committee. Total dollars (receipts) received $767.50; total dollars spent $814.88.

FEBRUARY 24, 1983

Topics:	Use of Micro-computers in Geotechnical Engineering
Speaker:	Dr. W. Allen Marr
Attendees:	26 including 4 under the "free lunch" program. We have received $251.50 and left $28.50 in the box for the cash bar. We did not yet receive the bill from Tufts University where this meeting was held. Mr. Castro paid $10.50 for the rental of 2 screens.

The Computer Group was planning to organize a lecture series on CAD/CAM beginning from May 10, 1983. Due to schedule conflict with the Structural Group, this lecture series has been rescheduled for February 28, 1984. There are a lot of activities in the Group to make this Series a successful one.

Respectfully submitted,
Mukti Das

Report of the Construction Group, 1982-1983

The Executive Committee of the Construction Group this year was comprised of the following members:

Mark P. Tedeschi	Chairman
Thomas Taddeo	Vice Chairman
Charles Costello	Clerk
Charles Rosselli	Member
Richard Sage	Member

Meetings of the Construction Group during this past year were as follows:

SEPTEMBER 14, 1983 - Joint dinner meeting with the Geotechnical group at Tufts University, Mugar Hall. Dr. George Goble, of the University of Colorado and Pile Dynamics, Inc., discussed the development of and utilization of dynamic measurement devices in the analysis of the capacity of driven piling. Also discussed were wave equation analyses and the computer programs currently available. Attendance - 62.

DECEMBER 2, 1983 - Dinner meeting at the Engineers Club. Four speakers discussed their involvement in the design and construction of the Exchange Place Building at 53 State Street, Boston. Giving presentations were Fred Driscoll, of Olympia and York (owner), Thomas Arthur, of Engineers Design Group (structural engineer), Daniel LaGatta, of Geotechnical Engineers, Inc. (geotechnical engineer), and John Alfano, of Gilbane Building Co. (general contractor). Attendance - 114.

FEBRUARY 8, 1983 - Joint dinner meeting with the Hazardous Waste and Geotechnical Groups at Tufts University, Mugar Hall. The subject of this evening's discussion was the design and construction of a slurry wall containment at an illegal hazardous waste site off Gilson Road in Nashua, NH. Speakers were John Ayres and Matthew Barvenick, of Goldberg-Zoino Associates, (engineer), and David Lager, of Case International Co. (contractor). Attendance - 70.

MARCH 10, 1983 - Joint dinner meeting with the Energy Group at Tufts University, Mugar Hall. Paul Pimentel, of Pequod Associates, Boston, Mass., discussed energy considerations in the design process. Mr. Pimentel gave as example the design considerations of several notable buildings in the Boston area. Attendance - 20.

Officers and Executive Committee Members for 1983-1984 are as follows:

Thomas Taddeo	Chairman
Richard Sage	Vice Chairman
John Minihan	Clerk
Mark P. Tedeschi	Member
Charles Rosselli	Member

Respectfully submitted,
Mark P. Tedeschi
Chairman

Annual Report of the Environmental Group, 1982-1983

The Executive Committee of the Environmental Group for 1982-1983 consisted of the following members:

James C. O'Shaughnessy	Chairman
Edward Boyjian	Vice Chairman
Richard K. Smith	Clerk
Stephen Geribo	Member
Peter Smith	Member
Sarah J. Simon	Member

The group held the following meetings:

OCTOBER 20, 1982 - Social hour and technical presentation by Mr. David F. Doyle, Vice President, C.D.M. Mr. Doyle's talk was "A Case Study of an Abandoned Hazardous Waste Site Cleanup Under Superfund". This was a joint meeting with the Hazardous Waste Group. Attendance was 48; the meeting was held at the MIT Faculty Center. This was an official BSCES meeting.

NOVEMBER 23, 1982 - Dinner meeting at Purcell's Restaurant. The speaker, Mr. Allan Jacobs, of Metcalf & Eddy, presented "Energy Management at Water Pollution Control Facilities". This meeting was a joint meeting with the Energy Management Group. Attendance - 41.

FEBRUARY 15, 1983 - Dinner meeting at Polcari's Restaurant. The speakers were Dr. Frank Heuston and Ms. Rozanne Burt, of Northeastern University. The topic was "Career Planning for Environmental Engineers". Attendance was 55, including 27 students.

MARCH 24, 1983 - The THOMAS L. CAMP LECTURE was held at Northeastern University Faculty Center. Dr. Perry L. McCarty, of Stanford University, was the 1983 Camp Lecturer. His talk, "The Movement and Biodegration of Hazardous Materials in Groundwater", was well received by the 130 people in attendance.

MAY 18, 1983 - Will be the annual Environmental Group plant tour. This year the group will tour the Fall River, (Mass.) Wastewater Treatment Facility. Following the tour, a dinner meeting is scheduled at the Venus de Milo Restaurant in Swansea. The speakers will be Mr. Stephen Buck, of Fall River; Mr. Anthony Prata, of C.E. Maguire; and Mr. Winfield Peterson, of M&E. They will speak on the design and operation of the facility.

Respectfully submitted,
C. O'Shaughnessy,
Chairman

Annual Report of Geotechnical Group, 1982-1983

The following were officers of the Geotechnical Group this year:

Lewis Edgers	Chairman
James W. Weaver (resigned)	Vice Chairman
Joseph G. Engels	Clerk
Nuri T. Georges	Member, Executive Committee

Bruce E. Beverly	Member, Executive Committee
Javed A. Sharwani	Member, Executive Committee
Elliot I. Steinberg	Chairman, Forum Committee
Asaf A. Qazilbash	Immediate Past Chairman

The following were members of the Geotechnical Group Forum Committee:

Elliot I. Steinberg	Chairman
Amr S. Azzouz	Member
Robin B. Dill	Member
Dean A. Grover	Member
William E. Hadge	Member
Louis R. Nucci	Member
John R. Risitano	Member
Allan D. Waller (resigned)	Member
R. Lee Wooten	Member

The Group held the following meetings this year:

SEPTEMBER 14, 1982 - "Dynamic Determination of Pile Performance," presented by George D. Goble, University of Colorado, and Pile Dynamics, Inc., at Tufts University. This was a joint meeting with the Contruction Group. Attendance - 62.

JANUARY 11, 1983 - "Soft Ground Stabilization Using Stone Columns and Reinforced Earth", presented by George Munfakh, of Parsons, Brinkerhoff, Quade, and Douglas, at the MIT Faculty Club. This meeting was sponsored by the Forum Committee. Attendance - 102.

FEBRUARY 8, 1983 - "Slurry Wall Containment of Hazardous Waste at the Gilson Road Site, Nashua, N.H.", presented by John Ayres and Matthew Barvenik, Goldberg-Zoino and Assoc. Inc. and David Lager, Case International Co., at Tufts University. This meeting was sponsored by the Forum Committee and was a joint meeting with the Hazardous Waste Committee and Construction Group. Attendance - 63.

MARCH 8, 1983 - "Stabilization of Soils by Means of Electro-osmosis State-of-the-Art" presented by Dr. Leo Casagrande, at Tufts University. This was the first ARTHUR CASAGRANDE LECTURE. The meeting was dedicated to Dr. Leo

Casagrande and his brother, the late Arthur Casagrande. Members of the audience offered tribute and reminiscences about their associations with these outstanding contributors to our profession. Attendance - 95 (dinner), approximately 150 (lecture).

APRIL 5, 1983 - "Ground Response Due to Advanced Shield Tunneling," presented by Dr. G. Wayne Clough, Virginia Polytechnic Institute and State University, at MIT Faculty Club. This meeting was sponsored by the Forum Committee and cosponsored by the US Department of Transportation.

MAY 3, 1983 - "A Geotechnical Review of the Status and Potential for Compressed Air Energy Storage", presented by J.L. Rosenblad, Stone & Webster Engineering Corporation, at the MIT Faculty Club. This was a joint meeting with the Energy Committee.

The Committee sponsored a motion, approved by the Board of Government, on February 14, 1983, that a $5000.00 fund, allocated from the GEOTECHNICAL GROUP LECTURE SERIES FUND, be established as the ARTHUR CASAGRANDE FUND. Ordinarily, the income shall be used to support a lecture given by an eminent engineer with longstanding achievements in practice, teaching, and/or research in geotechnical engineering. This shall be known as the ARTHUR CASAGRANDE LECTURE. The income from the CASAGRANDE FUND may on occasion be used to support other suitable activities, as approved by the Board of Government. The administration of this fund, including scheduling and selection of speakers, shall be the responsibility of the Geotechnical Group Executive Committee.

The officers and Executive Committee for 1983-1984 are as follows:

Joseph G. Engels	Chairman
Nuri T. Georges	Vice Chairman
Bruce E. Beverly	Clerk
Javed A. Sharwani	Member
Elliot I. Steinberg	Member
R. Lee Wooten	Chairman, Forum Committee
Lewis Edgers	Immediate Past Chairman

Geotechnical Group Lecture Series

A lecture series entitled "Engineering Geology" was presented by the Geotechnical Group in cooperation with MIT, in room 10-250 at MIT. Attendance was 130. Speakers and subjects were:

10/12/82	Dr. Douglas Piteau President Piteau and Associates West Vancouver, B.C. Canada	"Mechanics of Slope Failure and Basic Concepts in Rock Slope Engineering"
10/19/82	Dr. Miles O. Hayes President Research Planning Institute, Inc. Columbia, S.C.	"Role of Geomorphological Processes in Inlet and Port Entrance Sedimentation Problems: An Overview"
10/26/82	Dr. Robert F. Leggett Consultant Ottawa, Ontario, Canada	"Urban Geology"
11/16/82	Dr. Lloyd Cluff Vice President Woodward - Clyde Consultants San Fransisco, CA	"Seismic Safety Decision Making:
12/07/82	Mr. Richard L. Meehan President Earth Sciences Associates Palo Alto, CA	"Geology as Metaphor: Experts and Earthquake Faults"
12/14/82	Dr. Tor Brekke Professor University of California Berkeley, CA	"Tunneling in Sedimentary Rock"

A Proceedings Volume was printed, including papers from the first five speakers, and Dr. Dougal R. McCreath, Principal, Golder Associated, Vancouver, B.C., Canada, entitled "Engineering Geology in Underground Construction: An Engineer's Perspective".

List of Members
ORGANIZING COMMITTEE
1982 GEOTECHNICAL LECTURE SERIES

Ronald C. Hirschfeld	Chairman
Joseph G. Engels	Vice Chariman
Robert E. Stetkar	Secretary/Treasurer
Gregory B. Baecher	Member

Francis X. Bellini	Member
Joseph D. Guertin	Member
John T. Humphrey	Member
Thomas J. Lamb	Member
William J. Mallio	Member
Carol F. Sweet	Member
William Walton	Member

Respectfully submitted,
Lewis Edgers
Chairman

Report of the Hydraulics Group, 1982-1983

The Executive Committee for this year consisted of the following members:

Paul F. Shiers	Chairman
Athanasios A. Vulgaropulos	Vice Chairman
Eric Adams	Clerk
Varoujan Y. Hagopian	Member
Dean K. White	Member
Richard J. DiBuono	Member
Edward P Dunn	Member
Joseph O. Elmer	Member

Meetings held by the Hydraulics Group are summarized below:

SEPTEMBER 29, 1982 - An evening meeting was held at Alden Research Laboratory at Holden, Massachusetts, followed by dinner at the William and Paul House. Meeting was jointly sponsored by the Energy Group and the Western Massachusetts Branch. Professor George Hecker, Director of ARL, spoke on the history of the Lab and reviewed the ongoing research program. Following this lecture, tours were conducted to various projects in the lab including a steam-electric power plant intake, a steam-electric power plant diffuser, a river pumping station, and the Laboratory's flow calibration facilities. Attendance - 21.

DECEMBER 8, 1982 - Evening meeting was held at the Ralph M. Parsons Water Resources Laboratory, MIT. The subject was "Alternative Concepts for Controlling Runoff in Developing Areas". Professor Arnold L. O'Brien, of the Earth Sciences Department, at the University of Lowell presented a paper which reviewed current concepts on the production of storm runoff and described alternative approaches to the complex runoff process. Attendance - 31.

JANUARY 26, 1983 - A dinner meeting was held at the Faculty Club at MIT. The meeting was jointly sponsored with the Waterways, Port, Coastal, and Ocean Group, and the Boston Section of the American Society of Mechanical Engineers. The JOHN R. FREEMAN MEMORIAL FUND underwrote the expenses of the speaker, Dr. Robert R. Faddick, of the Colorado School of Mines. A paper entitled "Slurry Pipelines - An Overview" was handed out at the meeting. Dr. Faddick spoke on the state-of-the-art in the technology of movement of solids and slurries in pipeline. Attendance - 63.

APRIL 14, 1983 - An evening meeting was held at the Ralph M. Parsons Water Resources Laboratory, MIT. The subject was "The Impact of Acid Rain on the Bickford Reservoir and Its Watershed". Professor Harry Hemond, of the Civil Engineering Department at MIT, was the speaker. Attendance - 29.

The Committee worked to support the 1983 ASCE Hydraulics Group Speciality Conference to be held at Massachusetts Institute of Technology from August 9 through 12, 1983. The conference theme will be "Frontiers of Hydraulic Engineering".

The sale of lecture notes from the 1981 Small Scale Hydro Power Lecture Series continued during this year. The sale of notes was successful in eliminating the deficit that existed at the completion of the lecture series.

Hydraulics Group Officers for 1983-1984 were elected at the April meeting. the Executive Committee for the coming year will include the following:

Athanasios A. Vulgaropulos	Chairman
Eric Adams	Vice Chairman
Joseph O. Elmer	Clerk
Paul F. Shiers	Member

Dean K. White	Member
Edward P. Dunn	Member

Respectfully submitted,
Paul F. Shiers,
Chairman

Report of Structural Group, 1982-1983

The Executive Committee this year consisted of the following members:

Maurice A. Reidy, Jr.	Chairman
Thomas Tsotsi	Vice Chairman
Emile W. J. Troup	Clerk
Morris S. Levy	Member at Large
Nicholas Mariani	Member at Large
Prof. Richard Savage	Member at Large
Michael Bohn	Student Member
Kenneth B. Wiesner	Immediate Past Chairman

The following meetings of the Structural Group were held during the year:

OCTOBER 7, 1982 - The annual AISC T. R. Higgins Lecture was held at MIT. Dr. Conrad Heins, of the Department of Civil Engineering at the University of Maryland, presented "Steel Box Girders - State-of-the-Art" in which he discussed the latest information available on design criteria, preliminary details, design aids and computer aided design. His current paper was distributed at the meeting. A brief slide presentation was also made of the two New England bridges which received awards in the 1982 AISC Prize Bridge competition. Attendance - 55.

DECEMBER 1, 1982 - The new MBTA Alewife Station and Parking Garage was the subject of this meeting held at Barnum Hall, Tufts University. The presentation was made by three speakers: Leslie Moore, of Ellenzweig, Moore & Assoc., Inc.; H. William Hagen, of LeMessurier Assoc./SCI; and Domenic D'Eramo, of Sverdrup & Parcel and Assoc. The architect and structural engineers of this new terminal point to the MBTA Red Line Extension to the west discussed the selection of materials and the design of the structural framing system. Attendance - 70.

FEBRUARY 2, 1983 - C. Richard McCullough, Senior Architect of Ganteaume & McMullen, Inc., and Arthur L. Brown, Jr., President of Brown Rona, Inc., discussed "The Fargo Building: A Study in Recycling and Value Engineering" at this meeting held at the Ell Student Center Ballroom at Northeastern University. Mr. McCullough discussed the background of the recycling of the building constructed in 1909 with respect to conformance with the current building code. Mr. Brown discussed value engineering as it related to the design and construction of the new exterior structural frame. Attendance - 60.

FEBRUARY 17, 1983 - A special joint meeting with the Northeastern University ASCE Student Chapter was held at the Ell Center Ballroom. Dr. Edward Pfrang, Chief of Structures Division Center for Building Technology, National Bureau of Standards, made his presentation on the "Collapse of the Walkways at the Kansas City Hyatt Regency Hotel." Dr. Pfrang had directed the investigation of the collapse which included onsite inspections, laboratory tests and analytical studies which gained him the United States Department of Commerce 1982 Gold Medal Award. Attendance at this meeting was 125.

APRIL 6, 1983 - The final meeting sponsored by the Structural Group addressed the "Design and Construction of the Tropical Forest Pavilion at Boston's Franklin Park Zoo". This unique structure has an innovative steel frame formed of steel beams converging into "three dimensional space arches." The roof is an innovative, computer designed tent of Fiberglass fabric paraboloids stretched between the three converging steel arches. The speakers discussed the design development and construction phase and gave a slide presentation. Speakers were Dr. Steve Varga, of Weidlinger Associates, and Franklin Davis, of Precise Fabricating Corp. This was a dinner meeting held at the MIT Faculty Club. Attendance was approximately 50.

At this meeting elections were held for Executive Committee for the 1983-1984 year. The new Committee will include:

Thomas Tsotsi	Chairman
Emile W. J. Troup	Vice Chairman
Nicholas Mariani	Clerk
Morris S. Levy	Member at Large
W. M. Kim Roddis	Member at Large
John H. Slater	Member at Large
----	Student Member
Maurice A. Reidy, Jr.	Immediate Past Chairman

During the past year the Executive Committee of this Structural Group has been organizing a 1983 Lecture Series (six lectures) beginning in September, entitled "Structural Details in Steel and Concrete Buildings". Three of the lectures will be on structural steel and based on the revised AISC Engineering Detailing Manual scheduled for publication during the Summer of 1983. The remaining three lectures on cast-in-place concrete, will emphasize new design procedures and economical practices.

Respectfully submitted,
Maurice A. Reidy, Jr.
Chairman

Report of Transportation Group, 1982-1983

The Executive Committee of the Transportation Group in 1982-1983 consisted of the following members:

Paul A. Levy	Chairman
Francis H. McCarran	Vice Chairman
Robert T. Tierney	Clerk
Francis R. Sholock	Member
Guy Denizard	Member
David Weiner	Member
Edmund Condon	Member
Robert A. Snowber	Member, Past Chairman
Marvin W. Miller	JRTC Representative

The Group held six meetings in 1982-1983 as summarized below:

APRIL 13-27, 1982 - A five-session lecture series was held in the auditorium at the Massachusetts Department of Public Works. Dr. Bernard J. Mullin, of the University of Massachusetts, Amherst spoke on "Managing Stress: A Positive Approach for Engineering Executives". Attendance - 19.

MAY 13, 1982 - Luncheon meeting at Polcari's Restaurant. Russell Barber, of Harvard University's Institute for Conservation Archeology spoke on the "Archeology of the North Section of the Central Artery". Attendance - 75.

SEPTEMBER 21, 1982 - Luncheon meeting at Polcari's Restaurant. Gordon Slaney, Project Manager, Howard Needles Tammen and Bergendorf, spoke on the "Studies and Alternatives for a Third Harbor Crossing". Attendance - 101.

NOVEMBER 16, 1982 - Luncheon at Joseph's Aquarium Restaurant. Mr. Lester P. Lamm, Deputy Federal Highway Administrator, spoke on "Projected Federal Funding -The Five Cent Gasoline Tax". Attendance - 121.

JANUARY 27, 1983 - Bertram Berger Memorial Seminar at Pier 4 Restraurant, in conjunction with the Bertram Berger Memorial Committee. The theme was "The Future of Transportation". Speakers included Senator Paul Tsongas; Frederick P. Salvucci, Secretary of Transportation and Construction; David W. Davis, Executive Director of Massport; Norman Van Ness, Federal Highway Administration, Division Engineer; and John Clements, Commissioner of Public Works and Highways, New Hampshire. An engraving of Bert Berger was presented to Ms. Fran Berger by BSCES President, Stanley Rossier. Attendance - 215.

MARCH 23, 1983 - Annual Meeting of Group, held at Joseph's Aquarium Restaurant. Annual Elections were held. Mr. Robert T. Tierney, Commissioner, Massachusetts Department of Public Works, spoke on "New Transportation Policies". Attendance - 140.

The Group's Executive Committee for 1983-1984 will include the following:

Francis H. McCarran	Chairman
Francis R. Sholock	Vice Chairman
Robert T. Tierney	Clerk
Guy Denizard	Member
David Weiner	Member
James D'Angelo	Member
Edmund Condon	Member
Robert A. Snowber	Member
Paul A. Levy	Member, Past Chairman
Marvin W. Miller	JRTC Representative

Respectfully submitted,
Paul A. Levy
Chairman

Report of Ad Hoc Waterways, Port, Coastal and Ocean Group, 1982-1983

By a vote of the Board of Government on December 21, 1981, this Group was founded as an Ad Hoc Organization for the 1982-1983 year.

The Executive Committee for the year included the following:

Kenneth M. Childs, Jr.	Chairman
Peter Majeski	Vice-Chairman
Louis R. Nucci	Clerk
Athanasios A. Vulgaropulos	Secretary
John B. Creedon	Member
William J. Pananos	Member
Alexander Surko, Jr.	Member

The Group held four meetings in 1982-1983 through March 1983:

SEPTEMBER 22, 1982 - George C. Wiswell, President of Wiswell, Inc., spoke on "Rehabilitation of Marine Structures". The meeting was held at the MIT Faculty Club. Attendance - 34.

NOVEMBER 17, 1982 - Gary Clayton, Chief, Scientific and Engineering Section of Massachusetts Coastal Zone Management, spoke on "Management Issues in Coastal Zone Management". The meeting was held at the MIT Ralph M. Parsons Laboratory. Attendance - 24.

JANUARY 26, 1983 - A joint meeting was held with the Hydraulics Group at the MIT Faculty Club. Dr. Robert R. Faddick, Professor, Basic Engineering Department, Colorado School of Mines, spoke on the subject "Technology of Movement of Solids and Slurries in Pipe Lines - State-of-the-Art". This talk was supported financially by the JOHN R. FREEMAN MEMORIAL FUND. Attendance - 63.

MARCH 16, 1983 - Mr. Robert Calder, Executive Director, Boston Shipping Association, Inc., spoke on the subject. "Port of Boston - The User's Viewpoint". The meeting was held at the MIT Faculty Club. At this meeting the following were elected to the Executive Committee for the 1983-1984 year:

Peter Majeski	Chairman
Louis R. Nucci	Vice-Chairman
Athanasios A. Vulgaropulos	Clerk
John B. Creedon	Member
Alexander Surko, Jr.	Member
William J. Pananos	Member

Respectfully submitted,
Kenneth M. Childs, Jr.

1.00 Introduction

This Annual Report summarizes the activities of the Western Massachusetts Branch (WMB) of the Boston Society of Civil Engineers Section (BSCES) of the American Society of Civil Engineers (ASCE) for the period from April 1, 1982 to March 31, 1983. The financial report covers the period from September 1, 1983 to March 15, 1983.

Those responsible for furnishing information and advice on this report include: President William Hover, Vice-President Paul Kwiatkowski, and Past-President Walter Schwarz.

2.00 1982 - 1983 Officers

Since the WMB did not have any candidates for Secretary and Treasurer for the 1982-1983 slate, past and current officers Walter Schwarz and Paul Kwiatkowski assumed additional duties. The officers for this period are:

President (Elected):	William Hover Goldberg-Zoino & Associates, Inc. Vernon Professional Building 281 Hartford Turnpike Suite G-5 Vernon, Connecticut 06066
Vice-President (Elected):	Paul H. Kwiatkowski 104th Tactical Fighter Group Barnes Municipal Airport Westfield, Massachusetts 01085
Treasurer (Acting):	Walter Schwarz Gordon E. Ainsworth & Associates, Inc. 20 Sugarloaf Street South Deerfield, Massachusetts 01373
Secretary (Acting):	Paul H. Kwiatkowski

The Western Massachusetts Branch Board of Directors included the above personnel and Dr. John Collura, who used his past experience to help us in many ways.

The Newsletter Editor duties for this period were voluntarily accepted by Walter Schwarz.

3.00 Activities

A. FORMAL DINNER MEETINGS

The Western Massachusetts Branch held two formal dinner meetings and a joint meeting with the Connecticut Society of Civil Engineers Section.

The dinner meeting consisted of a cocktail hour, dinner, brief business session, and a speaker. Information on these meetings is as follows:

DATE: April 14, 1982
PLACE: Rodeway Inn, Chicopee, Massachusetts
SPEAKER: Mr. Gary Smith, Geologist
D.L. Maher Company
TOPIC: "Use of Fracture Tracing to Locate
Water Sources in Bedrock"

DATE: December 16, 1982
PLACE: The Lord Jeffery Inn, Amherst, Massachusetts
SPEAKER: Dr. Ernest Selig, Professor of Civil Engineering
University of Massachusetts, Amherst, MA
TOPIC: "Technical Aspects of Construction and
Geotechnical Engineering in the Soviet Union"

The announcement for this latter meeting is given in the Appendix.

On May 11, 1982 representatives of the WMB attended a Joint Meeting with the Connecticut Chaper of ASCE at the Sheraton Tobacco Valley in Windsor, Connecticut.

B. HAZARDOUS WASTE SEMINAR

On June 23, 1982 the WMB cosponsored a very successful Hazardous Waste Seminar with the University of Massachusetts Civil Engineering Department. There were sixty participants from a wide variety of career fields. An agenda of the Seminar is included in the Appendix.

Past-President John Collura and Secretary Paul Kwiatkowski were on the Seminar

Committee. Assistance to the Committee was given by all WMB officers, numerous WMB members, and officials from both the private sector and government.

Profits made by this seminar are to be used to publish the proceedings and for a donation to the University of Massachusetts Student Chapter of ASCE. The form of the donation is presently under consideration.

C. WMB BOARD OF DIRECTORS MEETINGS

The WMB Officers and Past-Presidents held Board of Directors meetings on the following dates:

March 24, 1982
May 5, 1982
June 16, 1982
July 14, 1982
November 9, 1982
November 15, 1982
November 30, 1982

D. BSCES BOARD OF GOVERNMENT MEETINGS

A representative of the WMB attended BSCES Board of Government Meetings on the following dates:

November 15, 1982
January 17, 1983
March 21, 1983

The representatives gave an update of planned and ongoing major WMB activities.

E. 1983 ASCE ZONE I MANAGEMENT CONFERENCE

The 1983 ASCE Zone I Management Conference was held at the Halloran House, New York, New York on January 26-28. The official delegate to this conference from the WMB was Vice-President Paul Kwiatkowski.

The Conference was held primarily to expose the Zone I delegates to new ideas and experiences so that they could use them in their own sections and branches.

The Conference was highlighted by the presence of President John H. Weideman and President Elect S. Russell Stearns, and by the talks that each gave.

The main topics of discussion throughout the Conference were: (1) the infrastructure problem, and (2) the possible change of location for ASCE Headquarters.

F. BORDEN BASE LINE

The Borden Base Line, a National Historic Civil Engineering Landmark, will be dedicated in early May 1983. Past-President Walter Schwarz has done a considerable amount of work on this project, and is presently organizing the dedication ceremony.

The bronze plaque from ASCE has already been obtained. The Massachusetts Association of Land Surveyors and Civil Engineers will be sending a representative to the dedication and it has made a financial commitment for this affair. It is expected that representatives from the following will attend: ASCE National, BSCES, and WMB.

According to Past-President Schwarz, "The plaque will be mounted on a buff-colored, granite box to be located on the front lawn of the Tilton Library in South Deerfield. The Deerfield Historical Society has assisted in the opening of a file in the library containing any available information on the subject."

After the presentation at the Library, there will be a luncheon at the Deerfield Inn.

G. NEWSLETTER

The first issue of the WMB Newsletter was circulated in September 1982. The Editor of the Newsletter is Past-President Walter Schwarz.

The contents of this issue included a president's message, a meeting or events column, ASCE and BSCES News, a listing of the WMB Board of Directors, WMB news and members, Student Chapter events, a schedule of events, and a profile.

The second issue of the WMB Newsletter is expected to be circulated in the Spring of 1983.

Respectfully submitted,
Paul Kwiatkowski

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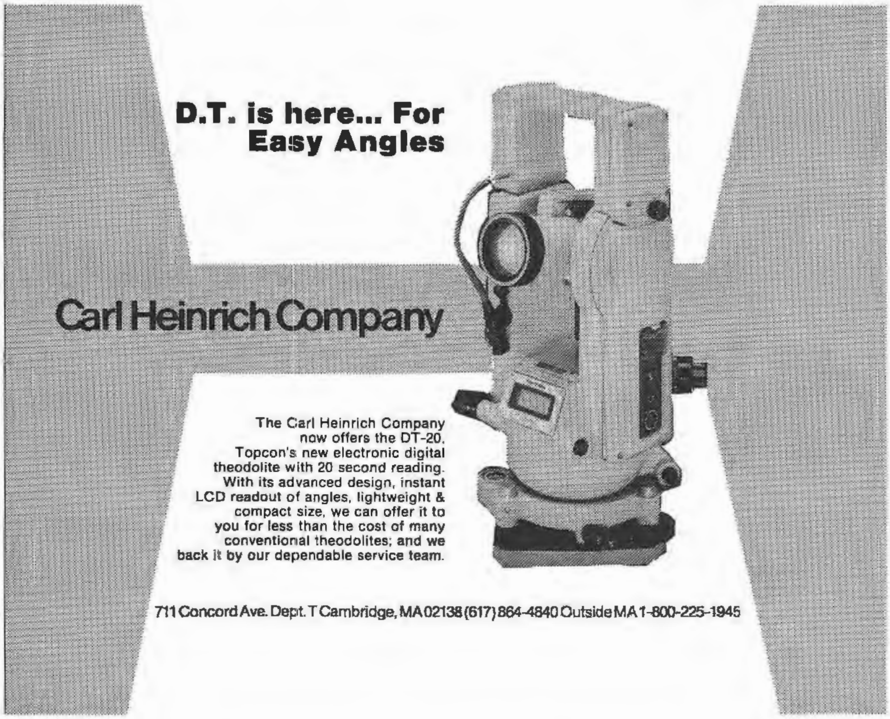

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