Memorial to Thomas W. Fluhr
1898–1987

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Thomas W. Fluhr, pioneer engineering geologist and well-known New York professional engineer, died on January 22, 1987, at Community General Hospital in Harris, New York. A long-time Fellow of the Geological Society of America, Tom was destined to be a leader in the application of geology for engineering works from the time of his 1920s association as a student and young geologist with Charles P. Berkey, one of the most prominent engineering geologists and consultants of that time. Tom made his principal contributions to applied geology for engineering works while working for the New York City Board of Water Supply from 1930 to 1963, and subsequently as the Board's consultant in the development of plans for a system of aqueduct tunnels that today brings water from the Catskill Mountains to New York City. He also worked on four major transportation tunnels and aqueducts and two of the bridges that link Manhattan Island to th boroughs of New York City.

Born in New York City on April 22, 1898, to George L. and Annie Warren Fluhr, Tom spent h early years in New York City. In 1917, he joined the Railway Mail Service and in 1920 he entere Columbia University, where he received his B.A. degree in geology in 1924 and his M.A. degree i 1927.

As a student and shortly thereafter, Tom served as an assistant and laboratory technician o numerous assignments for Berkey, such as preparing thin sections for petrographic analysis an compiling field-exploration logs and data for project drawings. During this period he becam acquainted with the "father of engineering geology in North America," W. O. Crosby of Boston. O questioning, Tom later recalled how Crosby, a superb field geologist, insisted on wearing a rubb raincoat and carrying a gas mask underground as a precaution against poisoning by unexpected gas. I contrast, Berkey rarely went into an underground opening or tunnel at all, for fear of danger; h preferred to use the observations and logs of others.

The projects of Tom's professional career form an impressive list of applied-geology milestone His first full-time professional position was that of assistant geologist in the office of the Board of Wat Supply of the City of New York in 1930. Within a decade of the completion of the Catskill Aquedu in 1920, the Board began a reconnaissance study to select the location for the Delaware Aqueduc Tom did a majority of the staff's geological investigations in planning and designing the new tunne Built in 1937–1942, it was the longest aqueduct tunnel in the world at the time. Tom stayed with th Board in various capacities for 33 years, becoming a senior geologist and later a project engineer. H work included geological study of 140 miles of aqueduct tunnels and four earth-fill dams, the last c which was the Downsville Dam, built in the 1960s.

Tom's affiliation with the Board allowed him to pursue other short-term projects and consultin work. In this manner, between 1933 and 1943, he collaborated with Berkey in the geologic investigation and construction design aspects of the Lincoln, Queens-Midtown, and Brooklyn-Batter vehicular tunnels; the Wards Island interceptor sewer tunnel; and the foundation for the major Triboro and Whitesboro Bridges. After these projects were completed, Tom retrieved the plans and drawings from Berkey, who had intended to discard them, and thereby saved for posterity these outstanding early examples of applied geology for siting and constructing engineering works. The drawings are on file today with the New York State Geological Survey in Albany.

During 1936–1939, Tom organized and supervised a Works Project Administration effort for the Board of Estimate of New York City to collect and compile records of 17,000 borings and other subsurface data throughout the New York City boroughs of Bronx, Brooklyn, Queens, and Richmond. This subsurface-data set was correlated with an assemblage of 10,000 bore records from Manhattan that was compiled by J. J. Murphy. The combined compilation of 27,000 borings formed the basis for the bedrock-soil maps of Manhattan and the greater New York area, released by the city (Murphy and Fluhr, 1944). This work also included mapping all rock outcrops and available exposures for the citywide map. A separate map of the Bronx is on file at Fordham University.

While assembling the citywide map and subsurface data, Tom became concerned over the abundance of highly stressed rock masses. He made critical observations and interpretations at several locations where the bedrock, under a strong relict stress, was causing concern among engineers for the safety of major engineering structures. This experience led to Tom's pioneering investigations into rock stresses and rebound features, beginning about 1940 with the East River Bridge, Queens Anchorage. There, rivets had pulled out of the steel, the anchorage had cracked into three parts, and the truss had ripped away from the anchorage. From disking of core and the sheetlike relief fracture patterns, he concluded that the Ravenswood Granodiorite that formed the bridge foundation was abnormally stressed; the bridge engineers designed accordingly. Tom presented similar evidence again in the 1960s when he used a flat-jack to measure rock stresses as high as 1400 psi in the 63rd Street Tunnel near Welfare Island, and again in the 1970s when he measured stresses as high as 1200 psi by the overcoring technique at the valve chamber in City Tunnel No. 3. From the 1930s into the 1980s, Tom also was a pioneer in developing some of the current practices of rock-mechanics specialists in building tunnels. These included the use of rock bolts to stabilize critical sections of an underground opening, the identification and mitigation of rock stress, and the avoidance of blasting in highly stressed masses. Tom also helped to advance the concepts of applied geology for tunnels and dams.

Among Tom's other major projects were the East River and Harlem River Drive improvements in 1944–1945; foundations for the Union Port Bridge, the 104th Street Footbridge, the Throgs Neck Bridge, and the Verrazano-Narrows Bridge during 1954–1964; the Round Valley and Spruce Run Dams in New Jersey during 1959–1965 and 1967–1976, respectively; and the 63rd Street Rapid Transit Tunnel during 1967–1976. He also served as a consultant to Consolidated Edison on pumped-storage projects and nuclear power plants and was the consultant on numerous water-supply and power projects in Colombia, Mexico, the Dominican Republic, Spain, Greenland, and India. He also advised on major water and sewer tunnels in Rochester, New York; the Metropolitan District of Boston; and San Juan, Puerto Rico.

In addition to Tom's major engineering-project design and construction activities, he frequently served as a geology expert in litigation that involved the New York City Board of Water Supply and Aqueducts system. He often expressed the feeling that "the contractors too frequently felt all the relevant geological data had not been given them as an aid in planning and executing the project works—and this led to unnecessary disputes and lawsuits for the Board."

Tom was honored by his profession many times. He was elected a Fellow of the Geological Society of America in 1954 and was a Life Member and Fellow of the American Society of Civil Engineers. He was a member of the American Geophysical Union and the New York State Society of Professional Engineers, and a Life Member of the Municipal Engineers of the City of New York, to which he belonged for 55 years.

Tom was an active member of the Engineering Geology Division of the Geological Society of

America from its inception in 1947; he served on such early committees as Teaching Aids from 1947 through 1955 and Tunneling Practices in the 1950s and 1960s. He was a leader in establishing the Engineering Geology Case Histories and Reviews in Engineering Geology series of the Division and served as co-editor of the first Reviews in Engineering Geology volume with R. F. Legget in 1962. His contributions to the Division also included serving as program chairman for one annual meeting and as field-trip chairman for the New York meeting in 1948. Tom's pioneering efforts and more than 55 years of contributions to applied geology were formally recognized by the profession in 1983 when he received the Distinguished Practice Award from the Engineering Geology Division of the Geological Society of America. In May 1986, the New York State Geological Survey elected him as the third James Hall medalist for his contributions to the earth sciences in New York State. In addition to his geological activities, Tom found time to participate as a member of the American Radio Relay League and spent much of his spare time on the air with long-time friends around the world.

Tom was always a crusader for competent geological investigations to support the planning of engineering works. For example, upon concluding that foresight and planning for the future water needs of New York City had been inadequate, he wrote the following (Fluhr and Terenzio, 1983):

> Throughout the 73 years of existence of the Board of Water Supply of the City of New York, the Board and its engineering staff have tried to look into the future so that they might provide a good and adequate supply of water for the City and its environs. To that end they have developed plans, trying to foresee what will be needed in the next forty years.
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> Water supply has always depended on crisis. The New Croton System of the 1890's came about because of shortage of good water and an epidemic of cholera. The Catskill System of the 1910–1920's was built only because the Merchants Committee realized the inadequacy of the previous supply. The Delaware System of the 1930's came about because of a drought. The Richmond Tunnel of the 1960's was built because of rapid development of bridges which provided access to the borough. Shortage of water at times in Brooklyn, and the need to supply Richmond have led to the beginning of City Tunnel No. 3.
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> We have had droughts and consequent water shortages in the past. We can expect them in the future. The final question is: "Will the public have the foresight to anticipate water emergencies, and provide a system which will avoid them?"

Tom was always able to explain his work in terms that were understandable to his colleagues in the engineering profession and to the municipal officials who were responsible for acting on his advice. That clarity is demonstrated in a newspaper article (*Sullivan County* [NY] *Democrat*, Dec. 30, 1983) about his receipt of the Distinguished Practice Award from the Engineering Geology Division of the Society, in 1983, in which he was quoted on some details of his findings while working on bridges and tunnels:

> Each bridge is a separate situation. One type of foundation will be good for one bridge, while another type of bridge requires something different. Not all are on solid rock; sometimes it's not only cheaper, but better, to have the foundation on sand and gravel. The Verrazano-Narrows bridge, for example, rests on a bed of gravel down only 100 feet.
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> The way the foundation is set can be quite simple. They may make a coffer dam and build the foundation inside it, and then gradually sink it. On the Throgs Neck Bridge they built a cellular caisson and excavated. Then the caisson was gradually lowered. This could be regulated as it went down by taking material out of the various cells in the caisson so that it wouldn't tip as it went down. They sunk those foundations about 170 feet.
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> The two main foundations on the Throgs Neck which hold the cable had to be pretty good. On the New York City side the main foundations were down 98 feet; on the Queens side they were based on sand and gravel. In one tunnel from the Neversink Reservoir we hit gas. Someone probably lit a cigarette one day and the gas caught on fire. It burned for three days. But then we hit a fault and there was no more gas. The gas had simply come up the fault and seeped through the sandstone. There is not an unlimited supply of gas in the Catskills. It burned off rather quickly.

In his last few years, despite declining health, Tom continued to work and keep abreast of other engineering geology projects. Even after his eyesight failed, he had journal articles read to him so that he could stay in touch with the progress of his science.

As I noted in presenting the Distinguished Practice Award at the November 1, 1983, luncheon meeting of the Engineering Division of the Geological Society of America in Indianapolis, Indiana:

> Few have been involved so deeply, for so long, in so many large engineering projects. Few have had the opportunity to make such significant contributions to their profession. And few have so steadfastly stood up to their ideals and principles. Thomas Fluhr stands out as one of the legends of engineering geology.

Tom was the widower of Wilhelmina Voelbel Fluhr, whom he married in 1924. He is survived by his second wife, Jacqueline B. Fluhr; three daughters, Wilhelmina Gibbs, Anne Jones, and Louise Kalanter; a brother, George L. Fluhr; and half brother, Lawrence Fluhr; and 12 grandchildren.

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ACKNOWLEDGMENTS

This memorial benefited greatly from review and additions by George A. Kiersch and Robert H. Fickies. Contribution number 595 of the New York State Science Service.

Printed in U.S.A. 12/88