U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

A History of The Waterways Experiment Station

1929-1979

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WES Directors

1st. Lt. Herbert D. Vogel
Oct 1929 - Aug 1934

1st. Lt. Francis H. Falkner
Aug 1934 - Jun 1937

Capt. Paul W. Thompson
Jul 1937 - Sep 1939

Capt. Kenneth E. Fields
Sep 1939 - Dec 1941

Mr. Gerard H. Matthes
May 1942 - Sep 1945

Lt. Col. Clement P. Lindner
Oct 1945 - Dec 1945

Col. Carroll T. Newton
Jan 1946 - Dec 1946

Col. John R. Hardin
Jan 1947 - Mar 1947

Lt. Col. Ralph D. King
Jul 1947 - Jul 1950

Col. Herrol J. Skidmore
Aug 1950 - Aug 1952

Col. Carroll H. Dunn
Sep 1952 - May 1955

Col. Andrew P. Rollins, Jr.
Jun 1955 - Jul 1958

Col. Edmund H. Lang
Aug 1958 - Aug 1961

Col. Alex G. Sutton, Jr.
Aug 1961 - Dec 1964

Col. John R. Oswalt, Jr.
Dec 1964 - Jun 1968

Col. Levi A. Brown
Jun 1968 - Jun 1970

Col. Ernest D. Peixotto
Jun 1970 - Jul 1973

Col. George H. Hilt
Jul 1973 - Jun 1976

Col. John L. Cannon
Jun 1976 - Present

A History of The Waterways Experiment Station

1929-1979

VICKSBURG, MISSISSIPPI

JUNE 1979

WATERWAYS EXPERIMENT STATION INSIGNIA

The insignia is designed on a round white disc with a scarlet border edged in gold and inscribed "U. S. Army Engineer Waterways Experiment Station." The colors, scarlet and white, refer to the Office of the Chief of Engineers, under whose direct control the Station operates.

In the center of the insignia is a shield, the lower portion of which consists of wavy blue and white bars which represent water and refer to the Station's establishment as a hydraulic laboratory after the Mississippi River flood in 1927. The upper portion of the shield consists of a scarlet band with an atomic symbol consisting of three gold electrons in interlaced silver orbits. In the center is a gold nucleus indented with small concave curves. The atomic symbol, as a whole, stands for the Station's present involvement in nuclear research, especially in the areas of soils, concrete, and water. The three orbits of the symbol stand for the Station's threefold mission, i.e., research, testing, and development. The small concave curves around the gold nucleus represent rays and allude to the light and knowledge which the Station disseminates.

INTRODUCTION

Born in America's struggle for freedom in 1775, the U. S. Army Corps of Engineers has since been instrumental in the evolution of a strong and independent Nation. For the last 50 years, the U. S. Army Engineer Waterways Experiment Station (WES) has made major contributions to the Nation's growth and development in its role as the Corps' principal facility for research, testing, and development.

From modest beginnings as a small hydraulics laboratory, WES has grown to cover nearly 700 acres, with capabilities for research in hydraulics, soil and rock mechanics, earthquake engineering, soil dynamics, concrete, expedient construction, nuclear and conventional weapons effects, nuclear and chemical explosives excavation, vehicle mobility, environmental impacts and relationships, engineering geology, pavements, protective structures, aquatic plants, water quality, and dredging.

Many WES projects have worldwide significance, while others have smaller scope; but each is a response to the special needs of the American people. The same careful planning and comprehensive study go into each project, whether it serves a small community or the whole Nation.

As part of our 50th anniversary, we invite you, through this history, to share with us some of the highlights of our half-century of research and engineering investigations. This proud past is not, however, the focus of our celebration. Rather, we view this observance as our "Fiftieth Year of Golden Opportunity," and look forward to a future of service to the Army and the Nation.

John L. Cannon

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

THE AUTHOR

Gordon A. Cotton is a native of Mississippi and was born just a few miles southeast of the U. S. Army Engineer Waterways Experiment Station. He holds B.A. and M.A. degrees in American History from Mississippi College in Clinton, Mississippi, and for eight years taught in high schools near Vicksburg. He is Director of the Old Court House Museum in Vicksburg and a former feature writer for the Vicksburg *Evening Post*. He is the author of two previous volumes, *Of Primitive Faith and Order: A History of the Mississippi Primitive Baptist Church, 1780-1974*, and *15 China and Other Tales*, a collection of 20 "Mississippi history stories not found in the average history book." Cotton also edited a photographic study for the Vicksburg and Warren County Historical Society, *Vicksburg Under Glass—A Collection of Early Photographs from the Glass Negatives of J. Mack Moore*.

AUTHOR'S PREFACE

When Congress authorized the establishment of a hydraulics laboratory to help combat floods in the Mississippi River Valley in 1929, some envisioned the facility as one to be constructed on a barge and floated up and down the vast waterway.

Since its beginning half a century ago, the work of the U. S. Army Engineer Waterways Experiment Station (WES) has been expanded into many fields other than hydraulics. Did you see the television pictures of the first lunar vehicle traversing the moon's surface?—it was rolling on tires tested at WES. Remember the Allied invasion of Europe at Normandy in World War II, and the success of the Berlin Airlift during the Cold War?—much of the know-how for the success of those two events resulted from tests at WES. Take a trip across the United States, and you will travel highways constructed better and more economically because of WES technology. And if you visit a public reservoir for a weekend of relaxation and fun, chances are that its dam and spillway were first built in scale-model size and tested at WES.

History is the story of man and his accomplishments, and many achievements, especially in an establishment such as WES, are often highly technical. In telling the story of WES, however, the nontechnical aspects have been accented as much as possible, for scientific and technical data in depth have been provided in the reports published by WES.

Most of the source material for this history came from the files of the Public Affairs Office at WES, and I wish to thank Mrs. Jane C. Cotton and her staff for their help. Also of great assistance were Miss Marie Spivey and Mrs. Elizabeth Garrett of the Library at WES. Providing valuable and constructive criticisms were Dr. Jesse A. Remington and Dr. Charles Walker of the Historical Division of the Office, Chief of Engineers (OCE), in Baltimore, Maryland, and Joseph B. Tiffany, Jr., Fred R. Brown, W. L. McInnis, and G. Brad Fenwick of WES. I am especially appreciative of the efforts of William M. (Billy) Pace at WES for his persistence, assistance, and faith in my ability.

The work performed at WES is exciting to me. I hope I have presented it in such a manner that you will enjoy reading about it.

Gordon A. Cotton
June 1979

ACKNOWLEDGEMENTS

The WES Historical Program is under the direction of the Office of Administrative Services. The Historical Committee is responsible for collecting and screening historical documents and for providing guidance to the author of the WES History. The Committee is composed of:

Mrs. Katharine Mather, Chairman
Dr. Roger T. Saucier
Mr. John N. Strange
Mrs. Jane C. Cotton
Mrs. Edabeth F. Vavra
Miss Marie Spivey
Mr. Ellis B. Pickett
Mr. Cecil D. Burns
Mrs. Dorothy T. Atkinson
Mrs. Mary H. Cunningham

Mr. W. M. Pace, Chief, Office of Administrative Services, served as an ex officio member of the Committee.

Special recognition is due the Editorial Subcommittee composed of Mr. Strange, Chairman, Miss Spivey, and Mrs. Vavra; and the Photographic Subcommittee composed of Mrs. Cotton, Chairman, and Messrs. Pickett, Burns, and Pace.

The cover was designed by Mr. Robert E. McKlemurry. The text was typed and the photo layout was accomplished by Mrs. Elizabeth J. Garrett.

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CHAPTER I: BIRTH OF A NEW ENGINEERING ERA: 1929-1930

During the late summer of 1930, a group of men anxiously watched as water trickled into a meandering trench, gradually filling the recesses of the ditch. Only a few weeks earlier orders had come to the staff of the newly established hydraulic laboratory at Vicksburg, Mississippi, to build a scale model of the Illinois River. Carefully cutting and shaping the loess soil, engineers had calculated and carved the model. Templates had been cut from sheet metal and fitted to the ground; a weir box was built to regulate the flow and the weir calibrated, and then water was turned into the model. Loess soil was good for carving, but the first test had to be satisfactory, for the dirt could not be compacted and recarved.

First hydraulic model at WES

Only a month earlier, Brig. Gen. T. H. Jackson, President of the Mississippi River Commission, had requested the construction of the model in order to establish the limits of backwater on the Illinois River. The U. S. Army Engineer Waterways Experiment Station (WES) was in the construction stages at the time, and many engineers had looked with skepticism on the use of hydraulic models, making the success of the first project even more important. As it turned out, this initial effort at hydraulic modeling was a complete success, and with the information supplied by this first model test, Congress established mile 120 as the backwater limit on the Illinois River.[1]

Though the fledgling laboratory at Vicksburg was something new to most engineers, the idea of using scale models to solve problems had been used for years on a limited basis in other nations. This relatively new science had in reality been pondered for centuries. Archimedes, 200 years before the Christian era, had discovered some of the fundamental principles; and by 98 A.D. Rome was using 250 miles of aqueducts to supply its citizens with water.[2] Yet, scientific treatment of water in motion was basically ignored until the 17th Century when restraining measures were used along the Po River in Italy. Guglielmini was the master of the Italian school of hydraulics; he felt that silt was necessary to the functions of a river—that if solid matter were not in the water, the rushing current would dig into the river bottom.[3] Sir Isaac Newton, in 1686, also made an observation on the subject, writing that "the particles of similar systems will continue to move among themselves with like motions and in proportional times."[4]

Studies were made with scale models in 1787 by a Frenchman, Dubuat,[5] and by an Englishman, Froude, a naval engineer who used toy-sized boats in a tank.[6] But the first to investigate a specific problem by use of a hydraulic model was a Frenchman, Fargue, who in 1875 made a study of the Garonne River in Bordeaux.[7]

It was an Englishman, Professor Osborne Reynolds, who made the first tidal model study in 1885. He constructed two scale models, demonstrating the ability of a model to reproduce the bed configuration of the Mersey estuary. Reynolds produced tidal fluctuations and the resulting ebb and flow of currents, using a sand bed to demonstrate the bed configuration changes. He carried his experiments only to the study of the unimproved channel (without any improvement works by man), and in that sense has the distinction of being not only the first to attempt a model study of tides but also the first to confine his study to the geophysical aspects of the reproduction without carrying the study to include aspects of engineering. The following year, 1886, M. L. F. Vernon-Harcourt continued Reynolds' study of improvement works and also began a study of the mouth of the River Seine.[8]

A visit to a laboratory at the University of Michigan by a German professor before the turn of the century gave the idea of hydraulics science new impetus. Professor Herbert Engels of the Technical College at Dresden observed a Michigan instructor using a glass-sided flume to demonstrate the flow over a weir. Upon Engels' return to Germany, he built a small laboratory in the basement at the college where he taught. The idea was a popular one, and soon Dr. Rehbock had built a laboratory at Karlsruhe and Dr. J. Th. Thijsse constructed one at Delft in Holland where he was professor of hydraulics. In the next few years, shortly after 1900, hydraulics laboratories were established in France, Italy, and present-day Czechoslovakia.[9] In 1904, Rehbock was at Berliner Technische Hochschule conducting experiments relative to the Weser River; the work was spurred by the Prussian government.[10]

The European experiments created interest among some American scientists, notably John R. Freeman, who visited the Dresden laboratory on the eve of World War I. Upon a return visit after the war, he discovered that the laboratory had been completely rebuilt; there were also new ones at Karlsruhe and Delft. Noting the rapid extension of the idea throughout Europe, Freeman began campaigning for the construction of a hydraulics laboratory in the United States, to be established by the Government. He found one Louisiana legislator, Sen. Joseph H. Ransdell of Lake Providence, especially interested, and through Ransdell's influence Senate hearings were held by the Sixty-Eighth Congress in their first session in 1924.[11]

Endorsements came from L. W. Wallace, Executive Secretary of the American Engineering Council which boasted 42,000 members, and from Dr. Elwood Mead, Commissioner of Reclamation, who noted that small-scale experimental work was being conducted at the Agricultural College laboratory in Fort Collins, Colorado, concerning design of spillways at Tieton Dam, Washington.[12]

Probably the most impressive testimony came from internationally respected engineer Herbert C. Hoover, who was at that time Secretary of Commerce. Hoover wrote:

> *I believe that the investigation of river control through model experiments gives promise of important results.... It seems only the better part of wisdom to establish this laboratory which, at a relatively slight additional cost, may yield results of such far-reaching importance.*[13]

Hoover pointed out that flood control was costing a great deal, and that models would not only help to cut costs but would make certain of the results.

On 21 May 1924, Ransdell's committee produced a resolution to

Flood scene in the 1920's, Greenville, Miss.

establish a national hydraulics laboratory. Senate Joint Resolution Number 42 stated:

> *Whereas floods are causing increasing losses along many of the streams of the United States; and*
>
> *Whereas there is a great lack of information on this matter which is of vital concern to the people in various sections of the United States; and*
>
> *Whereas there is disagreement among the best authorities on fundamental practices involved; and*
>
> *Whereas systematic research and comprehensive study of flood control experience and practice in all ages and in all countries promises to be helpful in meeting problems on streams in the United States: Therefore be it*
>
> *RESOLVED BY THE SENATE AND HOUSE OF REPRESENTATIVES OF THE UNITED STATES OF AMERICA IN CONGRESS ASSEMBLED, That a national hydraulics laboratory be established in the District of Columbia, in connection with and as a part of such bureau as the President may designate, for the conduct of research, experiments, and scientific studies in connection with the problem of river hydraulics, and an appropriation of not exceeding $200,000 is hereby authorized for that purpose.*[14]

The resolution made it no further than committee, however, and many proponents of the laboratory were dismayed. Freeman, finding the Corps of Engineers cool to his idea, turned to the Bureau of Standards, which was under control of Herbert Hoover.

It was a tragic flood which finally brought new impetus to the plan for a

The Sprague, with a barge load of 1927 flood refugees laboratory. Flood control had long been a major problem in the Mississippi Valley with local citizens and property owners fighting the periodic deluges with a system of levees during the years before the War Between the States. Congress had authorized surveys of the river and its tributaries in 1819, 1820, 1824, and 1850; but the major interest of the Federal Government had been keeping the channel clear. Snag boats had been authorized on 24 March 1824 with an appropriation of $75,000 for that purpose. But flood control was still in the hands of local levee boards.

The devastations of war had left the channel of the river clogged, and destitute citizens in the Southern States could no longer shoulder the financial responsibility of building levees after 1865. In March 1867, Congress authorized the building and use of dredge boats to keep the channel clear, and on 22 June 1879 Federal commitment to the river problem was made certain through the formation of the Mississippi River Commission (MRC) where civilian and military personnel would work together for a unified system of control.

Work included opening the channel so that by 1907 an all-season passage was available for river commerce. Some revetment work was also undertaken, but the major thrust of effort was toward building levees. Though some warned against such a policy, the "levees only" idea was predominant and generally accepted by the MRC, local levee boards, Congress, and apparently the people of the Mississippi Valley.

From 1896 until 1927 the program was extended, defined, and elaborated on despite warnings that relying solely on levees was inadvisable. By 1926, many felt the problem of the flooding river was solved; but at the same time Major John C. H. Lee, District Engineer at Vicksburg, saw the ominous signs of a disastrous flood such as the Valley had never before experienced. The following spring his fears were confirmed when the rampaging waters washed away the levees and destroyed the theory that they were sufficient to control the river.[15] It was at this time that Freeman persuaded Sen. Ransdell to again assume leadership in the Senate to secure the passage of a bill establishing the laboratory.

In 1928, Ransdell introduced a bill authorizing the construction of a hydraulics laboratory by the National Bureau of Standards in Washington, D. C. The measure passed the Senate and was reported to the House of Representatives where hearings were set before the Committee on Rivers and Harbors for 26-27 April 1928.[16] The proposal came before the Committee while the Corps of Engineers and the people of the Mississippi Valley were trying to clean up after the flood. Maj. Gen. Edgar Jadwin, Chief of Engineers, had little time to prepare a presentation when he was notified that he was to appear before the Committee on 15 May 1928. Many distinguished engineers preceded him in testifying, and they wholeheartedly endorsed the measure. It seemed a certainty that it would pass, for this time it had the backing of President Hoover.

Gen. Jadwin and Col. Ernest (Pot) Graves both favored such a laboratory, but they opposed its location in Washington and its placement under the jurisdiction of the National Bureau of Standards. Both felt that it should be a practical tool, located near the problems requiring solution: on the Mississippi River.[17] Jadwin told the Committee on Rivers and Harbors:

The essential of a hydraulics laboratory which will be capable of dealing with the problems of the Mississippi and the similar great alluvial rivers throughout the country is that it be located on the Mississippi, where experiments can be carried on with the types of alluvium and sediment characteristic of the valley, and where a laboratory force can be in immediate contact with the field forces which are executing the actual river work, and can check its theoretical conclusions against their practical observations. It is an error to think that a few barrels of sand can be shipped from the Mississippi Valley to a laboratory in Washington and made to represent actual conditions.[18]

The Committee had heard charges from some that European engineers were more progressive than those in America, and Jadwin denied the accusation:

> *The exact contrary is the case. The science of river hydraulics in America, both theoretical and practical, as a whole is more advanced than that of any other nation in the world, and this advance is due almost exclusively to the activities of the Army Engineers.*[19]

Jadwin told the Committee members that the Corps, ever alert to new ideas, had gained information from the European laboratories by sending men there to study. Three were already in Europe, and another was preparing to go, he said.

The hearings continued for some time, and discussions included the exact point on the Mississippi River where such a laboratory should be constructed. Some thought that perhaps it could be put on a barge and moved where needed; others wanted it to be built at Lake Providence, La., the hometown of Sen. Ransdell.[20]

Jadwin's testimony had caused the congressmen to defer action until more information could be obtained, and the General lost no time in dispatching two Army engineers to Europe for that purpose. Col. E. M. Markham and 1st. Lt. John Paul Dean left in the late summer and fall of 1928. When the hearings resumed 29 January 1929, testimony gathered by Markham and Dean stressed the need for bigger models than those in Europe because of a difference in problems in America. A hydraulics laboratory needed room to grow with space for outdoor models, the congressmen were told. On 28 February 1929, however, the Committee adjourned without taking any action.[21]

It appeared that plans for a hydraulics laboratory were dead when Gen. Jadwin set things in motion again, issuing a directive to the President of the Mississippi River Commission to establish such a facility. Jadwin's directive was based on authority granted him in Public Law No. 391, passed 15 May 1928 by the 70th Congress. Though the Flood Control Act did not specifically authorize such a laboratory, it did say that whatever steps that were necessary for effective flood control could be taken, and Jadwin deemed the hydraulics laboratory a necessity.[22] He wrote the following letter on 18 June 1929:

> *You are directed to establish a hydraulics laboratory in the Alluvial Valley of the Mississippi at or near Memphis, Tenn.*
>
> *This laboratory will be constructed gradually as information develops as to the needs of such a laboratory. Such apparatus and personnel as have been used and are no longer*

needed at Bonnet Carrè may be transferred to Memphis.

The general conclusion in Europe with reference to hydraulics laboratories is that one should be merely sufficient covered space to accommodate experimental apparatus, which is constructed as it is needed for each problem. There should be a considerable outside level space adjacent for larger experiments. Water supply should be near at hand and plentiful.

Your hydraulics laboratory should develop into a central place for scientific investigation with respect to the Mississippi Valley and its personnel can well conduct experiments and make computations at or for any part of the valley or for any problem. Experiments at the laboratory itself may be needed continuously or intermittently.[23]

President of the Mississippi River Commission, Gen. T. H. Jackson, replied on 20 June 1929:

1. Steps will be taken at once to establish this laboratory adjacent to the shop and depot of the Memphis district.

2. The district officer has been directed to submit subproject with estimates covering the fiscal year 1930.

3. A tentative program for the first study—backwater influence—will be offered for approval in the near future.[24]

Gen. Jackson then informed the District Engineer at Memphis, Lt. Col. F. B. Wilby, of the directive from Gen. Jadwin and requested him to undertake the following:

Take the necessary steps to provide a suitable space for this laboratory in or adjacent to your shop and depot. For the present, all that need be provided is a suitable space and a building of good width and reasonable length. A width of about 60 feet and a length of about 100 feet is suggested. The building should be so located as to be capable of extension to at least 200 feet as needed. The building should be a simple type of galvanized structure.[25]

Studies were made in October and November 1929 to determine the best use of the funds to produce results of any consequences. Four sites near Memphis were under consideration; the east bank area was considered too small, and the west bank was large but was subject to periodic flooding. Plans were all but complete when a telegram to Col. Wilby from Maj. Gen. Lytle Brown, Chief of Engineers, arrived: "HYDRAULICS LABORATORY MAY BE REMOVED STOP SUSPEND ALL CONSTRUCTION WORK ON IT."[26] The headquarters of the Mississippi River Commission was being moved from St. Louis, Mo., to Vicksburg, Miss., and the hydraulics laboratory would be built there, too, Maj. D. O. Elliott, Assistant to the President of the MRC, advised in a letter to Col. Wilby dated 25 November 1929:

1. By verbal orders given on November 16, 1929, the Chief of Engineers directed that the hydraulics laboratory be transferred to Vicksburg with its operations placed directly under this office.

2. Orders have been requested this date for the change of station for Lieutenant Vogel from Memphis to Vicksburg, and on receipt of such orders he should comply therewith with least practicable delay.

3. I have discussed the above with Lieutenant Vogel, and he understands that the work of the establishment of the laboratory will continue and that he will make such trips to Vicksburg as may be necessary, pending his change of station.

4. You are hereby directed to submit the subproject for the establishment of the laboratory at Vicksburg in accordance with such general plans as Lieutenant Vogel may submit to you.[27]

As early as 13 October 1928, just a short time after the construction of a hydraulics laboratory was authorized, some had realized that Vicksburg was a potential site, for Maj. John C. H. Lee made such an observation on that date.[28]

A subproject for allotment of funds was submitted by District Engineer Wilby at Memphis on 19 August 1929 and was approved by the Chief of Engineers on 26 August 1929. It included $300,000 for "constructing and equipping the necessary initial structures," those expenses consisting entirely of salaries.[29] Provision was not made for the purchase of land.

In Vicksburg, a search was on for an appropriate site for the new laboratory, and the final report on 9 December 1929 suggested the Durden Creek area, which was then about four miles south of the city on land which had once been owned by Vicksburg's first dentist, Dr. Foster Lightcap, who lived there before 1860. During the Siege of Vicksburg in 1863, Gen. U. S. Grant had used the Lightcap home, Magnolia Hall, for a temporary headquarters.[30]

The new Chief of Engineers, Gen. Lytle Brown, approved the site and wrote:

An experimental and research force, with the necessary personnel and equipment, should be set up at once and expanded according to need. The director of same should operate directly under the Division Engineer.[31]

Purchase of the land was approved by the Secretary of War on 14 February 1930,[32] and immediate payment was authorized by the Attorney General on 29 August 1930.[33] In later years, a Vicksburg attorney who helped handle the land transaction, Alex J. Brunini, recalled the events:

In 1929 I was a young lawyer just out of law school, having been admitted to the Bar in June 1929 and became associated with my father's law firm consisting of himself and Mr. J. K. Hirsch. It is my independent recollection that it was shortly thereafter that Lieutenant Vogel, now Gen. Vogel, made contact with either Mr. George Williamson and the First National Bank & Trust Company of this city or with our Mr. J. K. Hirsch. I do not know which one had the original contact, but it soon got on my desk that the Government was desirous of establishing the station here in Vicksburg and that the Government was willing to pay $4500.00 or thereabouts to the property owners, and it was necessary for someone to supplement that amount in order to satisfy the property owners who were required to furnish an abstract to the Government out of the purchase price and also to satisfy the property owners in the original purchase for the amount for which they were willing to sell.

It was my understanding at the time that $1,000.00 was all that was needed, but that no one knew what final cost of the abstracts would be. At any rate, George Williamson obtained the consent of several individuals who guaranteed to put up the $1,000.00. The names of the guarantors I do not know. I am sure, however, that Mr. J. K. Hirsch and Mr. George Williamson were two of the guarantors.[34]

Williamson, who was President of the First National Bank of Vicksburg, wrote to Hirsch on 18 April 1930:

At a meeting held this morning at the Chamber of Commerce, it was decided that we undertake to secure from the Advertising Fund of Warren County the $1,000 necessary to reimburse the guarantors in connection with the subsidy to property owners for the balance of the purchase price of the property on which the Hydraulics Laboratory is to be constructed by the Government.

I take it that the account under which this fund is created gives the Board of Supervisors rather broad powers as to how the money may be spent. It was thought, however, that the legal phase of the matter should be investigated before it was presented to the Advertising Committee in control of the fund, as well as the Board of Supervisors. I can imagine no better use to which the money may be put than in meeting just such a proposition as this. Certainly it is worth more than $1,500.00 which was thrown away to the Baseball Club of Vicksburg.

If you will look into this some time at your convenience during the next four or five days, I will then get these various committees together and see if they cannot get support in order that it may be presented to the Board of Supervisors at the May meeting.

In the meantime, if the deeds come back from Washington approved and it is necessary to go ahead and close the matter, the bank will put up the money and hold it until it can be recovered. I might add that the Merchants Bank has verbally agreed to join with us in this matter.[35]

Hirsch wrote to Williamson on 25 April 1930 quoting state laws concerning powers of Boards of Supervisors, concluding:

I can conceive of no construction of the statute warranting the Board of Supervisors of this County in appropriating any sum out of its advertising fund, worthy though the purpose may be, in paying a part of the purchase price for the hydraulics laboratory.[36]

Who finally paid the $1,000.00 is not disclosed, but according to Brunini's files, the transactions for the acquisition of the property were completed and final deeds delivered in August 1930. The law firm was paid $358.65 as settlement for legal services "in connection with the transfer of property from various owners to the United States Government for use of Hydraulics Laboratory..." and was paid by the Chamber of Commerce.[37] The establishment of the laboratory at Vicksburg was finalized 13 February 1931 when Mississippi Gov. Theodore G. Bilbo wrote to Major D. O. Elliott at the MRC stating that he had prepared the proclamation ceding jurisdiction of lands in

Warren County to WES.[38]

There were few engineers available for work at the new hydraulics laboratory. New appointments in civil service were prohibited by law because of the depression, and the Vicksburg District, Corps of Engineers, could spare little manpower because of a major flood control construction project under way. In addition to the manpower limitations, all salaries had been cut because of the Nation's shaky economy.[39]

Lt. Herbert D. Vogel, the man sent from Memphis to set up the laboratory and get it functioning, had been in Germany where he had studied hydraulics. At age 29, he had returned to the United States just in time to be assigned to the Vicksburg task.[40]

Prior to the land purchase, the Vicksburg District assigned James G. Jobes, a young junior engineer just recently graduated from the University of Michigan, and Isham H. Patty, an assistant engineer with a basic education in pharmacy, to WES. William Willingham Woods of Washington, Ga., a recent graduate of Georgia Tech, transferred from the Vicksburg District as a junior engineer and there were one or two others. Laborers consisted of college graduates working for $100 a month or unskilled men at $65, both less 15 percent.[41] But youth was an asset, not a hindrance. Vogel wrote in later years:

> *The silver lining of this cloud was that during its formative years the Experiment Station gained a staff of young, brilliant engineers, who were willing to undertake any task, whatever the challenge. None had lifetime theories to uphold, and any one of them would have been glad to prove Sir Issac Newton wrong. All were iconoclasts in that sense.*[42]

Such spirit was necessary to instill life into the new facility. Soon a dam was built and water was being caught with each rain; a building, emblazoned with an engineer castle over the main door, served as a workshop and office. Costs were far above those anticipated—$122,000 instead of $50,000—but Brig. Gen. T. H. Jackson, President of the MRC, and his assistant, Major P. S. Reinecke, had become extremely interested and requests for additional funds were approved.[43]

Construction of the dam was begun 1 May and completed 14 October 1930, and during the same summer the first buildings were erected. Preliminary design of the dam was made by F. G. Christian and final design was by P. E. Cunningham, associate engineers. The buildings were erected by the Vicksburg Shop, and the preliminary designs, drawn by a Memphis architect, were completely revised and inspected by Jeff Posey, assisted on the inspection by Lloyd W. Hamilton, who was also inspector for the dam. Fred P. Johnson was Construction Supervisor and Overseer, and John H. Kurrasch was Assistant and Resident Engineer.[44]

The U. S. Army Engineer Waterways Experiment Station was born out of strife and the tragedy of the 1927 flood and was designed to meet a unique need. Since 1930, thousands of models have been constructed and tested by WES, and the hydraulics laboratory has branched out into many different fields of scientific and engineering research. Projects have aided mankind in peace and in war, have benefited governments and private enterprise, and have resulted in untold millions of dollars of savings for the taxpayers. Sophisticated and highly technical equipment has replaced the crude implements that were first used, and

Early photograph of WES dam and lake

Construction of Headquarters building, 1930

Completed original building

military and civilian personnel have invented and perfected many new products and tools.

At WES a new era in engineering was born.

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1. Herbert D. Vogel, "Origin of the Waterways Experiment Station," *The Military Engineer* (March-April, 1961), p. 134.
2. J. P. Kemper, *Rebellious River* (Boston: Bruce Humphries, Inc., 1949), p. 33.
3. Ibid., pp. 33-34.
4. Lloyd William Taylor, *Physics, The Pioneer Science,* Houghton Mifflin Company, Boston, Massachusetts, 1941.
5. J. M. Caldwell, from a paper presented before the National Bureau of Standards, Sept. 13, 1939, p.2.
6. Dallas *Times Herald,* June 28, 1954.
7. Caldwell paper, p. 2.
8. Ibid., p 2.
9. Vogel, "Origin," p. 132.
10. Ibid., p. 132.
11. *National Hydraulic Laboratory Hearings* (Washington: Government Printing Office, May 24, 1924), p. 1.
12. Ibid., pp. 1, 7.

13. Ibid., p. 4.
14. Ibid., p. 1.
15. Albert E. Cowdrey, *The Delta Engineers* (New Orleans: Corps of Engineers, 1971), pp. 2-32.
16. Vogel, "Origin," p. 132.
17. Ibid., p. 133.
18. *National Hydraulic Laboratory Hearings,* 70th Congress, First Session, House Committee on Rivers and Harbors (Washington: Government Printing Office, 1928), p. 64.
19. Ibid., p. 68.
20. Ibid., p. 79.
21. Vogel, "Origin," p. 133.
22. Ibid., p. 133.
23. Letter from Major Gen. Edgar Jadwin, June 18, 1929, Washington, D. C. On file in WES archives.
24. Letter from Gen. T. H. Jackson, June 20, 1929.
25. Claude C. Lee, *Events Leading to and History of Establishment of the U. S. Waterways Experiment Station* (Vicksburg: WES, Sept., 1938), Appendix J, p. 8.
26. Ibid., p. 9.
27. Letter from Major D. O. Elliott, Nov. 25, 1929, St. Louis, Missouri. On file in WES archives.
28. Vicksburg *Evening Post,* Oct 13, 1928.
29. Lee, *Events,* p. 8.
30. Vogel, "Origin," p. 134. Dr. Lightcap came to Vicksburg from Pennsylvania in the late 1830's. His successful practice enabled him to purchase a farm outside the city, and he named the home he built there Magnolia Hall. It stood on the site of the present Administration Building. Dr. Lightcap died before the War Between the States, and his wife and daughters were living at Magnolia Hall when it was used temporarily by Gen. U. S. Grant as headquarters in 1863. Descendants of Dr. Lightcap still owned much of the land when it was purchased for the hydraulics laboratory. Information about Dr. Lightcap was supplied by V. Blaine Russell, eminent local historian and journalist.
31. Ibid., p. 134.
32. Brig. Gen. H. D. Vogel, "Genesis of the Waterways Experiment Station" (1962), unpublished manuscript in WES archives, p. 10.
33. Postal telegram from Gen. Lytle Brown, August 29, 1930, Washington, D. C. On file in Wes archives.
34. Vicksburg *Evening Post,* June 17, 1969.
35. Ibid.
36. Ibid.
37. Ibid.
38. Letter from Gov. Theodore G. Bilbo, Feb. 13, 1931, Jackson, Miss. On file in WES archives.

39. Vogel, "Origin," p. 134.

40. Dallas *Times Herald*, June 28, 1954. In later years Vogel said he picked the Durden Creek site because "It looked like a good place to build a lake, and with space below the dam for our models." One of his favorite stories concerned the dedication of the bridge across the Mississippi River at Vicksburg in the early 1930's. He was named as a judge of the floats in the parade, along with Mrs. Charles Schweizer and Mrs. Charles Senour. Vogel said that he "saw the Ole Miss float with a lot of pretty girls, and with persuasion convinced Mrs. Schweizer and Mrs. Senour that it was the best. I wrote down the number 16 and handed it to the master of ceremonies." The MC turned the paper upside down and called out number 91 as the winner. Vogel said, "I had no idea what 91 looked like" and he grew panicky. But when 91 appeared, fate was on his side: it was a buggy with two cute little old ladies carrying the Confederate flag. The young Michigan officer said that he was "a true Southerner from then on." The story appeared in the Vicksburg *Evening Post*, June 18, 1969, when Gen. Vogel was visiting the Lab during its fortieth anniversary celebration.

41. Vogel, "Origin," p. 134.

42. Ibid.

43. Ibid.

44. "Beginning of the Waterways Experiment Station," *Vicksburg Engineer District Magazine* (Dec. 25, 1930), p. 41.

CHAPTER II: FLOODS IN MINIATURE: 1931-1940

Success of the Illinois River model gave added impetus and enthusiasm to the plans of the young engineers at WES, and they soon tackled a much more involved model—the Lower Mississippi River. Determining the reaches of the backwater of the Yazoo River was a primary concern, and much of the overflow was caused by the rampaging Mississippi.[1]

Even though WES engineers were confident of the worth of models, the idea was still unproved in the minds of many others, who skeptically considered such models to be a waste of time and money; therefore, expenditures had to be kept at a minimum.[2] For the model built to study the Mississippi backwater in the Yazoo Valley, a concreted area was planned as the model would be used many, many times and a natural loess soil riverbed such as was used in the Illinois River project would not suffice. After long hours of consideration, the model scale was selected to be 1 to 2400, an even multiple of 12; this was chosen for convenience in plotting (graph papers available at that time were divided into 12 increments per major division).[3]

From the beginning, engineers had realized that European ideas would not always apply to American problems. Europeans used a scale of 1 to 300, and their principles in the matter of distortion would not apply to a model constructed to portray the Mighty Mississippi. Measurable depths and proper characteristics of flow could be obtained only with a vertical scale of at least 1 to 120, so a 20 to 1 distortion was chosen.[4]

A model of the Lower Mississippi, designated the "Mississippi Flood Control Model" or the "Helena to Donaldsonville Model" but usually referred to as "Old 94" (from job number 94), was begun in the early 1930's. It gave engineers not only a

"Old 94"; guide is pointing out the portion of the model used in tests to prevent capture of the Mississippi River by the Atchafalaya River

view of an immediate problem, such as a river bend, but also an overall observation of the Mississippi Valley. Completed by 1935, it reproduced 600 miles of the river in 1,100 feet; 16,000 square miles had been reduced to an area of less than 2 acres.[5]

Seeing the model for the first time was described as "like looking through the wrong end of a telescope," and visitors said it was reminiscent of "Gulliver's Travels" where everything was reduced in size: they could step across the Mississippi at its widest point, hills and dams fit under their insteps, and the current of the Father of Waters seemed a mere ripple.[6] Everything was there in miniature—levees, tributaries, bridges, swamps, and forests, even the willow thickets. The model required intensive study and research, and when completed every sandbar, every miniature clump of willows, and every prominent terrain feature had its place and its reason for being there. Forests and thickets were simulated by galvanized screen, turned upright in an exact pattern determined from aerial photographs.[7]

It may have looked like a toy to visitors, but the model was a valuable tool for hydraulic engineers. The flood of 1927 was duplicated, and by taking the river readings for any given day in the past, the model could be activated to represent that particular time.[8] A crew of 18 men was needed to operate the model and read its 210 gages. A day's rise and fall on the river could be reproduced in 5-1/2 minutes, and the 1927 flood that sent the river rampaging out of its banks for five months could be recreated in 14 hours.[9]

The practical purpose of the model was to test the effects of possible improvements along the river. Would a levee of a certain height be sufficient to protect an area from a flood such as occurred in 1927, assuming that all levees held? If a cutoff were made in a certain bend, what would be the effects on flood heights and flood duration? Would the backwaters be raised or lowered? It would be much cheaper to make an experimental cutoff on the model for a few dollars than to spend a half million on the prototype without knowing what the results would be.

Roughness was the real secret of the accuracy of the model, according to Lt. Paul Thompson, Director of WES in 1937, who said that "'Roughness' means trees and foliage on the overbanks of the river which retard the flow of the water." [10] Thompson added:

> *Verification is a matter of a month. The model is molded to conditions of a given year—say 1935. We know what the various gage readings were. Our problem is to adjust the model for "roughness" until the same gage readings are obtained as existed in 1935. When the gages are in adjustment, "roughness" has been overcome.*[11]

Prior to construction of what was then the world's largest model, engineers could only test their theories when there was a disastrous flood.

Lt. F. H. Falkner, Director of WES in 1936, explained the value of the models when he said:

> *It may require $100 to build model dikes here that would cost many thousands in the field. Having been tested out in these experiments, river improvements can be undertaken with confidence that the desired ends will be secured.*[12]

The model river was taking the guesswork out of levee construction and work in general along the mighty stream.

Though engineers could read blueprints as readily as a musician reads the score of a symphony, seeing their brainchild in miniature was just as important for them as it is for a composer to hear his new score performed. The model proved the soundness of new theories, verified some old ones, and corrected and refined others.

As the river model was being built, other construction was also under way, including necessary shops and buildings.

Work was also begun on studies such as the river bends at Greenville, Miss., where the river coiled back in a series of eight loops, looking like a slithering, sidewinding snake on a map of the area. Continually, the rushing waters shifted the banks, enlarging some curves, shortening others; and in 1931, erosion was working toward cutting through a narrow neck of land.

What would happen when the water finally cut through? Should a dike which might cost almost a half million dollars be built? And if built, would it do the job engineers envisioned? Two years earlier, no answer would have been available. But with the newly established WES ready to study the problem, finding answers was relatively easy. WES personnel reproduced every bend of the Greenville problem in miniature, every variation in slope of the bank and contour of the river bottom, every shoal and deep, every narrowing of the channel, and every widening of its course.

The model of the Greenville Bends was 49 feet long and cost $1,500 to build—a lot less than the half million dollar dike that the model proved unnecessary.[13] As water was turned into the model, it flowed leisurely like a creek at some places and rushed swiftly at other spots where a deeper stream and narrow banks speeded

Greenville Bends Model

up the flow. In miniature, the banks eroded in some places, shoaled in others. An engineer spurted some red aniline dye into the water; the progress of the water downstream, forming eddies in some places, becoming almost stagnant in others, was vividly demonstrated.[14]

While engineers studied cutoffs on the models, plans were made to construct a full-scale cutoff on the river. The Mississippi River often cut through narrow bends and shortened itself, but when it was announced that engineers would shorten the stream by 10 miles with a man-made

Diamond Point Cutoff

cutoff in 1933, some felt that to make a cutoff in one place would result in a new channel in another. The river had always been the same length, they said, and forming an unnatural cutoff would be "robbing Peter to pay Paul."[15] But on 8 January 1933, Gen. Harley B. Ferguson blew the plug that opened Diamond Point below Vicksburg, the first man-made cutoff on the Mississippi in almost a century.

Only two cutoffs had been previously perfected by man. Capt. Henry Shreve made the first in 1831 near the mouth of the Red River; the second, the Raccourci cutoff, was made a few miles downstream from the first cutoff in 1848.[16] Twenty-one cutoffs are known to have been made between 1700 and 1933—only three of them man-made. Engineers had been able to only speculate about the effects until WES made it possible to know the results ahead of time by use of scale models.

At Diamond Point, 15 miles downriver from Vicksburg, the channel of the Mississippi made two long bends around Davis Island, a distance of 11 miles. By cutting through the peninsula and diverting the main flow of water, the river could be shortened by 10 miles.

Actual work began in October 1932 when two big suction dredges were brought from New Orleans. They worked from opposite ends of the proposed channel toward the middle, where they left a 50-foot-wide strip of land, or "plug." Mud from the channel was piled back from the banks several hundred yards on both sides. When the plug was dynamited on the morning of 8 January 1933, water on the upper end was 0.4 to 0.8 foot higher than on the other end. The wedge-shaped channel had been dug 150 feet wide at the base and 300 feet wide at the top, though in some spots caving of the riverbanks had widened it to 500 feet. Engineers speculated that the rushing current would eventually widen it to a mile.

Gen. Ferguson of MRC and his party, which included Lt. Herbert Vogel of WES, departed from the Vicksburg waterfront at 8 a.m. on 8 January 1933 aboard the steamer *CONTROL,* which was pulling a quarter boat. Upon arrival at Diamond Point, they found everything ready for the blast. Several hundred pounds of dynamite had been sunk into the plug about 15 feet below the surface and packed with dirt. It

Men at Diamond Point Cutoff, 1933

took four blasts to open the channel. The first was set off at 11 a.m. A great geyser of earth and mud was sent at least 100 feet into the air, but the charge was not enough to allow the water to flow through. Another charge was detonated half an hour later, and then a third charge. Workmen with shovels then aided the water on its first trickle through, but it took a fourth charge to complete the job.

At first, the trench was only a foot or so in width, but the rushing waters quickly tore away at the banks, causing the spectators who had crowded near the edge to get out of the way quickly as more and more of the earth sloughed off into the current. Within an hour, the crevasse was 60 feet wide.[17]

The Diamond Point cutoff was the first of 15 constructed after careful testing at WES. Studies had been started in 1930 at WES for the MRC and were made to determine what effects the cutoff would have on navigation, backwater, channel shortening, and lowering of flood heights. It was found that benefits would be significant; navigation would be facilitated and local flood heights would be considerably lowered. It was predicted that in the Yazoo basin, the water would be lowered from 1 to 6 feet, depending upon the stage of the river, and in Vicksburg water levels would be about 4-1/2 feet lower for a stage comparable to the flooding in 1929.[18]

Twenty years later, in a return visit to Vicksburg, Gen. Ferguson, a man described as having a "wiry physique and a barbed tongue,"[19] recalled the opposition to that first cutoff at Diamond Point as "a lot of hot air."[20] Gen. Ferguson said:

> *It was a natural. The cutoff had to work. At 11 o'clock on the anniversary of the battle of New Orleans, a stone's throw from Jefferson Davis's Palmyra Island home, and a cannon shot from Grant's Hardscrabble camp—it was a crapshooter's natural.*[21]

Eventually, 151.8 miles were trimmed from the river with the 15 cutoffs between Memphis, Tenn., and Angola, La. Each had been tested in miniature at WES, and the success of each was a certainty.[22]

Not all problems on the river could be solved with cutoffs and levees, of course—often efforts had to be made to keep the Mississippi River in its proper place, and studies included the effects of revetment work and dredging.

Another project on the Mississippi River concerned the Bonnet Carré Floodway, constructed in South Louisiana before WES was established. It was an escape route over which high water could take a short cut to the Gulf of Mexico, relieving the strain on the Lower Mississippi. On each side of the spillway were levees nearly 7 miles long, made by scooping up the soil from the bed of the floodway and piling it up along the banks. The earth, taken from its bed, left pits and depressions where two trunkline railroads had rights-of-way across the floodway. Railroad engineers worried about what would happen to the trestles when the river overflowed and the floodway itself became a raging torrent. They were afraid that the deep borrow pits would accelerate the flow of water, also speeding erosion and undermining the trestles.

An outdoor model of the floodway was made, and all the details were reproduced to scale—borrow pits, railroad trestles, trees, and thickets. Even dirt from the floodway was brought by truck

Construction of Bonnet Carré model

200 miles to the laboratory at WES so that actual soil conditions could be reproduced. Numerous experiments were run on the model, showing that erosion would not occur and that the trestles were safe.[23]

There were problems other than those along the Mississippi River waiting to be solved, and one which WES engineers tackled was the flooding that had inundated Johnstown, Pa., 23 times in a century. Channel improvements at Johnstown were planned in the fall of 1937 following the devastating flood of the preceding year. A preliminary survey was studied by Joseph B. Tiffany of WES to determine if a scale model would be feasible. Tiffany explained to Johnstown officials just how the model would work: first the river channels would be modeled in the condition in which they existed before the 1936 flood; then they would be calibrated, with water flowing through the miniature channels in order to reproduce the exact volume and flow of the flood. Subsequently, the channels in the model would be changed to reproduce them as they would be after improvements by the Army Engineers so that studies could be made of their effects on floods of various sizes.[24]

Johnstown residents were anxious that something be done. Their city had become famous because of the floods, the first occurring in 1833 when Stony Creek and the Conemaugh River, converging in the center of town, had risen 27 feet above flood stage. The most disastrous flood had happened on 31 May 1889 when the South Fork Dam broke; over 2300 people died and property damage was in the many millions of dollars. On St. Patrick's Day, 1936, the waters rose to 20 feet above the riverbanks, 15 people drowned, and damage amounted to more than 42 million dollars.[25] Johnstown citizens were willing to put up two million dollars of their own money to see that something was done.[26]

A reservoir control project was planned, but it was proved not feasible. That's when WES began model tests. Hundreds of trials were made in Vicksburg, and they showed that the streams could be controlled by deepening and widening the channels. In 1938, the work was started; then the War stalled it. However, in January 1944 Johnstown faced the spring thaw with confidence; the improvements had been completed.

Beginning in August 1938, U. S. Army Engineers, basing their work on the model specifications from WES, began widening and deepening the river and creek. Cost was $8,670,000; 2,989,333 cubic yards of dirt were moved, and 156,631 cubic yards of concrete were used in realigning, enlarging, and paving to dimensions determined in the model tests in order to keep the streams within their banks. It was estimated that the dirt, if piled in a heap, would be 200 feet higher than the Empire State Building; and the concrete used would build a 62-mile highway.[27] Considering the cost of past floods, the money and time were well spent at Johnstown. And by using the facilities at WES to test their ideas, engineers were able to eliminate any guesswork and unnecessary costs.

The Johnstown project was just one of several hundred tested by WES before World War II; the worth of the institution had already been proved many times, and yet not everyone was aware of the importance of the work. A Mississippi Congressman, for example, received a letter from a constituent wanting to know if "that place outside Vicksburg where men

Model used in studies of Johnstown flood control project

sit around on boxes and watch water run through ditches is an old soldier's home."[28]

Local residents soon shortened the name from Waterways Experiment Station to simply "The Lab" or less frequently "The Waterways," "The Pipe Shop," or "The Station." Not until after World War II was it referred to generally as "WES."

Just as it was a new facility, so the science of hydraulic engineering was new; and many problems were encountered because of the magnitude of the prototype rivers which were to be modeled. A need for new methods and materials was soon evident, and when instruments were lacking, substitutes were improvised. This resulted in new discoveries and inventions, including the Bentzel tube, later commercially produced to measure low-velocity flows.[29]

Much of the administrative work in those early days was handled by the MRC in Vicksburg, and Chief Clerk at the MRC, R. N. Duffey, had to approve all requisitions. One day Duffey called WES, greatly annoyed. He reportedly said:

> *I've handled all kinds of requisitions for you men out there, and I have never complained. I've bought confetti, potassium permanganate for dye, soft coal, sand and gravel, and even oats, but when you send me an order like the one I have here, I have to object. I'm not going to*

have the Comptroller General asking me why I submitted a requisition for half a dozen breast pumps.[30]

When Duffey had cooled a bit, it was explained to him that the pumps were to be used to draw water up in manometer tubes, but it is doubtful that he was ever completely convinced.[31]

Soon after WES was established as a hydraulics laboratory, it became evident that it would be feasible to organize the work into sections or groups. More than 65 different problems had been studied in the first two and one-half years of operation, a fact which illustrates the necessity for such organization.[32] The first WES organization was formulated in January 1931, consisting of three groups with coordinators supervising each—the Hydraulics group, the Sediment group, and the Soils group.

The volume of work and its diversity grew so rapidly that by October 1932 two independent hydraulic sections, one to handle fixed-bed models and the other movable-bed models, were established; this plan was abandoned the following January, however, for functional subdivisions were needed. Each group was assigned specific problems, and the group leader was responsible for and actually performed all work of design, construction, and operation of each of his models. In addition, he was required to handle all necessary correspondence, complete his own drafting, and write his own reports.

Three functional sections, plus a separate Construction Section, were established in January 1933. The Construction Section was a service unit designed to free the technical units from the burden of construction details. Also established was an Administrative and Reports Section, formed to provide clerical and drafting services, although the technical units continued to perform most of this work themselves.

In September 1933, the three following sections were established: Experiment, Research and Publications, and Operations. The Operations Section took over all service functions, including construction, administration, and the soils laboratory. The Experiment Section, divided into three groups, was charged with designing and operating its models—fixed-bed, movable-bed, and tidal.

The Research and Publications Section conducted technical experimental research pertaining to WES work programs and edited all reports that had to be published.[33] It was at this time that the format for such reports was drawn up, a format that has continued in use until the present.[34]

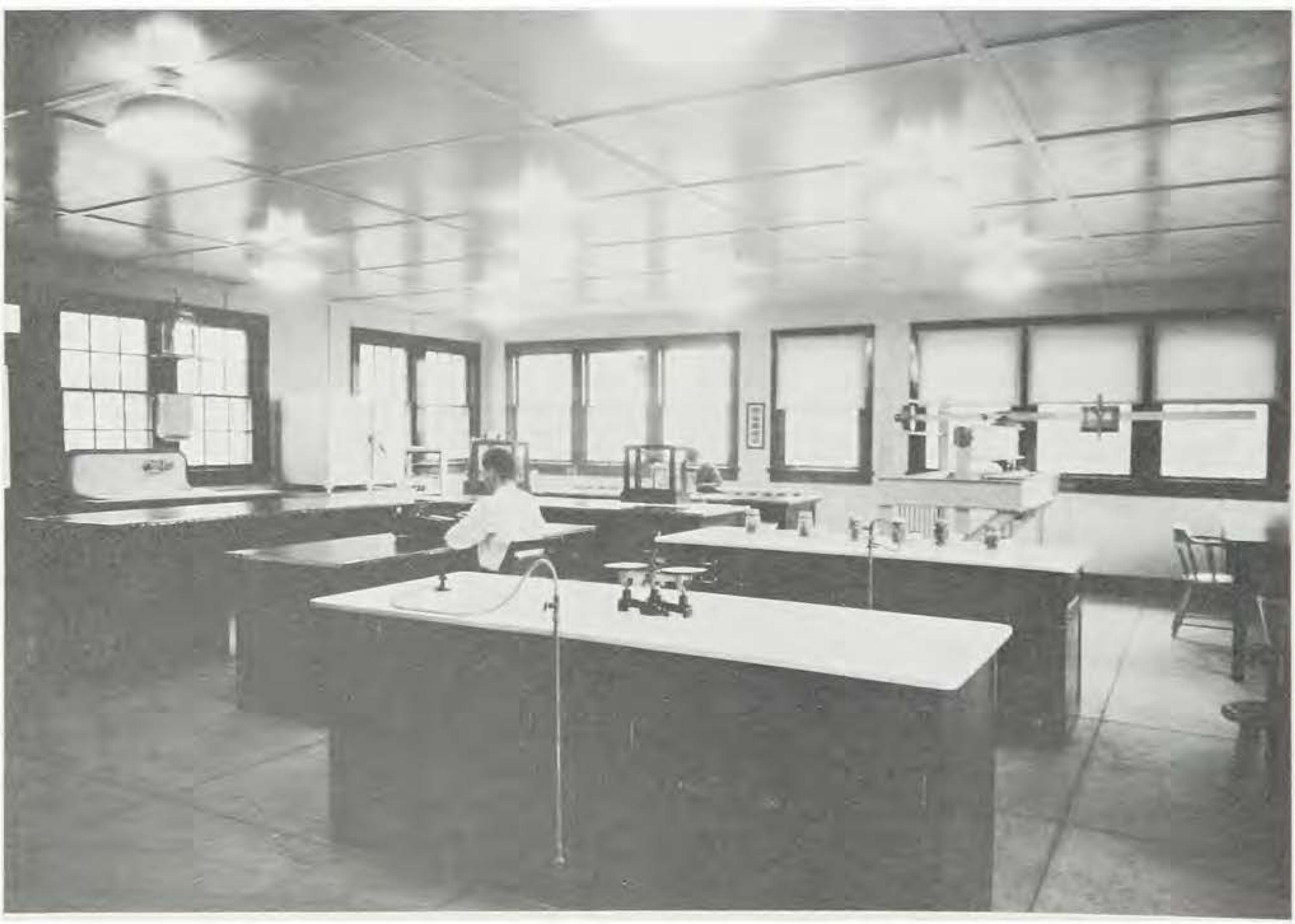
Further reorganization was accomplished on 4 November 1935 when Director Lt. Francis H. Falkner abolished the hydraulics Experiment Section's "group" arrangement and established a "project engineer" system in its place. Under this setup, project engineers were designated, each being assigned to a single model project for which he was responsible, reporting directly to the Assistant Director or Director of WES. Other personnel were placed in a pool of assistants, and project engineers made requisitions daily from that pool according to the needs of their projects.

The project engineer idea was abandoned under the directorship of Capt. Paul W. Thompson, who was Director of WES from July 1937 to September 1939. He planned a Hydraulics Division, but it didn't get off the drawing board at the time. Thompson wanted the

Division to be subdivided into three sections—one concerned with tidal models, one with hydraulic structures models (both would handle some river models), and a third concerned only with the large Mississippi River model which reproduced the river from Helena to Donaldsonville. In October 1939 Capt. K. E. Fields, Director of WES from September 1939 to December 1941, implemented the division plan.[35]

Another early organizational element at WES was the Soils Laboratory, which had its origin in 1932 when a small group of men began to make grain-size analyses of samples of bed load and sediment taken from the Mississippi River. Although the Soils Division as such did not come into existence until 1939, its work was carried out by sections and groups on a part-time basis. Spencer Buchanan was placed in charge of the soils work in late 1933, giving it the status of an organizational element rather than a sideline effort.

As the Soils Division responsibilities increased, the staff was enlarged and in 1934 a 40- by 60-foot frame building was erected to house the work. There were no textbooks available on soil mechanics, and virtually all soils literature came from foreign publications and pamphlets, basically German and Swiss, and had to be translated by the Research Department. The staff of the Soils Research group increased until in the 1936-37 era it included a laboratory section and a research center. The laboratory section was



Early Soils Laboratory

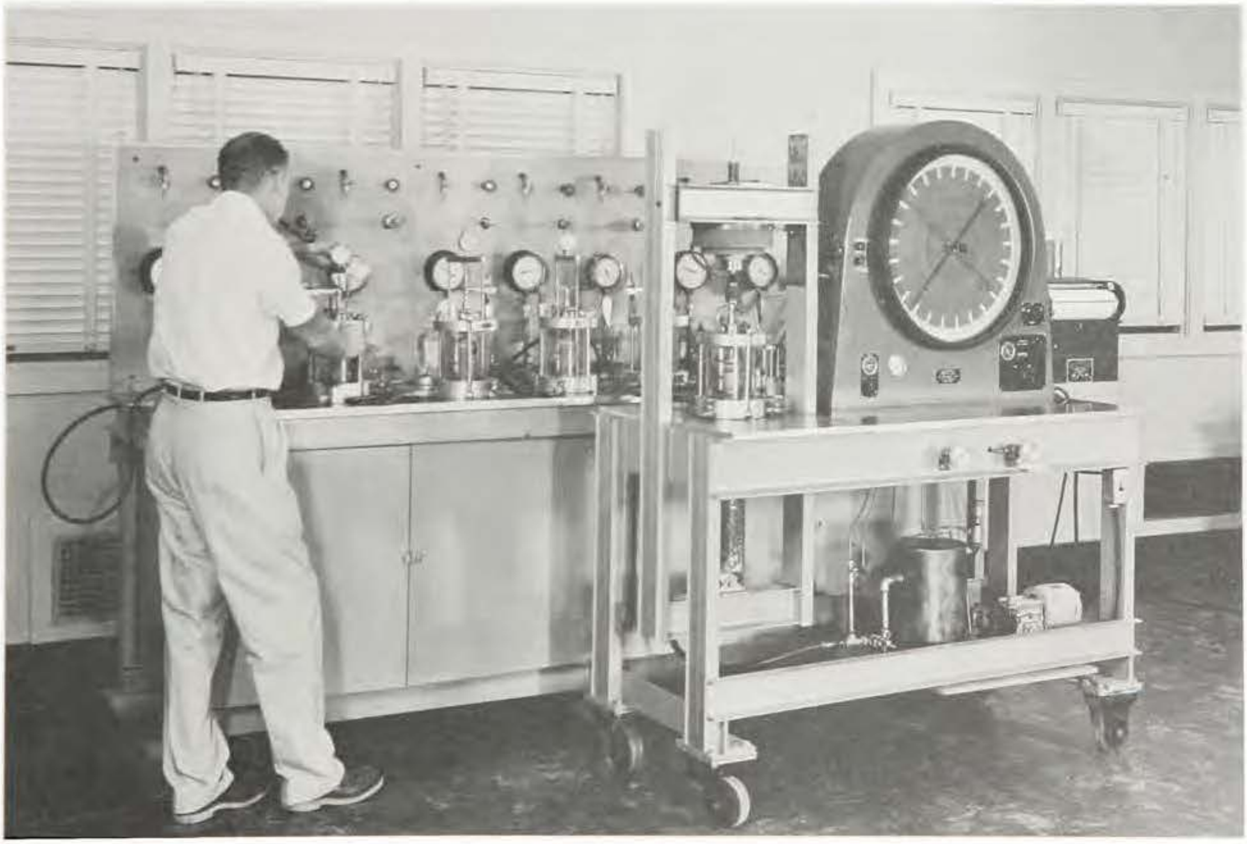
equipped to perform sieve analyses and simple chemical tests as required. It was the only Corps of Engineers soils laboratory, and tests for branches other than those at WES became routine.

Work outside the Soils Division came about when a truck-mounted drill rig was obtained for field work. Soon much assistance in design problems was provided by the field crew in addition to the already established field and laboratory work.

Typical of the work was that performed in 1939 when a levee near Pendleton, La., was built by the Vicksburg District, Corps of Engineers. In one place where construction was planned, the bed was soft clay, and it was evident it would not support the weight of the levee; the clay would have to be replaced in some manner. Soils Division engineers, after running appropriate tests, determined that the weight of the levee, overbuilt through the area of soft clay, would displace the soft material by its weight. This deliberate foundation failure was observed and studied; the result was the verification of the wedge method of stability analyses.

Another study undertaken was for the California Debris Commission when an investigation was initiated to establish the lateral pressure exerted by mining debris on impounding structures. In the study, the lateral forces against a vertical surface during placement and consolidation of debris were measured.

Another first for the Soils Division was the building of a machine for triaxial tests in 1938. Made of brass in the WES shops, it was developed from a design by Prof. Arthur Casagrande to test a sample 1.4 inches in diameter. The machine



WES–built triaxial test apparatus

attracted a great deal of interest because the volume change in a sand specimen could be readily observed by means of a manometer connected to the interior of the saturated specimen.

Testing for the construction of Sardis Dam in North Mississippi, a hydraulic-fill structure, necessitated the shops at WES to practically go into mass production of triaxial test machines, for other laboratories also needed such equipment. The machines were also used on a seven-day, double-shift basis in tests involving reconstruction of the Fort Peck Dam after a massive slide occurred there in September 1938. Many of the machines were sent to Fort Peck for on-site testing, supervised by WES personnel.

It was necessary to observe prototype structures to determine if they were performing as expected, and this required the development of suitable instruments such as hydrostatic and earth pressure cells. A major contributor to the design of the WES pressure cell was Dr. J. O. Osterberg; R. A. Ford and W. H. Rodgers were instrumental in developing machining and welding techniques for the construction of the pressure cells, and when the first ones were made, no resistance gages were available. The gage wire was bought on spools and the gage actually built on the metal of the cell with glue, tweezers, handrests, and magnifying glasses; the gage was then covered with bakelite and baked.

An additional achievement of the early Soils Division was the use of seismic and electrical resistivity tests to investigate damsites, notably those in the Arkansas Ozarks.[36]

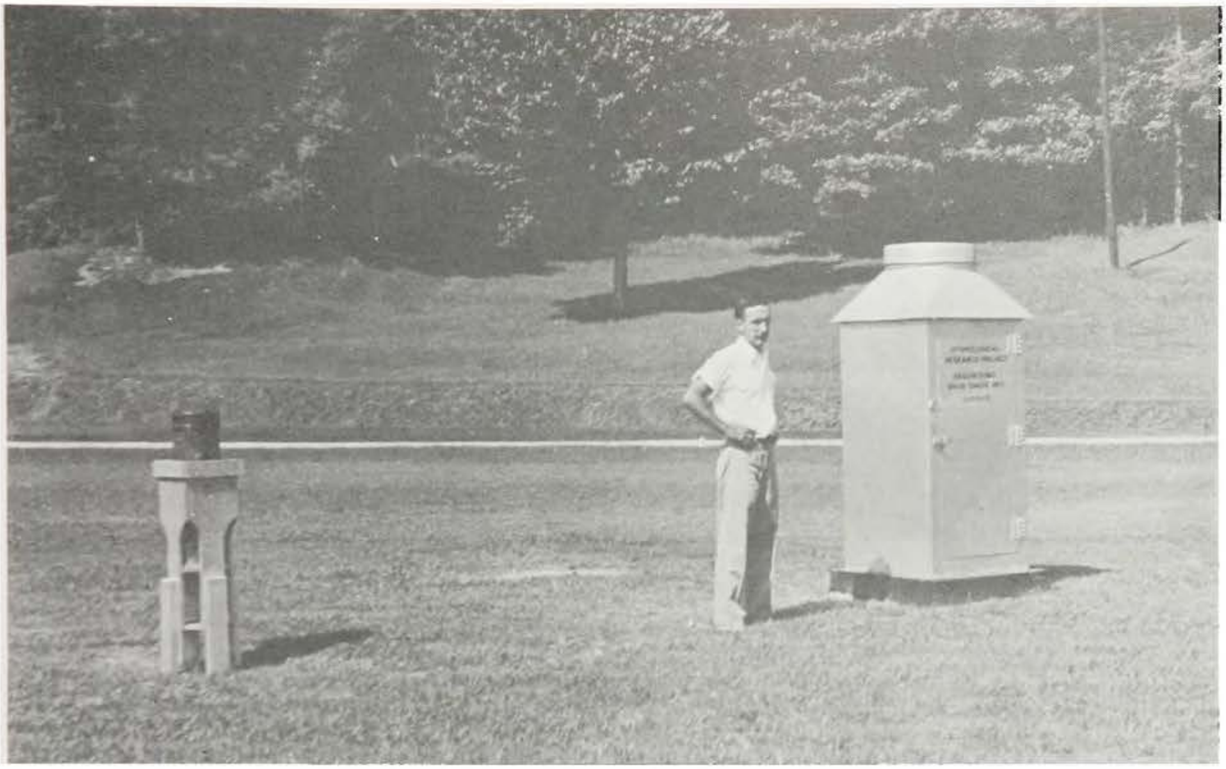
Another important step in the development of WES—a step far removed from engineering—involved expense budgeting, and Director Kenneth E. Fields remembered in later years that this came about in the fall of 1939.

> *...immediately following my return from Omaha. There, the then Col. Hogue had roasted me to a burnt brown because a model study of bed flow in the Missouri had cost about 50-100% more than the $1200.00 estimate! (The figures are suspect, but the total cost was small and the increase large).*[37]

Fields also recalled some emergency flood-control measures that were taken along Durden Creek in order to preserve the main WES building.[38] A reservoir, or lake, had been one of the first construction projects at WES and was to supply water for model operations. It had a 120-foot-wide spillway and an automatic gate control located under the dam where a 5- by 5-foot conduit was also located. On the watershed were placed rainfall gages. Adequate water wasn't supplied, so a 3-foot weir was added, which raised the pool level upstream by 3 feet.

As early as December 1938 the Office, Chief of Engineers, was considering investigation of rainfall and runoff above the station dam, and a land evaporation station was put into operation in May 1939 with equipment supplied by the Great Lakes Survey Office. A set of watershed maps was needed, which was secured through the help of the Vicksburg District, Corps of Engineers, which did all the field survey work and a portion of the final drafting of the maps.

Three streams fed the reservoir, and gaging stations were established on each. Water wells were also drilled for the purpose of determining the annual



Rain gaging station showing special type recording rain gage (right) and nonrecording check gage

Nonrecording rain gage

Inside of special type recording rain gage

A floating evaporation station

fluctuation of the water table, and a floating evaporation station was established on the lake. The guesswork had been removed from knowing the water level of the lake.[39]

In the late 1930's, many spillway and outlet works studies were undertaken for the various Corps of Engineers districts that represented the kind of cooperation which Fields felt promoted an understanding of what WES was doing and could do for the Corps.[40]

In 1934, while WES was still in its infancy, Director H. D. Vogel talked about the success of the facility:

> *The watchwords of the Experiment Station have been "flexibility" and "practicability" from the first day of its existence to the present. No cumbersome, fixed equipment is used where a home-made device will be sufficient, and the question asked with respect to every innovation is, "Will it work?" If it shows promise of working, and at the same time is of reasonable cost, it is given a fair trial and allowed to stand or fall on its own merits.*
>
> *Briefly reviewing the models in evidence about the grounds and within the building of the Station at the end of its first two and one-half years of operation it will be noticed that in both number and size they surpass those of any similar institution in the world.*
>
> *Obviously, to build, maintain, and operate these many and diverse models, the working organization*

of the Station must be maintained at high efficiency. No lost motion can be tolerated and every man must have an appointed task that he can perform accurately and perfectly at high speed. To attain this end the organization under the Director has been developed into three sections: Administrative and Reports, Research and Experimentation, and Construction. The Research and Experimentation Section is subdivided into four groups and the Construction Section is subdivided into two, one for general construction and one for constructing models.

When a problem is sent to the Experiment Station for consideration, a preliminary study is first made to determine its adaptation to experimental treatment. If it is found that a suitable model can be built at reasonable cost and operated with some definite promise of success, a favorable report is rendered and authority to proceed with the experiment is awaited. Upon receipt of such authority a more detailed study is conducted and a subproject is prepared which states in brief the laboratory conception of the problem, the proposed method of procedure, the recommended scale values, the estimated cost, and the estimated time of completion. Experience has shown that costs can be readily estimated to within 10 percent of the actual and that, except for contingencies, the time can also be accurately determined in advance. As a matter of interest it may be stated that the average time required for a Mississippi River problem, including design and construction of the model, is about six months.

When approval of the subproject has been given by the district or division for which the experiment is planned, the entire problem is turned over by the Chief of the Research and Experimentation Section to the group leader who is best able at the moment to take on new work, or whose special talents are indicated to be of value in solving the particular problem. This group leader, with the aid of his assistants, prepares a working drawing of the model, complete in every detail, and a series of plotted cross sections for use as patterns in cutting templates. These are turned over to the Chief of the Construction Section, who proceeds to build the model under inspection of the interested research group. Upon completion the model reverts to the group leader in charge of tests, and under personal supervision of the Section Chief the experiment is carried out. Services of the photographer, draftsmen, typists, and the entire Construction Section are available upon call at any time to the Research Section so that its work will proceed smoothly and uninterruptedly. The most important feature of the plan is that the persons conducting the experiment are freed from all details of construction and administration so that they can concentrate all energies toward the solution of the problem. Upon completion of the tests the facilities of the Administration Section become available to the research group in getting out their report, and as many copies as are desired are prepared by them. Throughout the entire study the Administration and Reports Section has been in contact with progress of the tests and it becomes, finally, a simple matter for its personnel to edit for *publication the report originally submitted. Naturally, all reports are not published, preference being given to those of general interest that may throw light on other problems occurring elsewhere, or those which are of particular interest because of their method of treatment.*[41]

There was always the practical, nonscientific answer to problems, too; and one day in the carpenter shop, Bill Rowland asked Riley Findley how to keep from making hammer marks in wood while he was building something. Findley's conclusion made sense: "just don't hit it that last lick."[42]

And even the most careful planning didn't always result in the desired results. The first movable-bed model at WES was of the Ohio River. Sand was hauled in for it from the Red River; it was cleaned, screened, and put in the model, which was constructed in the main building where the Soils Laboratory was later located. When the big moment came to turn on the water, everyone was there. The Director took over and the commands echoed down the line until they reached the man at the valve. Flashbulbs popped as the valve was turned wide open—and the rushing water flushed all the sand out of the model and into the basement. The Ohio River model was left clean as a whistle.[43]

But another test proved the worth of the models. Early in 1937 big flood flows were forming due to storms in the Ohio Valley, and unprecedented stages were being experienced along the Ohio River. The MRC worried about the ability of the Mississippi to carry off the waters to the Gulf, and though studies and computations had been made, no real floods had occurred to test the efficiency of the cutoffs and other improvements.

The Vicksburg District, using up-to-date field observations, computed the flow line that might be anticipated with the quantities of water which could be envisioned as building up in the Ohio, the Upper Mississippi, and the Missouri Rivers. The new, massive levees were only partially completed; would the water top them or not? WES revamped its Mississippi River model to include the shape of the river as it existed then, and by expeditious handling routed through the model the flows that were anticipated from the three flooding areas. The results very closely approximated the manually computed results, eased the tension of all concerned, and permitted orderly and properly planned preparations for the anticipated floodwaters. And when the waters passed Vicksburg, they were within fractions of the predictions made at WES.[44]

Nearly 250 model studies had been completed by the fall of 1938, and WES Director Paul W. Thompson wrote:

During the nine years of its existence, there has been developed at the Experiment Station a Corps of specialist-engineers. These engineers constitute the unique and irreplaceable element in the Station's facilities....Their talents form the invisible but highly important ingredient of every new study completed at the Station. Meanwhile, there also has been developed a small corps of expert craftsmen, skilled in such items as model-making, Pyralin-working, etc....All in all, it may be said with conservatism that the greatest asset of the Experiment Station is its specialist personnel.[45]

As WES completed its first decade of service, it had evolved into an organization that took and evaluated problems in an orderly fashion. It had proved its worth many times and was an accepted and valued institution, respected by both private enterprise and governments.

Aerial view of WES, 1936

1. Brig. Gen. H. D. Vogel, "Genesis of the Waterways Experiment Station" (1962), unpublished manuscript in WES archives, p. 12.
2. Ibid.
3. Herbert D. Vogel, "Origin of the Waterways Experiment Station," *The Military Engineer* (March-April, 1961), p. 135.
4. Ibid.
5. *Christian Science Monitor,* August 15, 1935.
6. Ellwood Douglass, "Pouring The Father of Waters into a Test Tube," St. Louis *Post-Dispatch* magazine (March 14, 1937), p. 2.
7. Marc A. Rose, "Trial by Models," *Today Magazine* (June 6, 1936), p. 11.
8. "1,000 Foot Mississippi River Model Tells Flood Danger for Army's Waterways Engineers," *Science Service* (February 8-14, 1937).
9. Rose, . "Trial by Models," p. 11.
10. New Orleans *Times-Picayune,* March 7, 1937.
11. Ibid.
12. St. Louis *Post-Dispatch,* September 28, 1936.
13. New York *Herald Tribune,* June 7, 1931.
14. Ibid.
15. Vicksburg *Evening Post,* May 22, 1951.
16. Ibid., January 9, 1933.
17. Ibid.
18. Ibid.
19. Ibid., May 22, 1951. Brig. Gen. Paul Thompson recalled Gen. Ferguson in 1968 as "my own most unforgettable character. Whimsical and picturesque and not very precise in conveying instructions, impatient of experimental results which failed to fit his own instinctive conclusions—but a man of moral courage unsurpassed (yes, unequaled), a man whose 'instinctive conclusions' were so often and so uncannily right—especially when the stakes were high. Fergy, the man who cut the bends of the Mississippi—I see him now on that misty morning when the plug was blown and the water surged through at Diamond Point...;" Tiffany, *History of WES,* p. IV-2.

    Ferguson was also most unforgettable to the managing editor of the *Vicksburg Evening Post,* Charlie Faulk. He called the General in 1951 when Ferguson returned to Vicksburg and requested an interview, which was granted. He arrived at Gen. Ferguson's suite in the Hotel Vicksburg, notebook in hand, on the evening of May 21, 1951. The interview proceeded smoothly, Faulk taking notes, when suddenly Ferguson demanded to know what he was going to do with the notes. Faulk told him that they were for a newspaper story, and he recalls that the General ranted and raved and threatened to "throw me out the hotel room window." Faulk suggested that the General call the publisher of the newspaper. Ferguson couldn't reach him by phone, and after fuming for a while, offered Faulk a drink and became completely amiable. The result was the story in the *Evening Post* cited in this footnote.
20. Ibid.
21. Ibid.
22. Ibid.

23. New York *Herald Tribune,* June 7, 1931.
24. Johnstown, Pa., *Democrat,* October 28, 1937.
25. "Flood-Free Johnstown," *Newsweek* (January 31, 1944).
26. Milwaukee *Journal,* January 26, 1944.
27. "Flood-Free Johnstown," January 31, 1944.
28. "Waterways Experiment Station," a typewritten manuscript on file in WES archives; p. 1.
29. Vogel, "Origin," p. 135.
30. Vogel, "Genesis," p. 15.
31. Ibid.
32. H. D. Vogel, "Organization and Operation of the Waterways Experiment Station," *The Military Engineer* (April 1934), p. 121.
33. J. B. Tiffany, ed., *History of the Waterways Experiment Station* (Vicksburg: WES, 1968), pp. V-I, 1-4.
34. Vicksburg *Evening Post,* June 17, 1969. According to the newspaper article, Joe Tiffany developed the format while he was a project engineer in the 1930's and was required to write technical reports for which there was little or no precedent.
35. Tiffany, *History of WES,* pp. V-I, 1-4.
36. Ibid., pp. VI-I-3.
37. Ibid., p. IV-5.
38. Ibid.
39. R. G. Cox, *Hydrological Research Project History* (Vicksburg: WES, 1943), pp. 1-13.
40. Tiffany, *History of WES,* p. IV-5.
41. Vogel, "Organization," p. 121.
42. Vicksburg *Evening Post,* June 1954.
43. Ibid.
44. Ibid.
45. Tiffany, *History of WES,* p. IV-4.

CHAPTER III: WAR, HOT AND COLD: 1941–1949

As WES entered its second decade, war clouds were gathering in both Europe and Asia, and America began to stir out of her isolationism.

Facilities at WES had been used almost entirely for civil works programs since the institution's beginning; but by early 1941, WES resources were "summoned in the race to rearm America."[1] Prior to that time, WES had made only a few studies concerning defense. One such project was improvement of the naval base at San Juan, Puerto Rico. A smooth water surface area in the harbor was needed for patrol planes to land and take off, and waves which entered from the ocean made it impossible. WES undertook a study on how best to eliminate such rough water in the harbor, using a scale model and experimenting with the location of a breakwater until the best possible alignment was found for construction. Exact results were known before construction began for that important defense base in the Caribbean.[2]

Another laboratory achievement at WES which proved valuable in wartime was the development of a pressure-measuring cell to determine pressure within earth dams. The device worked equally well in

San Juan model

designing bombproof air raid shelters.[3]

WES engineers were also in the process of acquiring equipment for testing materials used in construction of airfields, for if war came, and many believed it would, air power would be vital.[4] By the fall of 1941, WES was geared almost entirely to helping in the race to make America impregnable.[5]

Though military benefits could be derived from many civil works jobs, the first study of a purely military nature at WES had been conducted in 1939 when over 100 sets of miniature pontoon bridges were built and sent to military schools and training centers throughout the country. These models were made to scale and complete in the most minute detail. As equipment was scarce, these models were the only way of training engineer groups in the critical task of erecting standard military floating bridges. By working and learning with the model bridges, the actual job could be quickly and accurately executed.

The impact of World War II on WES was tremendous, and the civil works program was practically abandoned as WES became a war-oriented facility. Personnel rolls underwent significant changes as 631 employees left to serve in various branches of the Armed Forces. With many of the men at war, women technicians were hired in large numbers to fill their places; many were the wives of servicemen.[6] Capt. Kenneth E. Fields, who had been Director from September 1939, was reassigned in December 1941, and for the only time during the history of WES, the Director was a civilian, Gerard H. Matthes.[7]

Many of the staff members who had fabricated the first pontoon models were soon scattered around the country in military units, and to their surprise they were taken from their posts and flown to England where they formed the nucleus of the Engineer Model Maker Detachment. Among their achievements during the War was the construction of special models to aid in radar planning. Gen. Eisenhower singled out the Detachment for a personal citation and commendation.[8]

Models made by WES engineers aided all branches of the Armed Forces. Terrain models of selected landing sites along the coast of North Africa, Sicily, Italy, the Cherbourg Peninsula, and the sandy beaches running eastward to the Pas de Calais were made to help in planning Allied landings and invasions; and later in the War, models were constructed of the fortress at Metz and of the Rhine River crossings.[9]

For the Air Corps, recognizing the terrain and target sites was all-important, and WES made scale models of territories which were used by air bombardment crews. Specific areas were modeled to help the bombing crews—places such as Eder, Sorpe, and Moehne in Germany, the Italian island of Pantelleria in the Mediterranean, the ball-bearing works in Schweinfurt, Germany, the oil refineries at Ploesti, Rumania, Norwegian fjords, and V-1 and V-2 launch pads.[10]

Model studies were also made for wartime projects which would be beneficial in times of peace, and one of these was the New York Harbor. The model study was undertaken for the Navy in order to find a more accessible route to the Brooklyn Navy Yard. Only two routes could be used from the sea: the one through the lower bay and narrows, usable all the time, and an alternate route through the East River and Long Island Sound, accessible to big ships only for short periods during high tide. Military necessity

New York Harbor model

Model study of tidal currents in East River

required the availability of both routes, and WES studies resulted in recommendations that opened them for full use.[11]

Another east coast wartime measure was a study to facilitate the intracoastal canal; the use of the canal would keep shipping off the ocean and avoid possible sinking by enemy submarines.[12] One of the major problems in constructing the waterway was the fear that salt water from the sea would pollute the freshwater supply of thousands of people in scores of towns. Engineers felt the canal was a necessity for shipping; it would make possible a vast expansion in freight tonnage and at the same time take a large slice from costs of operation by ships plying the waters of the Atlantic Ocean along the coast. It would be 30 miles in length, costing an estimated two hundred million dollars and linking the Delaware River at Bordentown near Trenton, New Jersey, with Sayreville on the Raritan River just above lower New York Bay.

The problem of keeping out salt water was turned over to WES engineers. The canal model was designed with two sets of valves and separate systems for intake and flushing water. Fresh water flowed in through openings high on the walls of the locks, and tests showed that it did not mix with salt water, which clings to the bottom of the locks. Valves in the bottom sucked out the saline concentration.[13] The two waters retained their characteristics unless stirred excessively; and to illustrate this, the salt water in the models was dyed green so it could be seen as it moved into the stream.[14] Building of the canal, "the missing link" in the Intracoastal Waterway, was made feasible by WES studies. And years before popular anxiety over pollution, the Army Corps of Engineers showed its concern.

Tests and studies were also made to assist in winning the war in the Pacific. The Midway Islands were the site of a Navy base which assumed critical importance. Heavy westerly seas created conditions hazardous to navigation in the channel between the two islands, and various plans involving breakwaters and dredging of the channel were proposed to correct the condition. But would these plans provide the desired results? WES supplied the answer with model tests that showed that barrier works surrounding the central lagoon would effect the desired results; other schemes that had been proposed were tested and shown to be of little value.[15]

Closer to home were the various naval installations along the lower California coast, all of which were strategic in defense. Harmful wave action caused by storms plagued the base at Terminal Island in Los Angeles Harbor and the supply depots at San Pedro as well as the U. S. Naval Air Station at Alameda. These bases were of vital importance, yet the adverse wave action impaired their usefulness, and effective remedies had to be found quickly. Again, officials turned to WES for solutions.[16]

The model WES constructed reproduced to scale the 12-mile-long, crescent-shaped waterfront of Los Angeles Harbor and included a generous expanse of the Pacific Ocean. The model waters covered an acre, ranging in depths from several feet to an inch in miniature streams which penetrated the shoreline. WES engineers discovered that in addition to the familiar waves which came every few seconds, the harbor also had practically invisible surges, low and wide, that acted like water in a dishpan that is suddenly tilted, making the harbor water higher on one side than on the other and resulting in ships being suddenly moved about like a startled person taking a side step.

To reproduce these unusual waves in the scale model, a narrow, watertight, 25-foot-long box was built in the ocean area and an engine alternately raised and sank it with a slow pumping motion. Correct timing was important in reproducing the peculiar surges. There was no mathematical or computational method for calculating how such waves could be broken up, so the problem was solved empirically and in almost total darkness. Model ships, 2 feet long, were tied up at the miniature docks, and each ship was equipped with a flashing light fore and aft. These flashes were recorded on photographic film from platforms located just beneath the roof of the building housing the model; the photographs traced a path which told where the boats moved from second to second. The movements could be correlated precisely with the artificially produced surges. It was then relatively simple to set up breakwaters in the positions necessary to disrupt the surges, making Los Angeles Harbor safe for ships.[17]

Another problem on the west coast concerned San Francisco Harbor where shoaling was a constant and very serious hindrance to navigation to and from the U. S. Navy Yard on Mare Island. Access to the island was provided by San Pablo Bay and Mare Island Strait, and keeping the strait open required continuous dredging. Dikes constructed prior to 1920 when model testing was not available were ineffective in preventing shoaling. In 1917, a 35-foot projected depth for the strait was approved; but it was so expensive to maintain that the depth was reduced to 30 feet in 1927. The Corps of Engineers and the Navy's Department of Public Works each formulated plans to eliminate or reduce the annual maintenance dredging, and model tests were conducted at WES to determine the most effective and efficient plan.

Plans included construction work, utilization of water storage, spur dikes and sills, and a dredged basin for trapping the shoal materials. Model tests showed that plans other than those involving the storage of water during tidal cycles for release during subsequent ebb periods by a system of one-way gates would be ineffective. By following WES suggestions secured from the models, a 90 percent reduction in the shoaling was achieved in laboratory tests. The system has not been employed in the field. Leading WES hydraulicians during these important tests were Eugene P. Fortson and J. M. Caldwell.[18]

One of the most far-reaching contributions of WES during World War II was the development of criteria for the design and construction of airfield pavements. Work was begun in early 1941 at which time Air Corps officials were demanding concrete runways only.[19] But engineers were looking for a cheaper and better way of building landing strips.

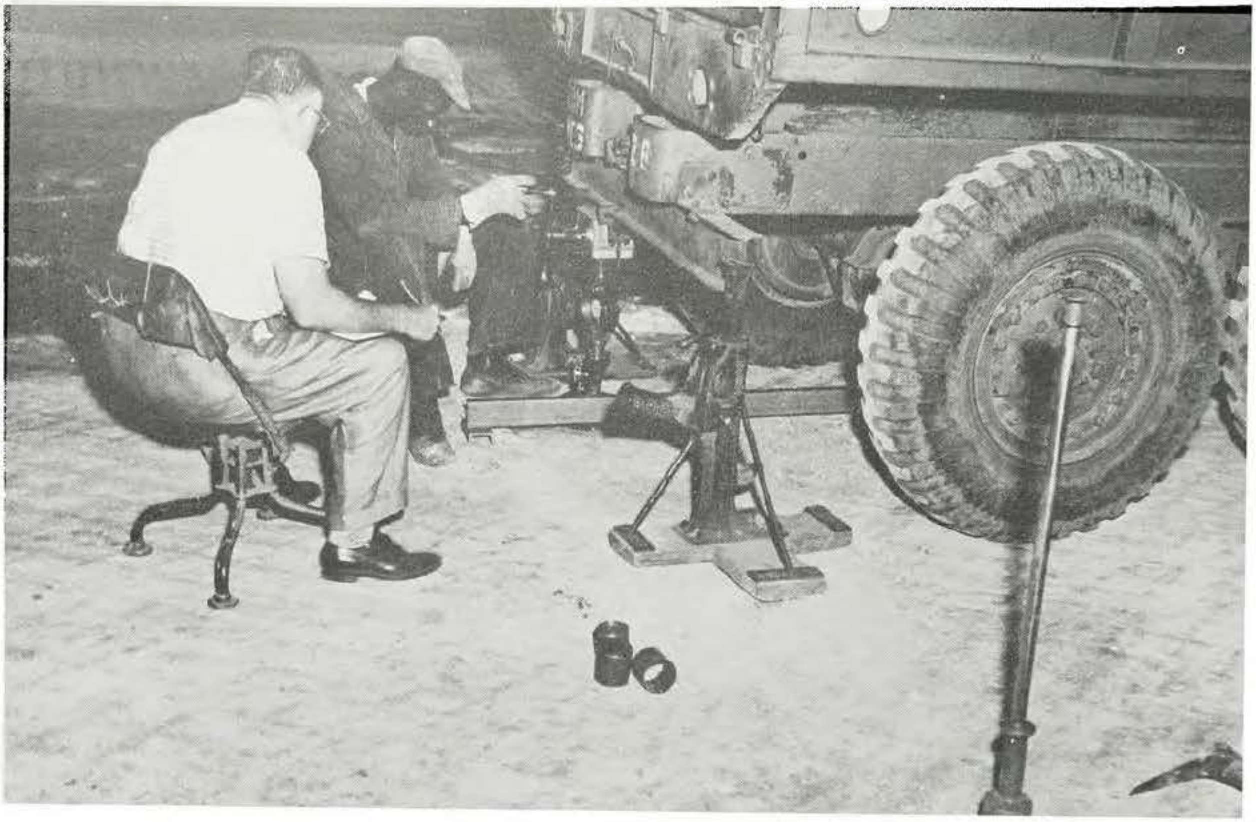
WES began studying general problems of airfield drainage, soil stabilization, and flexible pavement design in late January 1941. On 14 February the Districts and Divisions were asked to try out low-cost paving materials on runways, taxiways, and aprons and to report their findings to Washington as soon as possible. A short time later, the Norfolk District began to experiment with circular metal plates as a means of determining the bearing capacity of soils under flexible pavements.[20] Tests were planned at Wright Air Field and at Langley Field and were begun in September 1941. Crews of skilled technicians were sent from WES, and equipment used included specially built pressure cells constructed at WES.

Defects were found in CBR tests (California Bearing Ratio tests measure the shear resistance of base and subbase materials), and the Soils Division of WES was directed to make a step-by-step analysis.[21] The work assumed added importance when it was realized that stronger airfield pavements were necessary to support B-29's, so important in bombing enemy targets.[22]

At WES, the work to develop mats for military use was carried out around the clock in the fall and winter of 1942-43 under the direction of James B. Watkins, and from these tests emerged the pierced steel plank (PSP) landing mat as well as others. One, the M8 landing mat, was developed under the supervision of O. B. Ray, and was standardized for Army use and mass-produced. Vast quantities of the PSP were used in future years in the Korea and Vietnam wars.[23]

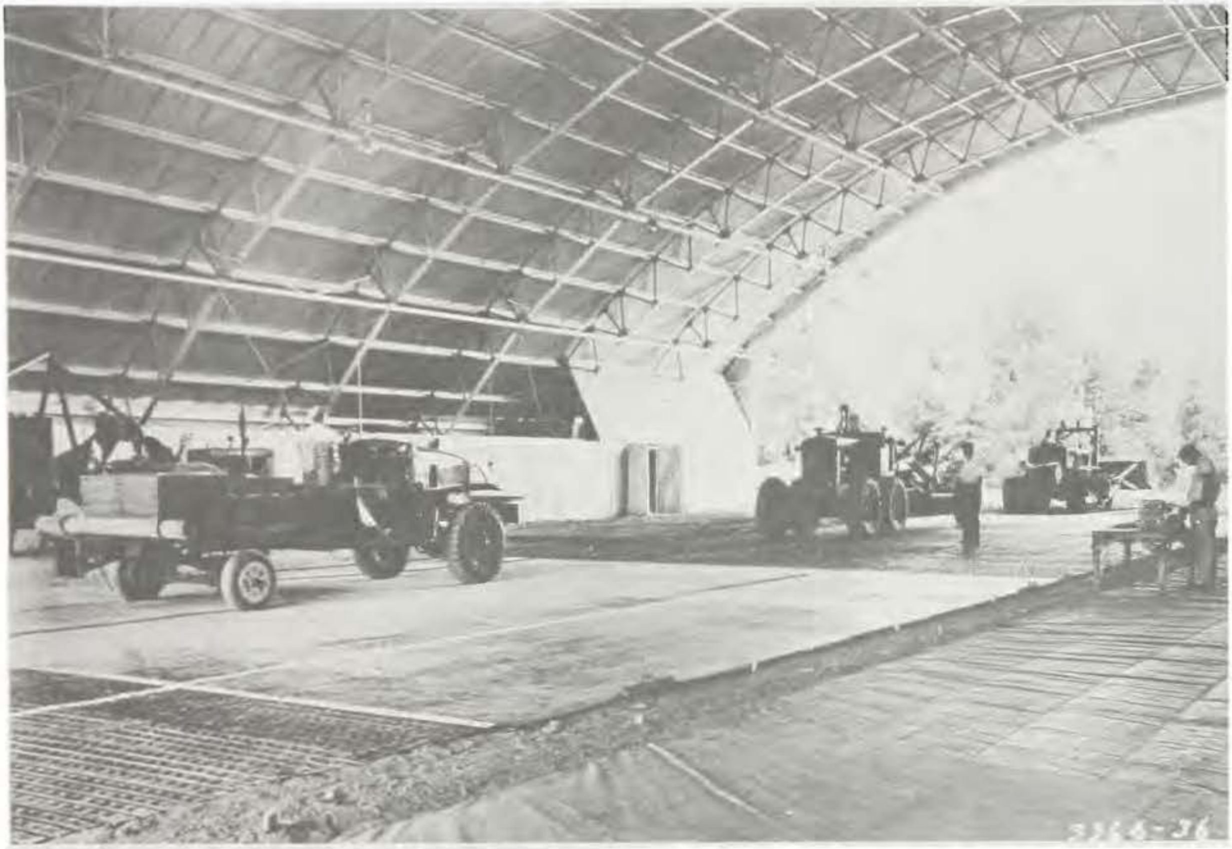
Early in 1943, Maj. Gen. Eugene Reybold, Chief of Engineers, directed WES to begin studies of flexible pavements, and the directive resulted in the formation of the Flexible Pavement Branch of the Soils Division. Its purpose was to investigate methods of design and construction of airfield flexible pavements, to determine the adequacy or inadequacy of methods of design and construction then in use, and to develop satisfactory criteria for such design and construction.[24]

WES was already emerging as the leading center of flexible pavement research. Soils Division Chief W. J.



Field in-place CBR test in progress

B-29 on pavement



Early landing mat test

Turnbull, who until the fall of 1942 had been concerned primarily with earth dams and embankments, now turned his full attention to military airfields. It had taken from 12 to 18 hours daily to keep abreast of the work, going over test reports, reviewing project sites, programming future investigations, and hosting several large conferences on CBR. New assignments meant the need for more men, and they came from the District offices in Little Rock and Vicksburg as well as the Mississippi Highway Department.[25]

Also needed was a building for the new Flexible Pavement Branch, and a $100,000 grant was made for that purpose in April 1943; it was named the Flexible Pavement Laboratory.[26] By late summer of 1943, the building was ready, and 25 persons made up the staff of the Flexible Pavement Laboratory. Included among the personnel were W. Keith Boyd, who was in charge, assisted by Charles R. Foster. A leading authority on soil mechanics and head of the Department of Civil Engineering at Northwestern University, Dr. Philip C. Rutledge, became Chief Consultant; and Bruce G. Marshall, inventor of a machine for measuring asphalt stability, was added to the staff.

In the latter part of 1943, a long-range program of research was launched which included laboratory and field investigations of base course design, compaction methods, moisture conditions under pavements, and many varieties of asphaltic surfaces.[27] The scope of the investigations was enlarged to include problems of engineers in the field. Across the Mississippi River, WES had a test site at Mound, La., and men conducted studies of base course requirements under landing mat and

Mound, La., test site

experimented with a new type of temporary surfacing consisting of burlap, duck, or osnaburg fabric impregnated with bitumen and laid down by a unique machine called a "stamplicker." Marshall redesigned his asphalt stability machine so that it could be used by troops.[28]

In June 1944, the use of landing mats was dramatically illustrated in Europe and Asia. Allied troops landed on the Normandy coast to begin the liberation of France, Belgium, and Holland on 6 June. Within less than a week after the soldiers waded ashore in the greatest offensive in the history of wars, the Allied High Command announced that air bases had already been established in the liberated territory and that an umbrella of air protection was being raised from them.[29] At about the same time, on the other side of the world, U. S. Superfortresses took off from an airfield in China on the morning of 15 June 1944 to carry out an extensive bombing raid over Japan.[30]

The airfields which were being built in both theaters of war were being surfaced with PSP landing mats or with a material known as prefabricated bituminous surfacing (PBS). British and Canadian engineers had begun the development of the PBS material, but intensive investigations at WES, designed to improve the product and increase its utility, resulted in a membrane which was produced in great quantities and gave satisfactory results as an airfield covering. Principal tests were made in the spring of 1944.

Popularly known as "Hessian Mat,"

Mat-surfaced runway (PSP)

the quarter-inch-thick material was placed on more than 100 landing strips between D-Day, 6 June 1944, and the crossing of the Rhine, 7 March 1945. It held up under a steady stream of cargo and fighter planes as well as medium-sized bombers. PBS was made of nothing more than burlap, impregnated and coated with an asphalt which gave it the appearance of a roofing material and was very inexpensive. It could be put down at the rate of 2-1/2 to 4 miles per hour by a crew using a stamplicker which wet the mat on one side with a solvent that softened the asphalt, producing a sticky surface. A second layer, half covering the first, stuck to it and produced a thin, tough weatherproof and dustproof landing strip. A fine layer of sand on top of that provided an all-weather, nonskid surface.

The nickname "Hessian" came from the fact that Hessian migrants at Dundee, Scotland, over a century before, had woven Indian jute into mats.

An extraordinary feature of PBS was the simplicity of repairing it. Two men with a mop, a bucket of asphalt, and a strip of PBS could make small repairs by swabbing it, laying it, and then walking across it to pack it. For larger repairs such as damage due to bombing or soft spots formed by trapped water, the surface material was slit and folded back while repairs were made to the soil, then restored to its place and sealed by the addition of a fresh strip. With the use of PBS, the enemy found themselves "hunted like rabbits before eagles by planes rising from fields which appeared by the magic of modern engineering."[31]

Another problem concerning airfields was determining the depth of cover

Placing PBS with stamplicker machine

required over their subsurface drainage systems. Heavier loads required careful placement of underground drainage works. Corrugated metal pipes, plain and reinforced concrete pipe, and an expedient hexagon-shaped pipe made of wooden staves were tested to failure at depths of from 1 to 6 feet.[32]

Another important series of tests run at WES during World War II involved the effects on the CBR of changes in the molding moisture and compacted density of soil, both in soaked and unsoaked conditions. An important by-product was the development of the "family of curves," showing the full range in the strength of a remolded soil with changes in moisture and density in both the above-mentioned conditions. This discovery and the entire study resulted in a real breakthrough in the understanding of the behavior of soils under pavement, information vital not only for building airfield runways but also in highway construction.[33]

Also significant in highway and airfield construction was the development of mix design procedures for bituminous concrete for use as binder and wearing courses. Bruce Marshall of the Mississippi Highway Department had developed a relatively simple process for evaluating the suitability of bituminous concrete mixes which underwent further experimentation and improvements at WES; Marshall was hired by WES, and the method he developed (which bears his name) is the

Marshall stability test in progress

most widely accepted in the bituminous concrete industry.[34]

In addition to its role in the war as a testing facility, WES also provided some key personnel in the Allied operations. Of interest to many in Vicksburg was the fact that former WES Director Col. Paul W. Thompson was formulating the invasion program for the Allies. It was Thompson's job to see that both the infantry and engineer contingents, who would spearhead the D-Day invasion, were ready for the assignment.

Thompson began conferences in May 1943 with officers from every branch of the service, British and French as well as American, who had had experience in combined operations or had knowledge of coastlines and fortifications in Europe. Thompson was considered the Army's outstanding expert on assault techniques as practiced by both U. S. and enemy combat engineers; and he planned the Allied training center in England, supervised its construction, and operated it. When D-Day arrived, the troops had been well rehearsed.[35] And when those troops, trained by a former WES Director, went ashore on Normandy, their invasion was made possible by studies performed in Vicksburg at WES.

Two artificial harbors tested at WES, then built in secrecy and towed across the English Channel behind the assault forces for installation on the Normandy beaches, were used to furnish supplies to the invasion armies and, according to a statement from Supreme Allied Headquarters, "made possible the liberation of Western Europe."[36]

WES engineers, who had spent untold hours of tedious toil testing models of the artificial harbors, had already predicted the outcome. A decision to use artificial harbors had been made by British and American officials at the Quebec Conference in the summer of 1943; French ports could not possibly have the capacity for handling the needed stores to support the invasion, they reasoned. Almost immediately WES engineers were given the job of testing model harbors. Two proposed types of concrete caissons were built to scale. One building at WES contained a huge wave tank and was equipped with intricate measuring and recording devices. Crews worked for 7 days a week, 24 hours a day, for several months until the final test was made in December 1943. The task was so urgent that the usual written reports were discarded; as soon as some important fact was determined, it was transmitted immediately to Washington.

The caisson models were placed in the tank and subjected to waves simulating storm conditions that could reasonably be expected off the French coast; every reaction was noted, and any flaws in the original design were corrected, then the new design tested until one was found which could be expected to withstand the final test. To aid in the structural design, pressures were measured at various points on the face of the caissons, and studies of tide and wave action were made to ascertain the stability of the sections with respect to overturning, settlement, and sliding. Determining the proper amount of ballast to be used where the sections showed a possibility of movement was also done by testing; in this manner, spacing of the caissons was also decided. Final data were flown directly to England from the Office of the Chief of Engineers. In England, the full-size caissons were constructed.

Gerard H. Matthes, WES Director, gave credit for the success of the tests to Capt. Joseph B. Tiffany, Jr., Fred R. Brown, Robert Y. Hudson, and Eugene H. Woodman, who spearheaded the work. Woodman devised the measuring and recording devices used in the tests while the others did the hydraulic work.

Among the changes in the original models which experiments showed to be feasible was the shape of the caissons' tops. The originals were slanted, but tests revealed that waves would go over the slanting summits and strike the caissons in such a way as to endanger their stability. The tops were changed, the tests were repeated, and the trouble was eliminated.[37]

When D-Day came, one of the worst channel storms in history wrecked a harbor before it was completed but after it had already contributed greatly to the stream of men and equipment pouring into France. The other was finished as planned. It was a port as big as Dover, complete with docks, piers, and breakwaters, and was capable of unloading at least 12,000 tons of stores and 2,500 vehicles each day. The ports had been built in three sections—blockships, caissons (sea walls), and breakwaters. Sixty old ships were sunk to form the five small breakwaters along the French coast. Included in the harbor construction were 150 caissons of six different sizes to suit various depths of water up to 33 feet. The largest caisson displaced 6,044 tons and the smallest 1,672.

Towing the caissons and other equipment was done with 85 tugs and 500 tows in the face of enemy attack, and staffs and personnel had to be trained. Only a few tugs were lost to enemy action as they crossed the choppy waters at an average speed of four knots.

Construction of the caissons alone had employed 20,000 British laborers, and many thousands more were engaged on other structures for the artificial harbors. The whole operation was far larger and more technical than most would have imagined possible, and despite the number employed in their construction, there was no case of leaking vital information.[38] In Vicksburg, WES personnel who had worked for months on the project must have experienced a great deal of satisfaction at the success. Now their families and friends knew what project had consumed so much of their time and interest for so many months.

Joseph B. Tiffany, Jr., Executive Assistant to the Director of WES at the time, recalled 30 years later the worry the project had caused him. He had figured out where the invasion would take place because of the specifications concerning tides, he said, and then he wished he did not know for fear that "it would slip out in conversation, or that I might talk in my sleep" and accidentally reveal the military secret.[39]

While D-Day was successful, additional plans were also being made for winning the war in Asia. If the Japanese couldn't be bombed into submission, invasion of the island nation would be necessary. But the boggy rice paddies could make it an almost impossible feat for heavy equipment such as tanks. The answer to how much traffic the soil could bear would be supplied by a small instrument called a penetrometer if an invasion became a reality.

Cone penetrometer in use

The penetrometer consisted of a metal rod, about 3/4 inch in diameter, on one end of which was mounted a cone of slightly larger size, and on the other end a meter, set in the center of a circular spring. Pressure on the handle of the device caused the spring to compress, pushing the rod, cone down, into the earth. As it went down, the number of pounds of force required to make it move was read on the scale. For the meter to be of any value, its readings had to be correlated with information gained from thousands of tests which were conducted at WES and at Yuma, Arizona.

WES selected 14 Army vehicles, all considered to be representative of those which would be used in an invasion. Each was operated over a test lane, gradually made softer, until the vehicle bogged down. Readings taken with the penetrometer during the tests showed the worst conditions under which operation was possible and also the condition at which the vehicle became immobile. Information gained from the tests was compiled into tables showing the conditions under which each vehicle could operate.[40]

The penetrometer would have been a lifesaver on Iwo Jima, where tanks stalled on the beaches in volcanic ash which had been mistaken for sand. The bogged-down vehicles were "sitting ducks" for the Japanese gunners; similar situations confronted U. S. troops on every battlefield.[41] For the invasion of the Japanese mainland, the Army planned to use the penetrometer, particularly in the rice fields on the approach to Tokyo. Scouts were to be sent ahead to test the soils before tanks and other pieces of heavy equipment were landed.[42] The tests were conducted at the Rifle Range near WES by the Flexible Pavement Branch of the Soils

Division for the Engineer Research and Development Laboratories at Fort Belvoir, Va. Silt soils native to Vicksburg–hillside clay and loess–were mixed to simulate every type of soil condition.[43] Agreement of the Japanese to surrender on 14 August 1945 after the dropping of two atomic bombs made the invasion unnecessary. But if there had been no such bomb, WES technicians had literally performed the groundwork needed to provide for successful landings.

Rivers rather than rice paddies were faced by Allied forces sweeping across Europe, and it was recognized that floods could cause a slowdown in efforts to end the war. The Germans had used artificial floods on the Roer River, postponing the crossing of the Allies for nine days, and they could use the same tactic on the Rhine, for in their publication DAS RHEINSTROMGEBEIT ("Artificial Flood Waves on the Rhine"), they had outlined possibilities of creating floods by opening power dams that would sweep away pontoon bridges as far south as Strasbourg.

Immediately preceding and immediately after the first crossing of the Rhine, Allied forces would need amphibious equipment, floating craft, pontoon bridges, cable ferries, and temporary fixed bridges–all would require that special precautions be taken to minimize interruption of services and avoid loss of supplies. A study of the Rhine was necessary, and data for such a study were secured from the MRC and WES libraries where materials included German atlases of 1872 and 1889 which gave widths and depths of the Rhine at a number of crossings. From a private library, flood data from 13 selected years were obtained; it also gave flood stages for all gages on the Rhine and the time of travel of flood crests downriver from Lake Constance to the Dutch border, plus flood data for the lower Rhine in Holland, including data for the greatest flood on record.

WES also had 24 sheets of hydrographs showing annual river stages at half a dozen critical points, an article about Rhine cutoffs, tabulations showing the zero elevations of existing gages, a dozen precipitation charts giving detailed information about rainfall at various points along the Rhine, and a temperature chart showing the variation in temperature for a selected year.

With such data, predictions could be accurately made without actual observation of the river, which was still in enemy hands, and twice daily Radio Luxembourg gave 48-hour predictions, possibly prearranged in collaboration with the Allies; each forecast was introduced by the playing of "Ole Man River."[44]

The Rhine was crossed by the Americans on 7 March 1945 at Remagen, and again the name of a WES-connected official made the news. The 1200-foot Ludendorff Bridge, after providing safe crossing for many, was undergoing repairs by Army Engineers, who were busy working on a weakened main support girder which the Germans had damaged in an abortive attempt to destroy the bridge during their hasty retreat. Approximately 200 men were working on it when it fell, plunging them into the water, injuring some and killing others. Immediately, plans were made to repair the bridge and the man who was chosen to oversee the job was Lt. Col. Kenneth Fields, who had been WES Director from September 1939 until December 1941. The bridge at Remagen was promptly repaired; ironically, the span had collapsed only a few hours before a German announcement revealed that four officers had been executed for cowardice and negligence in permitting seizure of the bridge intact.[45]

Not all repairs were on the front lines during the war, and WES conducted wartime model studies of the Navy's floating drydock YFD-15 at Charleston, S. C. The model was used to develop a method of eliminating heavy shoaling in the basin which seriously hampered the use of the drydock to repair war-damaged vessels.[46]

Another WES project concerning the war effort did not take place on the battlefields or even in Vicksburg, but it did involve enemy troops; it was the building of a gigantic model of the Mississippi River at Clinton, Miss., and the basic work was performed by German prisoners of war.

The site for the Clinton POW camp was purchased in 1942 for $49,000. It consisted of 790 acres and when completed accommodated about 3,000 men.[47] Gen. Eugene Reybold, Chief of Engineers, had suggested to WES Director Gerard Matthes and Executive Assistant Joseph B. Tiffany, Jr., in May 1942 the need for a river model, and a short time later survey plans were launched. The POW camp was completed in the late spring of 1943.[48]

Gen. Reybold had been District Engineer at Memphis in 1937 when the great flood of that year came down the river, and he was credited by many with preventing the river from breaking through the levees and inundating the lower valley. Data from the WES lower river model had been essential in his work, and he realized the immense value of a model to portray the entire Mississippi Valley and its tributaries.[49]

By August 1943, men of Field Marshall Rommel's elite Afrika Korps were hard at work on the model. Over a thousand of them, captured at Tunisia, had

Early MBM model construction by German POW's been sent to the new Clinton camp. Dressed in their bright blue prison togs emblazoned with an orange PW, they began the task of reshaping a 200-acre tract to resemble a relief map of the central United States.[50] The 1,245,000 square miles of the Mississippi River watershed involved 40 tributaries in 31 states and 31,000 square miles in two Canadian provinces.[51]

The POW's scooped out 850,000 cubic yards of earth, cutting away the land at "Fort Peck in Montana" and carting it by wheelbarrow for instance to the "Tennessee Valley" where it was used to duplicate the hills around Muscle Shoals. The POW's became engrossed in the work, especially since some were engineers.[52] Cost of the model was estimated at $3,000,000 plus an estimated $6,000,000 in "free" labor (the POW's were payed 80¢ a day).[53]

When completed, the model could be used to establish how floodwaters could be diminished by impoundment in the 150 storage reservoirs that were then completed or planned in the immense watershed, which had an estimated 14,000 miles of inland waterways. The most easterly point in the watershed was 250 miles from the Atlantic, and the most westerly 500 miles from the Pacific. All would be reproduced to scale on the giant model.[54] After the excavation, the molding of dams and riverbeds in concrete was undertaken; a road encircled the model. Water was provided by two deep wells which had been bored to supply the prison compound; an estimated 900 gallons each minute would be needed. Matthes said that the model would be operated by remote control; otherwise, an engineer would have to be at each reservoir model.[55]

Teams taking water-surface elevations along Omaha-Council Bluff levees in the Mississippi Basin model. Circular can-like objects are automatic gages recording stages in main river channel

Interior of Missouri River Control House, Mississippi Basin model, 1950

A visitor to the camp in late 1943 described the POW's as "suntanned" and "making the best of their situation."[56] They were governed and disciplined by their own chosen leaders, and when they went outside the compound on official assignments, they were guarded by American soldiers. Despite their confinement, they had many privileges. Their daily fare consisted of the same food as was given American troops, and their housing was comparable to Army barracks. Generals lived in neat bungalows and were not required to work. POW's organized musical groups, some had hobbies, and many of them participated in a variety of recreational activities.[57]

During design and initial construction of the model, Gen. Max C. Tyler was head of the Mississippi River Commission and Gerard H. Matthes was WES Director. Lt. Joseph B. Tiffany, Jr., and E. P. Fortson, Jr., were in charge of the overall operation. Capt. H. G. Dewey, Jr., designed and executed the blueprints. He was assisted by G. B. Fenwick and many other WES personnel, both engineers and laborers. Stockade Commander was Maj. Harry B. Miller, with Col. James I. McIlhenny as Camp Commander.[58]

Even before the war was over, but following the surrender of Germany, WES made plans to participate in another historic occasion. Vicksburg, which had capitulated to Gen. U. S. Grant on 4 July 1863, during the War Between the States, had not celebrated Independence Day since that time. However, with a war nearing a successful conclusion, the City Fathers planned an immense celebration for 4 July 1945. WES had done much to help win the war, but since most of the experiments were still classified as Secret, the WES float for the parade, authorized by Matthes, was simply a Failing drill rig, mounted on a platform, with a poster telling the name of the sponsor.[59]

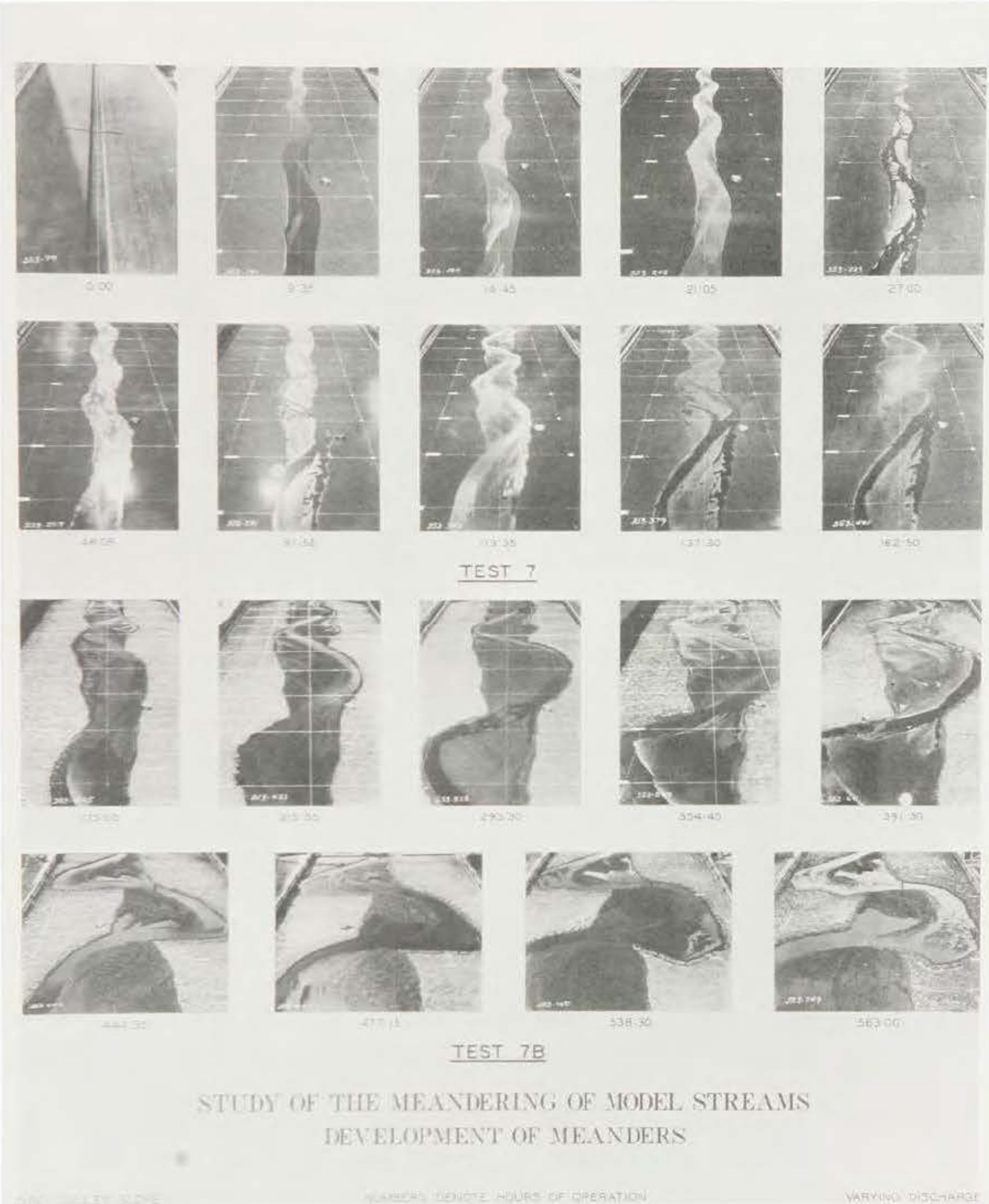
Soon after the victory over Japan, the Director, Mr. Matthes, announced his retirement effective 30 September 1945. A native of Holland, he had come to the United States as a youth, had spent 50 years as an engineer, and for 31 years had been employed by the Government. He came to Vicksburg as a consultant to the President of the MRC in 1932 and did much of the planning concerning cutoffs on the lower Mississippi. He had reached retirement status during the war but had remained active because of the emergency. During his tenure, he was honored in December 1944 with the Exceptional Civilian Service Award, the highest civilian honor the War Department could bestow.[60]

Once World War II was over, WES was able to devote its time once again to civil works projects. Some undertaken before Pearl Harbor, such as control of the Johnstown floods, were completed during the war years. Other projects, such as control of surges in the harbor at Wake Island, had been started as wartime measures but were also beneficial in times of peace.

One civil works project undertaken during the war was a comprehensive series of potamology (or study of river science) investigations which led to the authorization of the 1944 Mississippi River Flood Control Project, including the 12-foot navigation channel and the bank stabilization program. One of the discoveries made by the potamology studies explained why the Mississippi River meanders from side to side. The course of the river is a series of loops from 15 to 40 miles in length but often only 2 or 3 miles across land "as the crow flies" from one end to the other. Man had speculated that these meanders had been formed because of a number of reasons—the side sway of the earth's rotation, the excess slope of the riverbed, or the obstructions in the channel. The real reason, however, as determined by the WES tests conducted under the direction of Capt. J. F. Friedkin, was the sediment carried by the river.

At WES, huge models of the river valley were built, using crushed coal as a bed material. Overhead cameras recorded what happened, one minute on film being the equivalent of a year in the life of the river. The channel was constructed straight as a yardstick and the water was turned into it at the upper end. In only a few minutes the river model was serpentine in shape, and within 3 hours the meanders were huge. The loops were invariably caused by water cutting sediment from a bank to initiate a bend and then depositing it farther downstream, creating a shoal; the process was repetitious all the way to the mouth of the stream.

Sediment both speeded the cutting and, when it was piled high in shoals, deflected the stream for the subsequent bankcutting. The investigation showed that the Mississippi carries enough sediment in a year to build a 10,000-mile, 4-lane highway with a 5-foot fill. When the soil was uniform, the meanders moved downstream, pushing the sediment with them, one after the other at regular intervals. In areas where the soil was not



Potamology studies

uniform, the forward edge of a bend would slow down as it reached a stratum of tougher soil, the upper edge of the bend overtaking the stalled front half, producing oxbow loops. Ultimately the model river, just like the real one, would make a cutoff channel through the narrow part of the loops.[61]

Also beneficial in the study of the river was the formation in 1943 of a Geology Division at WES, headed by Dr. Harold N. Fisk of Louisiana State University, who conducted a comprehensive geological investigation of the Lower Mississippi Valley. A report of Dr. Fisk's findings was made in 1944.[62]

During the final three months of 1945, after the retirement of Matthes, Lt. Col. Clement P. Lindner was Director. It was during this time that steps were taken to acquire the first aircraft hangar to use as a model shelter. Employees also needed housing, and in the postwar period the shortage was critical. WES began construction of apartments for its personnel as an emergency measure in November 1945. Lindner also promoted the idea of sectionalizing the big model at Clinton so the river could be studied in various parts or as a whole.[63]

The postwar era called for some master planning to accommodate the long-delayed projects which would be undertaken. Also, personnel were returning from military duty to resume their posts at WES. Additional employment was necessary to meet the increased work loads which compounded the problems of beginning new studies while at the same time providing the necessary physical plant.[64]

Serving as Director for the year 1946 was Col. Carroll T. Newton. It was during his tenure that additional property was purchased, increasing the acreage by more than 50 percent. A new access road was opened, new internal roads were built, and the old ones were improved. Extensive earthmoving was undertaken to provide large, flat areas for new model studies.

There was a shortage of materials and equipment, and war-surplus items were used in many cases. Some orders were never filled while others were duplicated, resulting in an excess of items such as lumber, hardware, electrical and plumbing needs, some equipment, and numerous portable hangars.[65]

One of the immediate improvements concerned housing for the Hydraulics Division. Models had been in a hodgepodge of wooden sheds along Durden Creek. War-surplus materials provided adequate buildings, and the Hydrodynamics Laboratory was installed in a hangar and provided with water, pumps, controls, and instruments.[66]

Changes were also made in other divisions. The Soils Division was relocated in the central portion of the main building. Some of the laboratory work was performed in a building made available a few miles away in the Vicksburg National Military Park, and expanded field office space and heavy equipment were provided near the paving test area.

Down near the main gate on Halls Ferry Road a group of orderly buildings were erected where the old sheds had been; these were used by Construction Services. Also developed was a heavy equipment yard near the pavement test pad, and new utility lines for heavy power and increased water supply were provided throughout WES.[67]

Housing construction for WES personnel, which began in the fall of 1945, consisted at first of a dozen single-family dwellings located around the WES lake, completed in the spring of 1946 despite the shortage of supplies. A second phase of construction began soon with the erection of six buildings, each containing six apartments. A trailer park was also begun. Housing was assigned according to position and need, and for a time a neighborhood store was operated by the concessionaire at WES.

Part of the project included the beautification of lands adjoining WES and Durden Creek. Bushes were cut, and a battle was begun to trap the turtles that infested the shorelines. Each week the Director of WES received a "turtle report" which, on one occasion, also listed a three-foot alligator.[68]

Changes were also made at the Clinton installation, and in mid-1946 transfer was made from military status to WES as a civil works facility. Construction of the model was changed from a manual labor operation to one of big machinery, and adequate pumps, utility lines, and water supply piping were installed.

Housing was also a problem at Clinton, and old POW facilities were converted into accommodations for engineers and technicians. Construction and maintenance were carried out as a subsidiary of the Construction Services Division at WES.[69]

An indication that WES had "come of age" was the decision in 1946 to shift direct control of expenditures from the MRC to WES personnel. Expanded activities at WES illustrated the need for direct control of cost accounting and fiscal matters. Accounts were transferred from the Vicksburg District, refined, and revised within the guidelines of the Civil Works Orders and Regulations to better reflect activities at WES. Also, buildings and fixed facilities were zoned and numbered. The numbering system helped to identify projects, reports, and applicable cost accounts. Financial forecasting and budget programming were also introduced.[70]

It was also in 1946 that a small subsidy was allotted from the Office of the Chief of Engineers for the WES library and research center as it had become evident that WES, its library, and research center were beneficial to the Corps of Engineers at large.[71]

There were other changes immediately after World War II: the library was moved to the main building from Quarters No. 1, and a "Visitors' Bureau," fire squad, and guard force were established.[72]

One of the most important events in the postwar years was the establishment of the Concrete Research Division at the Clinton facility in 1946. The Concrete Division had its origin before WES was established when construction projects in the Mississippi Valley were undertaken in the 1920's. Vital work included the building of the Bonnet Carré Spillway and planning for the Passamaquoddy Tidal Power Project in Eastport, Maine. A laboratory functioned at Eastport until 1936 when it was moved to the U. S. Military Academy at West Point, N. Y., and was known as the Central Concrete Laboratory of the North Atlantic Division, Corps of Engineers. There in 1939 a study was begun on the role of cement variation on the durability of concrete. Soon afterward further studies of air entrainment in concrete and of alkali-aggregate reaction were undertaken. Such efforts necessitated the employment of chemists, engineers, and geologists.

When Pearl Harbor was attacked 7 December 1941, it was decided to move the Concrete Laboratory from West Point to Mt. Vernon, N. Y., where it was installed in March 1942. During the war, working with the National Bureau of Standards, the laboratory carried out sampling, inspection, and testing of all portland cement manufactured in New York and in New England that was used for Government projects both at home and overseas. It also conducted, in cooperation with the Ohio River Division Laboratory, the initial research and development of membrane-forming compounds for curing concrete, especially military airfield pavements. At the close of the war, studies were begun for civil works construction, primarily for flood control.[73]

Brig. Gen. James H. Stratton, Director of Civil Works for OCE, sent a memo to the Division Engineer of the Lower Mississippi Valley on 16 December 1945 concerning the work at WES. He stated that WES was relied upon for many model studies and much technical information and concluded:

> *With an increase in our Civil Works program expected in the near future, it is believed that the work load will be materially increased at the Experiment Station. Therefore, this office considers the present time opportune to analyze existing conditions at the Station with a view to taking such action as is deemed necessary to meet present commitments and future requests.*[74]

Several months later, 23 February 1946, WES Director Col. C. T. Newton sent a memorandum to the President of MRC including a comparison table of the Clinton and Vicksburg facilities with a view toward consolidation or expansion. Gen. R. W. Crawford, MRC President, sent a report to the Chief of Engineers in Washington on 2 April 1946 stating that C. E. Wuerpel of the Central Concrete Laboratory in Mt. Vernon had just visited the Clinton and Vicksburg facilities; Crawford believed that moving of the Concrete Laboratory to Clinton from New York would provide close coordination of work, that good facilities were available, that it should be done as soon as possible, and that the estimated cost was $250,000. A few weeks later, 18-19 April, a conference was held at Vicksburg and Clinton concerning a comprehensive development plan.[75]

The moving of the Concrete Laboratory to Clinton in 1946 consolidated and centralized research facilities within the Corps of Engineers. The Clinton installation provided the Corps with spacious facilities for research and testing. Existing buildings at the old POW camp were used, and in addition a modern laboratory was established with chemical, geological, petrographic, microscopic, dynamic, and physical testing facilities and equipment. Key personnel were brought from Mt. Vernon to Clinton, and by late summer of 1946 the Concrete Laboratory was in operation.[76]

A summary of activities published at the conclusion of 1947 gives an indication of the scope of activities at WES: the huge hangar buildings had been completed, the new Soils Laboratory was being installed in the old WES main building, a new administration building was under construction, an agreement had been reached with Louisiana State University for training students in engineering, new facilities on top of the hill were nearing completion, roads on the reservation had been surfaced, the store and post office were completed, and 36,000 visitors had toured WES during the year.

Concrete Division office and laboratory building, Jackson Reservation, 1946

Interior of Concrete Laboratory, 1946

Approximately 1,300 people were employed at WES.[77]

Although World War II had been over for several years, WES was used after the shooting had stopped to win a different type warfare—the Cold War. Since the Allied victory over the Axis powers, the United States had been threatened in a war of wits with the Soviet Union. The four major Allied powers—the United States, France, England, and Russia—had agreed to share control of Germany with each having a zone; the capitol city of Berlin, though surrounded by Russian territory, was also zoned. However, the Russian Government showed intentions of squeezing the free nations out of Berlin and controlling it and eventually all of Germany.

On 24 June 1948 Russia launched a move to starve Berlin into submission. All traffic between the Western or Allied zones and Berlin by rail, highway, or canal was banned. President Harry S. Truman, in collaboration with France and England, determined to supply the besieged city by airlift; and countless planes, regardless of the weather, winged their way through narrow air corridors across the Russian zone to and from Berlin.

But there was another problem: runways at the Berlin airports in the Allied zones were inadequate. During World War II, the Germans had not paved the runways; but when the war was over, the large American bombers and cargo planes required hard-surfaced airstrips. At Tempelhof in the American zone, one surfaced runway was constructed. With the entire burden of supply upon the airlift, however, this proved inadequate. Hemmed in and cut off from conventional materials used in airport construction such as sand, slag, and gravel, the Army engineers had undertaken the paving of two additional runways at Tempelhof. There was only one material readily available—an abundance of rubble from the bombed-out portions of the city. But runways had never been built of brickbats before, and the problems were legion. All machinery needed would have to be flown in through the airlift, and technical phases of construction would have to be left to guessing.

Engineers in Berlin sent their requests for information to the Office, Chief of Engineers, in Washington, and the problem was relayed to WES. Charles R. Foster, Assistant Chief of the Flexible Pavement Branch of WES, was sent to Berlin along with his instruments on one of the airlift planes from Frankfurt, replacing 13 sacks of coal. Once in Berlin where he could study the problem, he made recommendations concerning the density of aggregate and the amount of asphalt needed to complete the landing strips.

Using only the brickbats which had been piled up in more than three years of cleanup operations by the German people, the subgrades of the runways were laid 18 inches thick. More than a million cubic yards of the aggregate was used; on top of this was applied a penetrating surface "icing" of macadam. With the testing instruments, all of which were designed to show weights, stresses, and strains which the airport surfaces could safely handle, Foster was also able to help the French with their problems at Tegel Field in Berlin.

Because of technical help from WES, "Operation Vittles," as the Berlin Airlift was known, was doubled in a short time. The Russians lifted their blockade on 17 May 1949 after having been beaten in a major encounter of the Cold War, thanks partially to the help provided by WES.[78]

Its part in the Berlin Airlift was just

one of many examples showing that WES, though under the jurisdiction of the MRC, was vital to all Corps organizations. On 7 July 1949, MRC President Brig. Gen. P. A. Feringa announced that jurisdictional transfer of WES was being planned in the interest of coordinating the Corps' investigational activities on a nationwide basis. The move had been considered for some time, he said.[79] The transfer of WES, putting it under direct control of the Chief of Engineers, was announced on 9 August 1949, to be effective the following day. WES Director Col. R. D. King made the announcement:

> *The Waterways Experiment Station will now exercise technical supervision over all hydraulic model tests, whether performed at that installation, other Corps of Engineers' laboratories, or at university facilities; and over such concrete and soils investigations as may be directed by the Chief of Engineers. It is intended further that the Director will coordinate all testing programs, except testing of a routine nature normally performed in division laboratories, to insure that the capabilities of all Corps of Engineers' civil works experimental facilities are effectively utilized.*[80]

Under the new organizational structure, the Director would have delegated authority equivalent to that of a Division Engineer.[81]

As WES entered the 1950's, it was 20 years old. First envisioned as a building on a barge to be towed up and down the Mississippi, it had evolved into a sprawling reservation where a nucleus of engineers and scientists delved into problems of hydraulic engineering as well as soils and paving. Now it was no longer a branch of a parent organization but had equal standing with other governmental agencies.

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36. Newspaper clipping dated October 16, 1944, in WES archives.
37. Vicksburg *Evening Post,* 1945, no date given.
38. Newspaper clipping (see footnote 36 above).
39. Interview with Joseph B. Tiffany, Jr., "Mr. WES," December 3, 1975, Vicksburg, Miss.
40. Shreveport *Times,* September 21, 1947.
41. Vicksburg *Sunday Post-Herald,* September 21, 1947.
42. Shreveport *Times,* September 21, 1947.
43. Vicksburg *Sunday Post-Herald,* September 21, 1947.
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49. Ibid.
50. Vicksburg *Evening Post,* June 17, 1969.
51. *Times-Picayune,* January 16, 1944.
52. Edgar Poe, "Giant Test Tube For Ole Man River," *New York Times Magazine* (December 17, 1944), pp. 10, 37.
53. *Times-Picayune,* January 16, 1944.
54. Ibid.
55. Ibid.
56. Ibid., November 7, 1943.
57. Ibid. Among the German generals in Clinton camp was Gen. Dietrich von Choltitz who gained fame for his refusal to destroy Paris when Hitler ordered him to do so. The best-selling book, *Is Paris Burning?* by Larry Collins and Dominique Lapierre (New York: Simon and Schuster, 1965), was based on von Choltitz's action, or in Hitler's opinion, lack of action.
58. Ibid., January 16, 1944. Another WES employee, Karl Dupes, who supervised the layout of templates, found himself in a reverse role at the POW camp: in World War I he had been a prisoner of the Germans. Interview with Joseph B. Tiffany, Jr.
59. Memo from Gerard H. Matthes, WES Director, July 2, 1945, on file in WES archives.
60. Vicksburg *Evening Post,* September 12, 1945.
61. Ibid., August 6, 1945.
62. Tiffany, *History of WES,* p. VI-7.
63. Ibid., p. IV-6.
64. Ibid., pp. IV-6, 7.
65. Ibid.
66. Ibid., p. IV-8.
67. Ibid.
68. Ibid., p. IV-9.
69. Ibid., pp. IV-9, 10.
70. Ibid., p. IV-11.
71. Ibid.
72. Ibid.
73. Ibid., pp. VII-1, 2.
74. Letter from Brig. Gen. James H. Stratton, to Division Engineer, Lower Mississippi Valley Division, Corps of Engineers, Vicksburg, Miss., December 16. 1945. On file in WES archives.
75. Memorandum on file in WES archives.
76. Typewritten news release on file in WES archives.
77. Vicksburg *Evening Post,* January 1, 1948.
78. Vicksburg *Sunday Post-Herald,* November 28, 1948. Also see Arthur S. Link and David S. Muzzey, *Our American Republic* (Boston: Ginn and Co., 1966), pp. 647-648.

79. Vicksburg *Evening Post,* July 7, 1949.

80. Ibid., August 9, 1949.

81. Ibid.

CHAPTER IV: SWORDS AND PLOWSHARES: 1950-1959

WES was busily engaged in its research and tests in a variety of civil works programs, some new and some continued over the years, when an abrupt change took place in the summer of 1950. On 25 June, North Koreans invaded the Republic of Korea, more commonly known as South Korea. Almost immediately the Security Council of the United Nations condemned the action of the communist aggressors, and President Harry S. Truman responded by ordering American units into the fighting to help South Korea.[1]

Though the attack, like that of 1941 at Pearl Harbor, was not expected, Americans were more prepared for such a conflict, for reserve units stood in readiness. One such was a WES unit, the 434th Engineer Construction Battalion of the Army's Organized Reserve Corps, established in 1948.[2] On 19 August 1950, the 434th was called to active duty, one of two in Mississippi and also one of the first in the nation. When 70 reservists from WES left for training at Fort Carson, Colorado, a short time later, the local newspaper noted that "Their entry into active status brings the Korean War forcibly home to Vicksburg...."[3]

When the 434th was organized, Lt. Col. Ralph D. King, Director of WES, had been instrumental in having WES sponsor it. Commander was Lt. Col. Eugene P. Fortson, Jr., who in civilian life was Chief of the Hydraulics Division at WES; during World War II he had served with the 3rd Military Railway Service in Iran. WES facilities had been used for training, and the battalion functioned under the general supervision of the Third Army in accordance with policies and procedures established for the overall Reserve Training Program.[4]

From Vicksburg, the 434th went to Korea as part of the 32nd Engineer Construction Group after four months of training in Colorado. They sailed for Korea on 4 January 1951 and arrived at Pusan on 8 February after a 3-week stopover in Japan to secure more organizational equipment.

The military training at WES paid off for the 434th. Working in extreme weather conditions and in danger from guerilla activity for much of the time, they made an outstanding record. Much of their work involved rebuilding war-damaged roads, bridges, and railroads and constructing new ones essential in the drive of the United States troops toward the 38th parallel, which divided North and South Korea.[5]

Vital to American forces were the supply routes from Pusan to central Korea during the fighting around Wonju, and the 434th was given much of the credit for rebuilding and maintaining those routes. The battalion literally blasted its way through narrow, rocky, and winding portions of the main route in order to bring its heavy construction equipment into necessary areas; personnel from the Eighth Army in Japan had thought it an impossible task.

Within less than a year, the 434th had written an enviable record. They had left jobs where they worked with model rivers and miniature bridges and harbors to tackle the lifesize job of building bridges and roads across the Korean landscape, patterned with mountains and valleys and rivers. In their first six months in Korea, the 434th widened and surfaced 255 miles

The 434th Engineer Construction Battalion assembled on a bridge constructed in weekend exercise at WES Suboffice at Jackson, in 1950 of road, rebuilt 109 highway bridges, and repaired or rebuilt 25 railroad bridges. Major accomplishments were the construction of the 842-foot Han River Bridge at Tanyang, the reconstruction of railroad bridges at Andong and Tanyang, and the completion of a standard, two-lane highway through the mountainous Tanyang Pass.[6]

One of the most spectacular jobs was the building of a bridge at Naesong, Korea, a structure vital to the town in peacetime as well as in war, for it was the only connecting link between Naesong and the rich farmland to the west which furnished the town with a major portion of its food. Invading North Koreans had destroyed the bridge, and the townspeople had attempted to repair it, but to no avail. Naesong faced the possibility of becoming a ghost town; then the men from Vicksburg arrived. Thirty days had been allotted for the 434th to rebuild 10 bridges between Kumjong and Naesong of which the Naesong bridge was the largest and most important, for over it would move necessary supplies to increase the strength of U. S. forces.

On the day that the structure was completed, the townspeople planned a ceremony with much speechmaking. A platform was erected in the center of the span, and the entire bridge was festooned with pine and cedar boughs. A triumphal arch of similar material was located near the east end of the bridge at the entrance to the town. All local officials, from the mayor to the chief of police, made short talks in which they simply and sincerely thanked the Americans. Several engineers from the 434th, including Major John J. Franco, answered and reminded them that only through the cooperation of the local people was such a quick job accomplished. Later a grand parade was led by Korean dancers, who escorted the engineers on a tour of the town. A local school band furnished martial music, and the day was climaxed with a banquet at which Korean cuisine was served.[7]

In December 1951, Major Franco took command of the 434th when Col. Fortson was rotated for assignment in the United States. Franco was a veteran of four years in World War II and one of the original cadre of the 434th called to active duty in 1950. He had served as battalion adjutant and executive officer before taking command of the unit. He remained commander until June 1952 and was one of the last of the original troops to return home.[8]

When the Han River was bridged in the winter of 1952, the feat brought national fame to the 434th. With the river in flood and a drenching rain falling and high winds swaying a nearby temporary structure, the job was completed. The most vital girders were set in place in a record 22 hours, which was the longest traffic delay in the entire operation. Vital military traffic had continued to move over the temporary structure.[9] Fortson wrote of the incredible accomplishment that it was "admittedly due in part to the fortune that favors the bold."[10]

During its service in Korea, the 434th, which was one of the three battalions in the 32nd Engineer Construction Group, completed 65 percent of all railroad bridge work and 52 percent of all highway bridge work accomplished by the entire group. In addition, 330 miles of roads in its assigned areas were maintained by the WES engineers.[11] The performance of the 434th was so outstanding that it was given a Meritorious Unit Commendation, presented by Gen. James A. Van Fleet, Commander of the Eighth Army in Korea. He said:

The 434th Engineer Construction Battalion is cited for meritorious conduct in the performance of outstanding services in support of combat operations in Korea during the period 21 February to 30 October 1951. Despite seemingly insurmountable obstacles engendered by the most adverse weather and terrain and the frequent activity of the enemy, this battalion successfully accomplished its vital mission of reconstructing, improving, and maintaining the severely damaged railroad and highway main supply routes supporting the United Nations units fighting in Korea. Through the resourcefulness, outstanding ability, and aggressive determination of its members, this battalion, working under the constant strain imposed by the unprecedented magnitude of its tasks, completed timely repairs on many badly damaged railroad bridges, including bridges at Andong, Tanyang, and Wonju, thus contributing immeasureably to the continuous and effective logistical support of combat units during this critical phase of hostilities. Tasks thought impossible by higher headquarters were approached by the members of this battalion with the utmost self-assurance and carried out in the finest traditions of the Corps of Engineers. The 434th Engineer Construction Battalion displayed such outstanding devotion to duty in the performance of exceptionally difficult tasks as to set itself apart and above other units with similar missions. The superb technical skill and unstinting endeavor of the members of this battalion reflect great credit on themselves and the military service of the United States.[12]

The impact of the Korean War on WES was severe. Civil works activities were curtailed and over 100 civilian employees were eventually called to service with the 434th. In addition, many more were members of the National Guard, which was called to Korean service, and others went individually rather than with units.[13]

The arrival of a new director for WES, Col. Herrol J. Skidmore, coincided with the departure of the men for Korea, and many key WES personnel were included. Col. Skidmore wrote in later years:

> *My anxiety at their departure proved groundless. I soon found that WES was organized in such depth and of such calibre personnel that every new problem could be adequately staffed, promptly attacked, and properly solved. Nowhere have I seen the motto of the Corps of Engineers, "Essayons," exemplified to better purpose than at WES in 1950-1952. We not only landed on our feet, we landed running! For the fine showing made at that time, and since, I can take no credit. The technical and administrative staffs met every assignment willingly and capably. I cannot single out individuals to compliment; it was a team effort that produced the results. I consider myself most fortunate to have been assigned to WES during that trying, and rewarding, period.*[14]

With the transfer of WES from under the MRC, some wondered if perhaps the operations at WES would not have to be curtailed. Col. Skidmore directed a search for new areas of activity, and the scope of operations continued to expand.[15] A "Statement of Capabilities," published by WES, led to many projects, including work for the Atomic Energy Commission and other elements of the Department of Defense than the Corps of Engineers.[16]

One of the efforts was a series of light intensity explosions, the first of which was fired in mid-December 1950. Col. Skidmore advised that more blasts at various intervals could be expected in the following months. The first of the blasts was heard no more than a half mile away. No explosions were planned which would be large enough to break windows or cause other damage to adjoining property. Skidmore said that their nature could not be divulged, but the tests were nonatomic and were a contribution to the national defense effort.[17]

Small underwater TNT explosion in WES test basin

The blasts, designed to model nuclear explosions, were conducted to determine the effects of very large explosions in shallow water, with depths typical of those found in principal harbors of the U. S. By September 1951, part of the secrecy which at first cloaked the experiments was lifted, and WES engineers revealed that the studies were concerned with the defense of harbors. WES described the blasts:

> *If you've ever shot firecrackers in a mud puddle, you have a vague idea of how they are calculating the force of a bomb blast in New York Harbor. With miniature explosions in a miniature basin, they're stockpiling data for a day when the future of free men might hang by the thread of a quick and accurate decision.*[18]

The data compiled in the tests were applicable to harbors such as New York, San Francisco, New Orleans, or Philadelphia. The findings, basic to any blast whether atomic or conventional, could also be used to anticipate effects from every type of explosion in shallow water typical of harbors, estuaries, and continental shelf regions along the American coastline. The results would possibly aid in design and protection of vital but vulnerable harbor facilities during war.

Conducting the tests were veteran engineers Guy L. Arbuthnot, chief of WES' Special Investigations Section, A. H. Barnes, and John N. Strange. For their test-tube blasts, they applied the same theories which were used in other problems—scaling them down in size to miniature. Reproducing every conceivable natural condition in a model harbor, they recorded shock waves, cratering effects, the size and periodicity of surface waves, pressures, and various other phenomena required for accurate transfer of the findings to "real world" problems.

The laboratory for these experiments was a keyhole shaped basin located in an isolated area on the WES grounds. A small

Airblast gage array used in underwater explosion tests at WES Big Black test site

frame structure sheltered the necessary electronic and photographic instruments used to chart effects of the blasts, and approximately a hundred yards beyond it was a general purpose office building, where results were tabulated and studied.

Charges ranged from firecracker size to a few tens of pounds, and analysis of these detonations provided a pattern for calculating probable effects from any size explosion. The explosive used in all tests was trinitrotoluene (TNT), chosen because of its uniformity, high detonation rate, and safe handling characteristics. The tests were designed to model the effects of nominal-size nuclear explosions and to provide a method for predicting full-scale effects. The study was assigned to WES by the Department of Defense.[19]

The explosions also served another purpose: an investigation of specially designed electronic and photographic equipment for measurement and recording of test results. Prominent in the instrumentation development efforts were Messrs. Eugene Woodman, Francis Hanes, L. H. Daniels, and L. F. Ingram.[20]

During the next several years, the blast tests were staged more or less continuously, and in 1958 they were being carried out in the Big Black River swamps near Vicksburg. Blasts involving up to several hundred pounds of TNT were conducted at the Big Black Test facility. The area was blocked off and patrolled to ensure safety, and local residents were assured that blast levels would be kept sufficiently low to preclude off-site damage. In fact, following the first blast in November 1957, the only casualties were a severe case of poison ivy and one thorough dunking in the river. At the first blast, the plume was over 300 feet high with a column of water 50 feet in diameter at the base.

At the Big Black site, a shallow-water basin simulating a reservoir with a concrete dam in place was used for the scaled-down explosions. Various types and amounts of high explosives were used, detonated at different standoff distances from the dam. Instrumentation designed especially for the project recorded strain and movement within the concrete dam as well as water shock. The entire operation was filmed by a high-speed camera running at 4,000 frames a second plus a battery of other movie and still cameras. A sequence camera was used for taking large still photographs as fast as a movie camera. These pictures, made from 2-1/4 x 2-1/4 negatives, were shot at 25 frames a second with an exposure of 1/3000 second.[21] The experiments were made for the purpose of learning something about the vulnerability of dams to explosion attack.

The Weapons Effects Laboratory (WEL) and its predecessor organizations have played major roles in both the conduct of and technical participation in numerous large-scale weapons effects tests. The first such tests involved a 50-ton TNT explosion in the Sevier Bridge Reservoir in Utah in 1953. This test was a joint effort between WES and the U. S. Naval Ordnance Laboratory. At that time, it was the largest nonnuclear underwater explosion that had ever been performed.

Over the years WES has participated in a number of nuclear experiments at the Nevada Test Site (NTS) and the Eniwetok Proving Grounds (EPG) in the Pacific Ocean. At EPG, WEL had projects on the UMBRELLA Event of Operation HARDTACK. Participation at NTS included Events JANGLE S and U, TEAPOT ESS, PRISCILLA, TINY TOT, DANNY BOY, JOHNIE BOY, LITTLE FELLER I, LITTLE FELLER II, SMALL BOY, SEDAN, DISCUS THROWER, NEWPOINT PINSTRIPE, MIGHTY EPIC, HARD HAT, PILE DRIVER, HYBLA GOLD, and DIABLO HAWK. The WES Concrete Laboratory provided grouting services for many of the NTS events. Significant among these were HARD HAT and PILE DRIVER.

WEL conducted ground and water shock measurements at Amchitka Island in the Aleutians on the first nuclear test at that site (Project LONG SHOT).

Numerous large-scale, high-explosive tests with yields up to 600 tons have been managed, directed, and participated in by WEL engineers and scientists. Among them are SNOWBALL, the DISTANT PLAIN Series, PRAIRIE FLAT, DIAL PACK, the MINE SHAFT Series, the MIDDLE GUST Series, the Pre-DICE THROW Series, DICE THROW, the HARDROCK SILO Tests, and the ESSEX Series.

Test sites included the Greenland icecap, the plains of Alberta, Canada, the arid regions of the great Southwest, sites in the Rocky Mountain region, the salt domes in the southeastern part of the United States, and one of the beautiful lakes of the Ozarks (the Lake Ouachita Test Series).

A fascinating set of experiments was conducted during the summer-fall seasons of 1965 and 1966 in MONO LAKE near Lee Vining, Calif. These tests, commonly known as the MONO LAKE Experiments, were conducted to study the magnitude of the water-surface wave problem that results from underwater explosions on or near the rim of the continental shelf. Wave systems generated by large-yield explosions in such locales produce large wave systems that are

Underwater explosion at Mono Lake, California. Mono Lake was chosen because it contains no marine life except tiny shrimp, is located in a remote area, and has no commercial or recreational value

capable of shoreline inundation; it was this aspect of the problem that received the attention of the principal engineer-scientists involved—John N. Strange and Murray Pinkston. The MONO LAKE tests involved the detonation of 5-ton TNT spheres placed at various depths of submergence and then detonated. Wave amplitude-time measurements were made along radials that ran shoreward or along radials of near-constant depth. The MONO LAKE Experiments provided definitive information on explosion-generated wave phenomena, and prediction methods were developed that enabled the forecasting of wave dimensions resulting from large explosions in the deep ocean and near continental shelves.

Project Gnome, the first atomic test with a peacetime purpose, took place in a salt dome some 25 miles southeast of Carlsbad, New Mexico. The explosion was preceded by a series of high-explosive experiments, labeled Project Pre-Gnome.[22] The primary purpose of the operation was to determine the practicability of producing power and possibly isotopes as a result of underground nuclear explosions. Secondary purposes were to measure ground motion and to obtain basic scientific data.

Other WES work in connection with Pre-Gnome included the design and laboratory testing of special cement grout mixtures and the supervision of their placement at the project site. James Polatty and Ralph Bendinelli of the Concrete Laboratory served as consultants and technical advisors in connection with the grout work which had to be performed prior to the actual full-scale Gnome operations.

The Gnome testing was only one of several in which WES personnel participated; others included explosions in Nevada and the Pacific.[23] A former WES director was also taking part in nuclear advancement; Brig. Gen. Kenneth E. Fields, who was Director from September 1939 until December 1941, was named General Manager of the Atomic Energy Commission (AEC) on 14 April 1955. Fields had been associated with the atomic energy program for eight years, both with the Commission and the Manhattan Engineer District. Since 1951, he had served as AEC Director of Military Application after having been assistant from 1947. Fields was credited by the AEC with having "borne primary responsibility for the great improvement in the Nation's position in nuclear arms" during the four years preceding his appointment as General Manager.[24]

In another project of the atomic age, WES engineers were responsible for the field work and design support for the Savannah River hydrogen bomb plant.[25] In estuary models, constructed primarily to study siltation, radioactive tracer materials in the water provided direct observation of sediment transport by studying the distribution of the low-grade radioactive tracer.[26]

Using a model of the Savannah River at WES, Dr. Carlos G. Bell, Jr., a Northwestern University scientist, conducted studies in the spring of 1952 to determine river radioactivity. Findings would be important, he said, for nuclear power plants of the future would be built more and more along rivers which furnished water for drinking, navigation, and industrial use. Using water made from radioactive hydrogen, Dr. Bell injected tiny measures of this liquid into the flowing stream of the model river. The diluted mixture was too weak to excite a Geiger counter; yet extensive precautions were used in the tests, and the building which housed the river model was closed to all except a few who assisted Dr. Bell with his tests. At a dozen or more checkpoints Bell took one-ounce samples at a predetermined frequency, marking each with the time and location. The samples were analyzed at Northwestern's laboratories and the radioactivity measured. The data gathered would help in an understanding of what contamination levels could be expected from a nuclear detonation. The study at Vicksburg was the first of its kind—a truly pioneering step.[27]

Even though the Nation was at war in the early 1950's, civil works project tests continued, and while a hot war was being waged in Korea, the peacetime contributions of WES were broadcast to Europeans on both sides of the Iron Curtain in 1951 over the Voice of America.[28]

One of the most spectacular models built during this era at WES was that of Niagara Falls. Engineers, directed by Eugene P. Fortson, built and studied the model to determine what effect, if any, a huge power development plant might have on the famous tourist attraction. The objective at the real falls was to generate nearly eight billion more kilowatt hours of electricity without sacrificing the falls' grandeur.

Water in the miniature model flowed from a make-believe international boundary, then hurtled over rock-studded rapids and dropped into a mist-shrouded chasm spanned by a tiny bridge. Every significant feature of the Niagara River

Niagara Falls model

from the time it left Lake Erie until it passed beyond the rapids on its way to Lake Ontario on the Canadian-United States border was reproduced. Built to scale, the model compressed 23 miles of the river's length into a bed that was 260 feet long and scarcely more than a running jump wide. Its contours matched those made by nature, and in the lower reaches clusters of diversion gates marked the location of existing and proposed generating plants.

A 1950 treaty between Canada and the United States provided first for the continued beauty of the falls and then for the utilization of surplus water for power development. It established a formula that determined the minimum amount of water that must be allowed to pour over the falls.

The model at WES was designed to check against any possible error in the new diversion formula and to establish the most efficient installations for the power intakes. Nothing was left to chance; engineers even floated ice cubes across the cascades to reproduce winter conditions in the river.[29] Through the years, the Niagara model has been one of the most popular sites at WES for tourists.

Another series of far-reaching tests conducted at WES concerned the building of the St. Lawrence Seaway. As far back as 1945, engineers at WES were conducting channel experiments on a model of the St. Lawrence River; they threw confetti into a miniature stream and a still camera photographed it in the swirling rapids. When the pictures were printed, the confetti was reproduced as white lines representing the current flow through the main channel and the trick eddies. A fisherman from the St. Lawrence River was brought to Vicksburg to help in working out locations of currents and large boulders for the study.[30] In the 1950's, two models were built of the St. Lawrence, one to be studied for eliminating a complicated navigation hazard and the other for testing difficult dredging problems.[31] Conducting the studies was Ernest B. Lipscomb, Jr.

The St. Lawrence Seaway, a $300,000,000 project, was one of the biggest peacetime undertakings in years and was designed to link the Great Lakes with the Atlantic. The problems which were studied at WES were in a 55-mile stretch of river called International Rapids.[32] Drill rigs from WES were sent to Massena, New York, where boring and drilling surveys were made in the Cornwall-South Central reaches of the river. The models were constructed in Vicksburg for the Buffalo District, agents for the St. Lawrence Seaway Development Corporation.[33]

Another river project, one much closer to home, was the vast model of the Mississippi River at Clinton; and though it was only half completed in 1952, it proved its worth during the Missouri River flood of that year. By simulating the flood conditions on the model, predictions of the time and occurrence of the flood crest along the endangered levees were made a week in advance and with extraordinary accuracy. The predictions were a major factor in preventing an additional $65,000,000 damage to the Sioux City-St. Joseph area, for on the basis of the forecast, emergency crews were switched from areas previously thought endangered to those pinpointed by the model.

The Missouri River flood was the first major test for the big model, and luckily that portion of the valley had been completed. Engineers in the Omaha and Kansas City Districts of the Corps of Engineers called WES and provided WES engineers with predictions of the snow-ice melt runoff, plus the additional runoff expected from forecasted rainfall. A total of 70 or more phone calls were made, and Henry C. McGee, the model's project engineer, said "We fought the flood as hard as they did along the Missouri River."[34] Operating around the clock for 16 days, WES fired stage predictions back to the Missouri Valley personnel; and engineers on the scene were ordered to build levees along areas which they had not thought to be critical. The model's predictions proved correct.[35]

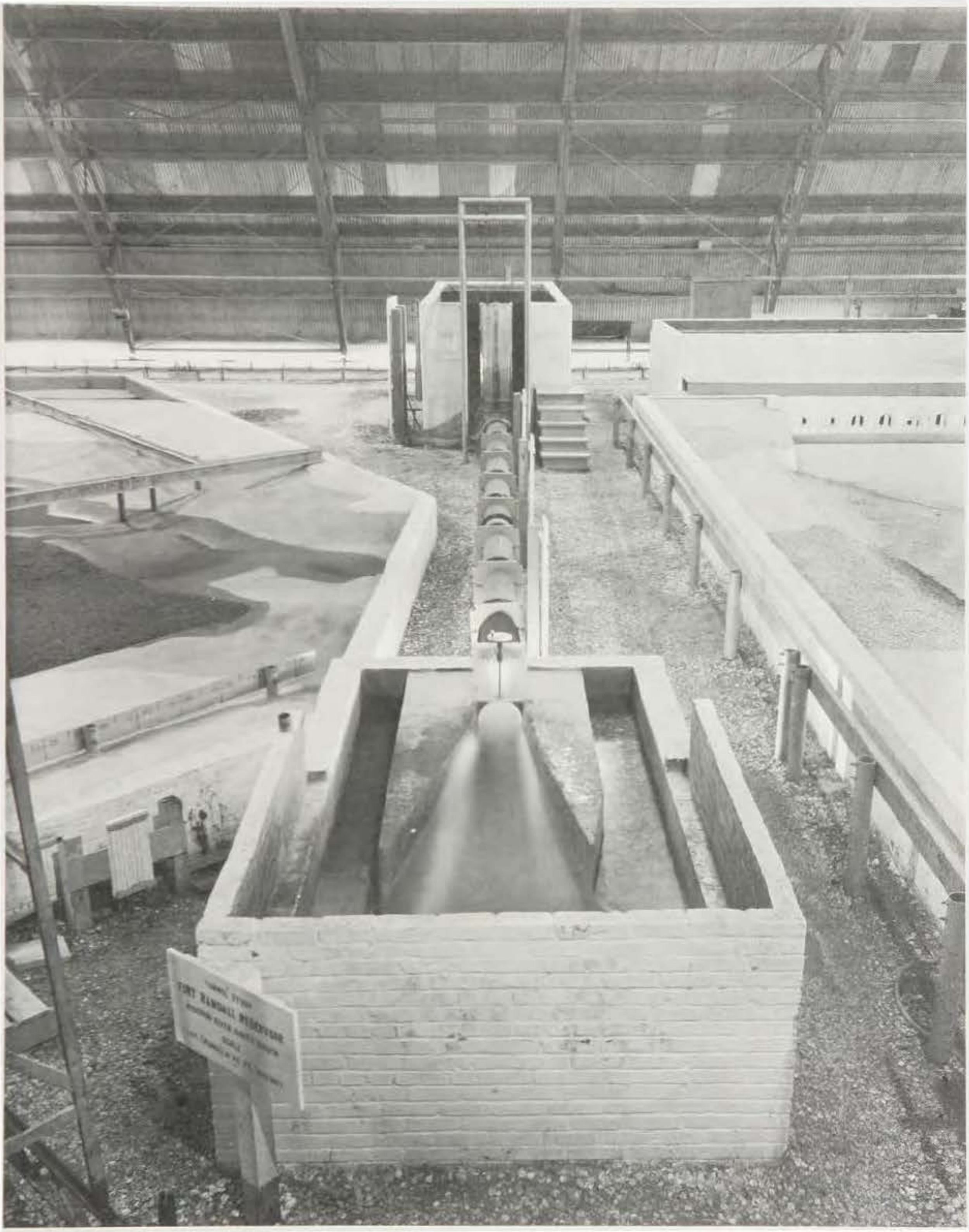
The accuracy of the model had a direct influence on the future of the Corps of Engineers, for the Hoover Commission had recommended that civil works projects be placed under the jurisdiction of the Department of the Interior. President Truman was reportedly ready to sign the measure when Gen. Lewis A. Pick, Chief of Engineers, persuaded the President to fly over the flooded area. Truman was so impressed by the work the Corps of Engineers had performed that he flew back to Washington and abandoned his plans for transferring jurisdiction.[36]

Civil Works programs during the 1950's included a number of projects. For example, a model study was made of the Greenup Locks and Dam to determine the best arrangement and method of operation to eliminate any undesirable flow conditions which might hamper navigation;[37] a dam model for Fort Gibson resulted in a saving of $375,000,[38] and harbor model studies of the Lake Superior shoreline at Two Islands, Minn., determined how to provide the area with smooth water for ships loading and unloading taconite, a low-grade iron ore which could be vital in supplying the world's steel needs.[39]

Another "first" for WES was the testing of a tunnel at Fort Randall Dam on the Missouri River in South Dakota. Testing of the tunnel provided information on friction factors and turbulence to aid in future dam design. The tunnel was 861 feet long and had a diameter of 22 feet; water flowed through it at rates up to 48 miles per hour. A strut 22 feet long was required to place the measuring devices, and since no such instrument was on the open market, F. B. Campbell designed one. The National Aeronautics and Space Administration tested the strut in a wind tunnel to ensure that the strut would not vibrate (or flutter) unduly. Fifteen instruments were installed within the tunnel to measure flow turbulence, velocities, and pressures. In addition, two small 12-inch struts extended from the walls to measure the near-wall velocities. Pressures were measured by 36 piezometers.[40]

One of the busiest rivers in the United States, the Ohio, was the subject of model studies when WES built a concrete model of the damsite near Markland, Ind., where a $68,000,000 high-lift lock and dam were proposed to speed traffic on the stream midway between Louisville and Cincinnati. The model reproduced the dam and two miles of the river on both sides. The dam would replace five low-lift locks and dams and create a pool extending 90 miles upstream. Plans for the dam included two locks instead of the standard one in each of the existing Ohio River dams.[41]

In the model, dam, piers, spillway, and lock walls were built of wood treated with waterproofing. A working model towboat, twin screws, powered with electric motors from batteries in the model barges, was used in the experiments. Rudders of the boat were operated electronically by remote control. The



Fort Randall tunnel model

actual dam was planned as a crested gate type with twin parallel locks with provisions for the development of a power plant. The model at WES showed that large boats would have no difficulty passing a chute that channelized ice and driftwood, but that small boats would have trouble. When the water on the model was high, tows passing downstream needed a straighter bank on the south side, and the model showed that dredging would be needed in that area. Experiments pointed out the feasibility of reducing the gates from 13 to 12; objectionable eddies were shown below the power plant, but these could be removed by opening the third gate riverward from the locks; the right bank would have to be dredged also to reduce stream velocities there.[42] These test results were typical of the problems which model studies at WES solved before actual construction began and changes were too late.

An unusual model built in 1956 was of interest to fish and wildlife officials and also to farmers. It was Vermilion Bay, located in the heart of Louisiana's rice and Cajun country. The problem was converting the huge bay from salt water to fresh water; it also involved one of the State's best game preserves where millions of migratory waterfowl winter and where some of Louisiana's offshore shrimp and oyster reserves are spawned. Strangely enough, the region experienced annually one of the heaviest rainfalls in the country. But the vast irrigation for the area's rice farms was already critical during the dry months and would no doubt become greater as production was expanded.

Engineer Henry B. Simmons at WES explained that rice required irrigation from April through August and in its early stages could tolerate only a trace of salt water. As it matured, the concentration could reach one-seventh seawater, but any greater amount was dangerous. In nature, Vermilion Bay practically reversed this routine. In late winter and early spring when surface runoff from the bayous was greatest, the bay would be almost pure fresh water. But during the dry months when water was needed the most for the rice fields, the bay became so salty that by July and August it was about a third seawater.[43]

The WES model was built inside a shed where a day was represented as 7-1/2 minutes long, a year as 45-1/2 hours. It was 18,000 square feet in size, representing 1250 square miles. The necessary distortion in the model's scale was the real headache for engineers. Horizontal dimensions were reduced 20 times more than were vertical dimensions. In order for the model to have had the same vertical and horizontal scale, the overall size of the model would have needed to be increased by 400 times. Such a size, plus housing for it, would have been prohibitive in cost. Building the model took three months, but collecting data on the salt content of the water in nature took two full years. To try to hold the fresh water in and the salt water out of the model, a dike was constructed at Southwest Pass. Tests were conducted to see how this dike would affect the salinity of the water in a dry year and then in a wet one. The dike proved effective.[44]

While farmers were concerned with growing rice, forestry officials were anxious about timber, and they turned to WES for help in 1954. The Vicksburg Infiltration Project, studying soil and moisture conditions, showed that the kind of soil conditions that would cause an Army tank to bog down could also be related to how rapidly trees grow in the area and the mobility of vehicles used in thinning timber.[45]

Another WES project in the 1950's concerned mapmaking—not ordinary maps, but ones that would read like books. The "all-knowing" maps were slated to be the end result of a new aspect of military science called "Military Evaluation of Geographic Areas." Knowing that the forces of nature could affect the movement of troops in scores of ways, WES engineers and scientists developed a process of classifying the information so that it would be concise and readily available. Such maps would be vital in warfare, with troops moving swiftly from one continent to another and to remote areas of the globe. In the past, weather conditions often determined the outcome. Mud controlled the tactical situation in World War I on the entire western front at times; volcanic ash almost halted the invasion of Iwo Jima in World War II. Nature always played an important role.

In the WES map studies, led by W. G. Shockley, military records of recent wars and maneuvers were combed to discover what elements of nature affected all sorts of military operations and to what extent. The data could supply vital information for those who planned and executed military operations. On the map before them, they would know about the density of forests, the problem of insects and poisonous snakes, soft soil, and scores of other important situations.[46]

Work at WES was world-famous and almost worldwide in scope when in 1954 WES engineers expanded their activities and studies to the polar ice cap; there they lived for several months performing a series of experiments. They discovered that life in the Arctic wasn't too bad after all. The group, including engineers and technicians, was sent to perform trafficability studies on the endless snow, just as they had previously done on dirt and sand in other sections of the world. While in Greenland, they lived in icebox-type structures called wanigans—metal houses with insulated interiors.[47]

The nine-man team was headed by Charles R. Foster, Chief of the Soils Foundation Studies at WES; others included Sterling J. Knight, A. A. Rula, Edgar S. Rush, Austin Helmers, John William Loviza, Claude A. Blackmon, W. J. Hicks, and L. M. Duke. During June, July, and August 1954 they worked 11 hours a day, 7 days a week, in 24-degree weather in unending daylight. Their work included pushing instruments into the snow and checking and rechecking for depth and hardness. They directed tractors to drive over the same spot dozens of times, until the vehicles bogged down in the deep ruts. The experiments were part of the trafficability study initially undertaken by WES in 1944.[48]

WES personnel again visited the Arctic in 1955; they were participants in a study that involved 60 engineers and scientists, 20 officers, and about 200 enlisted men whose primary mission was to bring back the facts on how to live and work in the area. Two projects were directed by WES engineers: construction of a stable road to permit access to the edge of the ice cap, and snow trafficability problems related to vehicle performance and movement of materials and equipment over the ice and snow.

Other projects planned for the summer of 1955 on the ice cap ranged from tunneling experiments under the ice and snow to facilitate the movement of materials, equipment, and troops to road

Trafficability testing of standard D-7 Caterpillar tractor on polar ice cap

Deep ruts left by standard D-7 Caterpillar tractor after 40 trips in same path on polar ice cap and airfield construction using snow as the construction material. The goal of the studies was to provide basic information necessary for establishing and overcoming difficult problems encountered in conducting military operations in arctic regions.[49] One of the proposals made by WES engineers was the building of arctic "subways," 25 feet underground and 12 feet wide, to be constructed of well-packed snow and ice. The cost would be relatively low.[50]

The Greenland studies were continued in 1957 and concerned two major projects: to develop design criteria and construction techniques for building earth-fill roads on glacial ice surfaces, and to provide data for use in determining the trafficability of Greenland ice-cap snows for existing vehicles. The first project, one that had been under construction for three summers, was substantially complete. This would permit easy access from a toe of an ice ramp to a zone on the ice cap where erosion and differential melting of ice decreased to the point that vehicles could move with greater ease.

During the summer of 1957, major efforts were made in observing the performance of the road and in collecting data to further strengthen the correlations established in earlier Greenland visits. A road was also constructed from a point in southern Greenland to a point on the edge of the ice cap, and a large variety of vehicles were tested on the ice cap to determine their operating capability.[51]

In 1958, the test results of the WES studies were revealed. Arctic snow had supported the movement of practically every tracked vehicle which had been driven over the snow during the testing. Based on measurements made in the snow, it was now feasible to estimate the chances for successful operation on snow of any existing vehicle made for that purpose. During the summers of 1954, 1955, and 1957, the men had conducted a total of 426 tests in the Arctic.[52]

Trafficability of Army vehicles in snow was just one problem studied by WES, for while many jet-age inventions solved problems, they sometimes created new ones. This was the case with jet planes landing on standard runways. New materials were needed for airstrips to withstand the pressure of the huge planes as well as the blast from takeoff and the dripping fuel which spilled onto the pavement.

An extensive landing mat testing program was initiated in 1950 in which a variety of new mats including mats made of aluminum, steel, magnesium, and plastic were tested. Two heavy-duty mats designated as M8 steel and M9 aluminum were type-classified and procured in quantity. These heavy-duty mats were capable of supporting heavy wheel loads of up to 50,000 pounds per wheel. A lighter steel mat designated M6 was also type-classified and procured in quantity. This mat was capable of supporting wheel loads up to 25,000 pounds.

During the early 1950's, a large-scale testing program was conducted at WES to develop criteria for the design of runways to be surfaced with landing mat. Accelerated traffic tests simulating aircraft taxiing operations were conducted on test sections having a range of subgrade and base course strengths and surfaced with M6 and M8 steel and M9 aluminum landing mats. Traffic was applied with load carts simulating single-wheel loads of 10,000 to 50,000 pounds and multiple-wheel loads of 50,000 to 100,000 pounds. Design curves developed from the data obtained

Aircraft operating on mat-surfaced runway

relate service life of the mat to subgrade strength, base thickness, wheel load, and tire pressure.

It had been discovered that jet fuel, which does not evaporate quickly, acted as a solvent and dissolved the asphalt from asphaltic concrete pavements. On parking and refueling aprons where the jet planes parked and stopped their engines at the same spot time after time, repeated fuel spillage resulted in rapid deterioration and disintegration of the pavement. Also, at the end of runways and warm-up pads, the heat from jet blast softened the asphaltic concrete and caused severe erosion of the pavement. WES conducted studies on tar and tar-rubber paving mixtures to develop a flexible pavement that was more resistant to jet fuel spillage and jet blast. For this test, an F-80 jet from the Greenville, Miss., Air Base was delivered to WES in a truck and used to study blast effects on the various types of pavements. Jet fuel was also spilled in controlled quantities at predetermined locations to determine the effects of fuel spillage. These studies showed that the tar-rubber pavements were more desirable for use on parking and hangar areas than were asphaltic concrete pavements.[53]

The ever-increasing size and weight of military aircraft have posed a continuing problem in regard to the design of the pavements upon which they operate. During the early 1950's, the B-47 and B-52 heavy bombers were operating from airfield pavements that were designed for lighter aircraft, and considerable distress was

Jet plane blast test

developing in the pavements due to severe overloads. The B-47 and B-52 aircraft had bicycle-type landing gears; and in order to operate on existing taxiways, aircraft would travel down the center of the taxiway resulting in a channelization of traffic in a very narrow lane. This resulted in a much larger number of load repetitions on the taxiway pavements than had been previously experienced with aircraft equipped with tricycle-type landing gears.

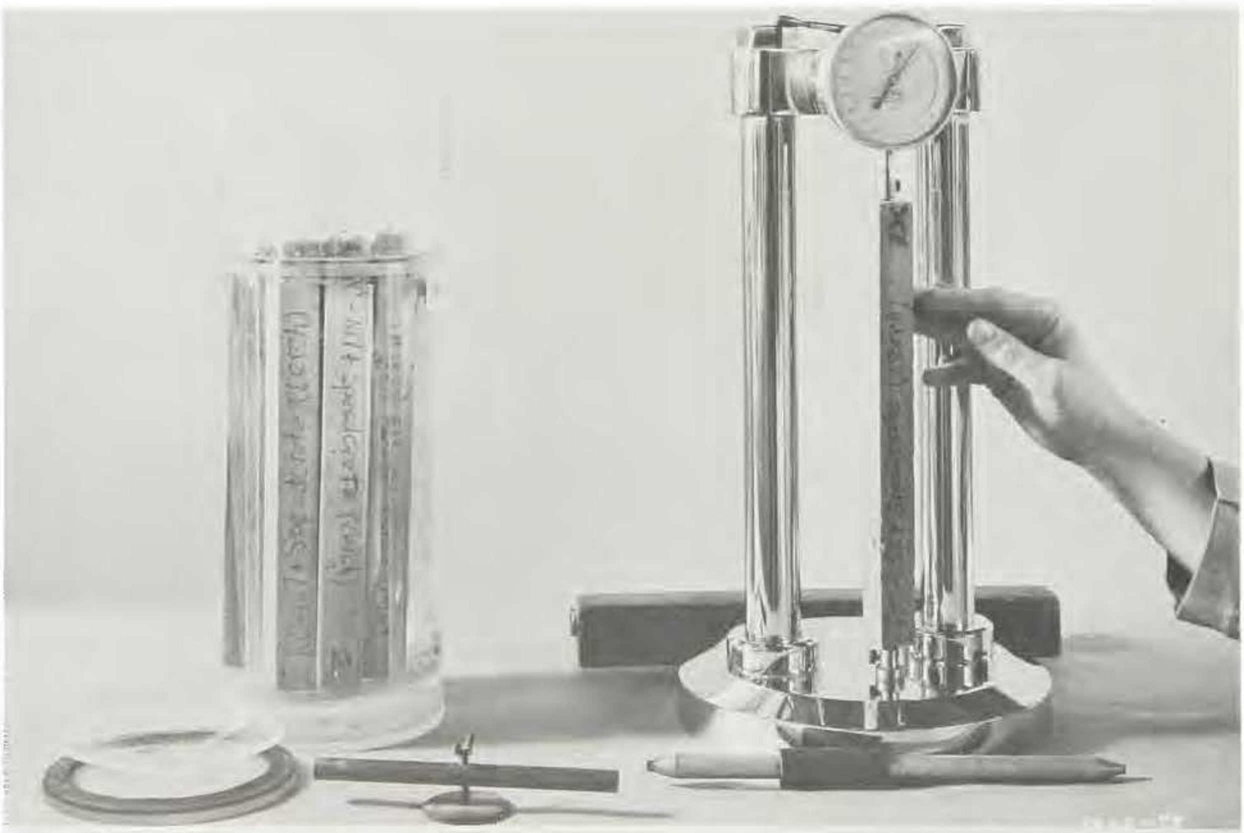
As a result of this experience, design criteria for heavy-load airfield pavements were revised to accommodate the heavier aircraft and channelized traffic. Interim criteria for flexible pavements were developed at WES, and criteria for rigid pavements were developed at the Rigid Pavement Laboratory at the Ohio River Division Laboratory, Cincinnati, Ohio. Test sections were constructed and tested to validate these criteria.

Air Force military officials were reluctant to permit use of flexible pavements on airfields that were to be subjected to traffic of the heavy B-52 aircraft; they preferred rigid portland-cement concrete, even though the first cost was in many cases higher than a comparable design using flexible pavement. Therefore, a Congressional committee requested that a proof test be conducted at Columbus, Miss., to determine the suitability of flexible pavement for runways of heavy-duty airfields. The test was conducted in 1958 on a portion of runway consisting of both rigid and flexible pavements which had been constructed in accordance with the revised pavement criteria for heavy-duty airfields. For nearly a month, day and night, 7 days a week, a tractor pulled a huge olive-drab load cart loaded with 212,000 pounds of lead bars back and forth over the test section. This load simulated one main gear of a B-52 aircraft. The pavement was subjected to a total of 5,000 coverages of traffic which was considered to be equal to 20 years of life under actual aircraft operations. There was some settlement and cracking of both the rigid and flexible pavements during the traffic period. However, it was concluded that both the rigid and flexible pavements performed satisfactorily and that the pavement design criteria were adequate.[54,55]

It was primarily during the period that Col. A. P. Rollins, Jr., was Director that WES faced the problem of developing and proving the capability of heavy-duty asphaltic concrete for pavements. This accomplishment was significant for economics as well as expediency in the construction and repair of airfields and roadways.[56]

In 1958, WES scientists and engineers developed a plastic landing mat which was described as looking like a huge sandwich. The "bread" was a solid sheet of plastic reinforced with glass fibers; the "filling" was a plastic honeycomb-core material, while the "dressing" was phenolic resin. It was made in panels 12 feet by 3 feet by 1-1/4 inch, having tongue-and-groove side and end connectors. The panels were fastened together in the field by aluminum drive rivets. The mats were both economical and easily transported.[57] Tests of the mats showed that they could be used for emergency operations for two weeks, and efforts were begun to modify them for service of as long as six months.[58]

Experiments with portland-cement concrete for a variety of purposes, including airport landing strips, made gigantic strides at WES. Included in the studies was the use of new instruments. One that was utilized was a modified length-change comparator for use in



Apparatus for measuring length change of specimens with 10-in. effective gage length studying concrete specimens. Changes of as little as 0.0001 inch in length of a concrete specimen were detected, and the comparator could be used with either cylindrical or prismatic specimens of any dimensions up to 10 inches in diameter and 24 inches in length. It was first developed at WES in the 1940's to meet the needs for an instrument capable of making such measurements on specimens of a size and weight that could not be accommodated on a vertical comparator.[59]

Also added to the Concrete Division facilities, which were located in Clinton, was an X-ray diffraction apparatus, the first in Mississippi. It was used in studies of cement, admixtures, aggregates, and other materials being investigated for use in the Corps of Engineers Civil Works Program. It was a powerful tool for identifying, classifying, and understanding the properties of concrete construction materials and increased the quality while reducing the cost of concrete.[60]

Numerous other tests concerning concrete were also conducted. Thermal controls were used to keep the temperature around a curing sample of concrete the same as that of the concrete itself in order to determine how the mixture would act away from the surface in mass concrete. By subjecting samples alternately to freezing and thawing, concrete would be given the equivalent of a hundred years exposure to freezing and thawing in a few weeks time. Other thermal, electronic,

X-ray diffraction equipment with portland-cement specimen mounted in sample holder, and chart of portland cement diffraction pattern appearing on potentiometer at above left chemical, microscopic, and physical tests were used to determine the behavior of concrete in simulated service.[61]

Experiments with concrete revealed that temperature and humidity were important. By making sample concrete blocks in accordance with carefully controlled specifications and then subjecting these specimens to tests, information could be obtained on how well any particular batch of concrete would withstand sudden temperature changes. The blocks were placed in special cabinets, so that their temperature changed from zero to 40 degrees and back to zero every two hours.

It was discovered that air bubbles make concrete more frost-resistant. This, plus the proper amount and size of sand and gravel, reduced the amount of cement needed.

WES also experimented with substitutes for cement, selecting 16 less costly materials for study; 169 separate concrete mixtures were studied. Other experiments verified the effectiveness of the first satisfactory 8-cubic-yard bucket for handling and placing mass concrete. Tests were also made to determine the durability of concrete beams reinforced with both old- and new-style reinforcing bars. Form anchors tested at WES made possible the placing of larger sections for dams, which resulted in savings in time and construction costs.

Other work with concrete concerned the development of an insulating blanket of foam concrete for use under airfield pavements placed in permafrost areas of Alaska.

Though most experiments were designed to simulate years of wear on

Placement of foam concrete

concrete in just a number of days, one unique test lasted much longer. A windswept island located off the Maine coast was the site of an exposure station established by the Army Corps of Engineers in 1936 to investigate the suitability of materials proposed for use in the concrete of the original Passamaquoddy Tidal Power Project.

In 1939, it was determined that this station could be used to develop data concerning the durability of concrete exposed to severe weather conditions. Located as far north as possible on the East Coast and yet still in the United States, Treat Island had low winter air temperatures, but the seawater temperature never dropped below 34 degrees. Tides in Cobscook Bay at Treat Island rose as high as 30 feet.

As many as 1,500 concrete specimens of all shapes and sizes were located at the island, most of them placed on a timber rack attached to a wharf at a level midway between high and low tide. The specimens were also exposed twice daily to the air and immersion in seawater.

The main purpose of the Treat Island Station was to determine the durability of concrete under severe conditions. Samples from a variety of places were exposed. Reinforced concrete beams, deliberately loaded to as much as 50,000 pounds per square inch in the reinforcement in order to open up cracks, were exposed to see what effect the cracks and stress would have on durability. Freezing and thawing of specimens and the resulting expansion and contraction were of primary interest.

One of the most spectacular

Condition of concrete beams after 1-1/2 years of freezing and thawing cycles and tidal inundation at Treat Island, Maine, weathering station occurrences at Treat Island was the almost certain destruction of even high-quality concrete in one winter's time if the concrete did not contain a proper amount of entrained air bubbles, which provided relief cells to take care of expansion when water, soaked up by the concrete, would freeze. The result was the same as proved in the laboratory at WES.

Properly made "air-entrained" concrete was found to be virtually immune to Treat Island's severe freezing and thawing. Some specimens have shown no effects in the entire existence of the station. Monthly data were sent by Montford H. Peabody of nearby Lubec, Maine, to WES in Vicksburg.[62]

Many other milestones occurred in the 1950's at WES: the reproduction facilities published training material for the Air Force;[63] a prototype analysis program was undertaken for OCE;[64] vehicle mobility tests in coarse-grained soils were begun for the Navy in 1953; and in 1956, a site for a small-scale testing facility for evaluating the effects of explosions was selected.[65] In 1959, an Army Technical Bulletin, TB ENG 37, "Soils Trafficability," was written at WES and published by the Engineer School. It described the equipment and procedures required to predict the performance of vehicles in fine-grained soils and was widely used by both the military and some manufacturers.[66]

Another first for Mississippi was the installation at WES in 1957 of the first digital computer center in the state. Procurement, installation, and operation occurred during the directorship of Colonel

First computer installed at WES, 1957

Rollins. Early in July, C. B. Patterson was assigned the responsibility of planning the new facility, recruiting the programming and operating staff, arranging programming training for user engineers, selecting peripheral equipment, preparing the site, obtaining supplies, determining operating procedures, and having enough problems programmed by the delivery date of mid-September to provide at least 50 percent prime-shift utilization. Two Army enlisted men with knowledge of IBM-650 equipment such as was to be installed, Pfc. Edward V. Resta and Pfc. Stephen A. Closs, were transferred to WES to assist; and two keypunch and EAM operators, Bernadine Reynolds and Alice M. Woody, were hired. By September 1957 the computer was in operation.[67]

WES also faced some serious problems. In 1952, as the result of a Department of Defense imposed freeze and required review of all ongoing programs, WES faced an immediate strength reduction of approximately 25 percent. Employment opportunities elsewhere were not abundant, and employees who were released were assisted in finding new jobs if they so desired. Careful planning ensured a minimum disruption to long-range capabilities of WES.[68]

Another aspect of employment was the initiation of the Enlisted Personnel Program in which draftees with engineering and scientific training were assigned to duty at WES following basic military training. This also provided a major source of recruitment for continued employment under Civil Service appointment for many when they completed their military service.[69]

Though WES had existed as a separate organization directly under OCE since 1949, attempts were made to take away this status. Various individuals, including two MRC presidents, recommended that the order be reversed; WES Director Col. Carroll H. Dunn vigorously and successfully opposed such a move.[70] Also, during Dunn's tenure, the decision was made to complete the large Mississippi Basin Model at Clinton.[71]

WES capabilities were no better illustrated than when tragedy struck Vicksburg at 5:35 p.m. on Saturday, 5 December 1953. A tornado hit the downtown section of the city and then moved on to residential areas. WES was not in the path of the storm and suffered no damage. When Col. Dunn learned of the disaster at 6:15, he immediately went to the downtown area after alerting security forces at WES and directing that J. G. Schaffer, Chief of the Construction Services Engineering Branch, be contacted and requested to report for duty.

In the downtown disaster area, Col. Dunn offered the assistance of WES to Mayor Pat Kelly; the Mayor suggested that Col. Dunn do whatever he thought best. The WES Director issued instructions for the mobilization of emergency forces and equipment, and guards on duty at WES contacted Construction Services Division personnel and asked them to report for duty.

Approximately an hour after the storm had struck, WES equipment and men were on their way to the disaster area. In a short time, three portable lighting units with attendant floodlights and cables were set up and a WES firetruck and crew were on the scene. Rescue efforts were under way at the Saenger Theater where a children's matinee had been in progress, in the vicinity of the First National Bank, and at Palermo's Clothing Store. The firetruck made two runs during the night to assist in fighting blazes at the Sears warehouse and the Federal Compress warehouse; it remained on standby during the rest of the night.

Col. Dunn established a command post in the telephone office. Capt. Carroll N. LeTellier and Lt. William L. Durham manned it throughout the night, directing operations of WES forces and equipment. Operations conducted during the night included the following:

> *1. A survey was made of power requirements of all hospitals in order that emergency service could be supplied in the event of power failure. At the request of Dr. Walter Johnston, the lighting unit in use at the corner of Walnut and Clay Streets was sent to Charity Hospital after a power failure there. However, service was restored before the unit could be put into operation.*
>
> *2. The third WES portable lighting unit was set up and operated at the YMCA for the Mississippi National Guard forces headquarters.*
>
> *3. The lighting unit that had been sent earlier to Charity Hospital was set up and operated at the corner of Crawford and Mulberry Streets to aid rescue operations at that point.*
>
> *4. A pumping unit was set up in the basement of the Hotel Vicksburg to remove water that had flooded the basement.*
>
> *5. Periodic checks of all equipment in use were made throughout the night and WES employees worked continuously with other volunteer forces to rescue persons trapped in collapsed buildings and to recover bodies of victims.*[72]

Cleanup operations began at dawn on 6 December, and equipment and men from WES assisted. Col. Dunn advised the Chief of Engineers of the situation by teletype that morning at 7:45. The message read:

> *Reference telephone conversation from General Hardin to Office, Chief of Engineers, 5 December, no damage to Waterways Experiment Station property or personnel. Damage to private property in city, center and northeast section, extensive. Overall casualty figures at 0700, 6 December, 18 dead, over 300 injured. Coordinating with General Hardin in rendering all possible assistance for disaster relief. Power out in Mississippi River Commission and Vicksburg District offices. Messages for those offices, as well as Waterways Experiment Station, should be routed to Waterways Experiment Station. WES station will operate on 24-hour basis until further notice.*[73]

Federal aid was officially requested by Mayor Kelly at a meeting held in City Hall at 8 a.m. on 6 December. At the meeting, the Corps of Engineers agencies were assigned the responsibility of relief activities. The major work to be done was removal of wreckage and recovery of victims.

Throughout the day, which was a Sunday, WES men and equipment were engaged in: recovering bodies of victims; shoring up buildings to prevent further collapse; removing overhanging debris such as dangling wires, tin, wood, etc., from poles and buildings; pulling down badly damaged and unsafe walls (with permission of city officials); clearing streets of rubble and wreckage; and providing equipment, material, and services to other relief forces when requested. Emergency work was completed at the Saenger Theater by around 5 p.m., and all bodies were removed.

Cleanup operations were discontinued during the night though duty officers were maintained at the command post and at WES to handle emergency calls and requests. The warehouse at WES was kept open and personnel of the Equipment Section were alerted for call during the night, if necessary. Several requests for minor help were met.

Operations resumed at dawn on 7 December and were completed shortly before noon. WES personnel had removed approximately 625 truckloads of debris. Over 400 employees had assisted in rescue, cleanup, and relief operations, putting in 5,000 man-hours during the period from 6 p.m. 5 December until noon on 7 December. Seven other employees served with the National Guard, and almost 450 volunteers assisted WES personnel in their area of responsibility with the volunteer forces present at any given time ranging from 50 to 150 workers.

Equipment, material, and supplies were provided by WES for its own work and for other agencies that needed it. In the absence of telephone communications, personal messenger service was utilized; teletype service for all three engineer agencies in Vicksburg and emergency messages for the Red Cross were handled by WES, which provided 24-hour teletype service. Total cost to WES for the operations was $3,950; employees declined any pay, which would have been overtime, for their services on 5 and 6 December, considering their work as part of the community effort.[74]

Several days later, in recalling the efforts put forth by WES and the other Engineer agencies, the *Vicksburg Evening Post* editorialized:

> *The work of the Engineers, every one of them and their trained personnel and their volunteer helpers, will remain indelibly inscribed on the pages of Vicksburg's history. In our saddest hour, the Corps of Engineers did more than anyone else to bring order out of chaotic Vicksburg. We proudly salute them.*[75]

One of the highlights of the decade of the 1950's was the 25th anniversary celebration of WES. Open house and appropriate ceremonies were held on Friday 18 June 1954, and Mayor Pat Kelly of Vicksburg proclaimed it WES day.[76] Ceremonies at WES were held on the lawn, and approximately a thousand people attended. On hand were Brig. Gen. Herbert D. Vogel, Col. Francis H. Falkner, Lt. Col. C. P. Lindner, Col. Carroll T. Newton, and Brig. Gen. John Hardin, who was President of the MRC. Congressman Cliff Davis of Memphis spoke briefly, and Col. Carroll H. Dunn, WES Director, introduced the visitors. Master of ceremonies was Vicksburg Businessman Shouphie Habeeb.[77]

Principal speaker for the occasion was Major Gen. Samuel D. Sturgis, Chief of Engineers. Gen. Sturgis recounted some of the activities of WES and told the crowd that research and testing of hydraulics alone at WES "have saved the taxpayers at least $100 million by enabling us to devise better, sounder, and more economical designs at less cost."[78]

In its 25 years, WES had touched the lives of millions of people in both peace and war. The results of its work were evident throughout the United States and much of the free world.

1. Wayne Andrews, ed., *Concise Dictionary of American History* (New York: Charles Scribner's Sons, 1962), p. 520.
2. Vicksburg *Evening Post,* June 17, 1954.
3. Ibid. Also see Vicksburg *Sunday Post,* August 20, 1950.
4. Typewritten manuscript on file in WES archives.
5. Vicksburg *Evening Post,* June 17, 1954.
6. Ibid.
7. Ibid., September 9, 1951.
8. Ibid., June 17, 1954.
9. Ibid., February 27, 1952.
10. Ibid.
11. Ibid., June 17, 1954.
12. Ibid. Two WES men, Major John J. Franco and Sgt. John M. Evans, received the bronze star on September 24, 1952, for their roles in Korea.
13. J. B. Tiffany, ed., *History of the Waterways Experiment Station* (Vicksburg: WES, 1968), p. 12.
14. Ibid., p. IV-15.
15. Ibid., pp. IV-14, 15.
16. Ibid., p. IV-14.
17. Vicksburg *Evening Post,* February 15, 1951.
18. Vicksburg *Sunday Post,* September 9, 1951.
19. Ibid.
20. Typed news release, August 27, 1951. In WES archives.
21. Typewritten manuscript, May 1958. In WES archives.
22. An amusing story about WES participation in the New Mexico tests is still told around the offices at WES. When some of the personnel arrived from Vicksburg, there was a dispute about their clearance papers, and the test facilities were Top Secret. While the problem was being worked out, the Vicksburg men went sightseeing, and at a nearby tourist attraction, on a high plateau, one of them dropped a dime into a telescope; there before his eyes was the "top secret" which he had not been allowed to see only a short time earlier. When Carlsbad officials learned of it, they wasted no time in correcting the situation.
23. Jackson *Clarion Ledger,* October 21, 1959.
24. Washington, D. C., *Evening Star,* April 14, 1955.
25. Vicksburg *Evening Post,* May 25, 1952.
26. Jackson *Clarion Ledger,* October 21, 1959.
27. Vicksburg *Sunday Post,* March 25, 1956.
28. Vicksburg *Evening Post,* February 15, 1951.
29. Jackson *Daily News,* September 4, 1951.
30. Typewritten manuscript, June 2, 1945. In WES archives.

31. Vicksburg *Evening Post,* December 22, 1955.
32. Ibid.
33. Watertown, N. Y., *Daily Times,* June 2, 1956.
34. Jackson *Daily News,* May 16, 1954.
35. Ibid.
36. Interview with Joseph B. Tiffany, Jr., "Mr. WES," December 3, 1975, Vicksburg, Mississippi.
37. Huntington, West Virginia, *Advertiser,* June 18, 1954.
38. Tulsa *Daily World,* July 4, 1954.
39. Vicksburg *Evening Post,* March 2, 1955.
40. Ibid., August 14, 1959.
41. Louisville, Ky., *Times,* June 17, 1954.
42. Louisville, Ky., *Courier-Journal,* June 17, 1954.
43. Vicksburg *Sunday Post,* September 30, 1956.
44. "A Day is 7-1/2 Minutes," *Dixie Roto Magazine* (December 2, 1956).
45. K. G. Reinhart and R. S. Pierce, *Southern Lumberman* (December 15, 1954).
46. "Army Maps Read Like Books," *Stars and Stripes* (Fall, 1957).
47. Vicksburg *Sunday Post,* August 8, 1954.
48. "Vicksburg Team Studies Ice Cap," *Dixie Roto Magazine* (October 24, 1954), p. 7.
49. Vicksburg *Evening Post,* May 29, 1955.
50. Jackson *Daily News,* May 16, 1955.
51. Vicksburg *Sunday Post,* April 7, 1957.
52. *Army Times,* March 22, 1957.
53. Vicksburg *Evening Post,* January 28, 1954.
54. "Flexible Airfield Pavement Tested at Columbus AFB, Miss., by Corps," *The Constructor* (October 1958) , pp. 46-47.
55. Vicksburg *Sunday Post,* February 1, 1959.
56. Tiffany, *History of WES,* p. IV-18.
57. Vicksburg *Evening Post,* February 4, 1958.
58. "Army Develops Plastic Airplane Landing Mat," *Civil Engineering* (June 1959).
59. Typewritten manuscript, July 7, 1951. In WES archives.
60. Vicksburg *Evening Post,* September 8, 1951.
61. Temple, Texas, *Daily Telegram,* May 28, 1954.
62. Portland, Maine, *Sunday Telegram,* November 22, 1959.
63. Tiffany, *History of WES,* p. IV-14.
64. Ibid., p. IV-15.
65. Ibid., p. IX-2.
66. Ibid., p. IX-3.
67. Ibid., pp. IV-18, X-1, X-5.

68. Ibid., p. IV-15.
69. Ibid., p. IV-16.
70. Ibid., p. IV-17.
71. Ibid., p. IV-16.
72. Ibid., p. XXIII-2.
73. Ibid.
74. Ibid., pp. XXIII-1-5.
75. Vicksburg *Evening Post*, December 9, 1953.
76. Ibid., June 16, 1954.
77. Vicksburg *Herald*, June 19, 1954.
78. Ibid.

CHAPTER V: BLENDING CONSTRUCTION AND COMBAT POWER: 1960–1969

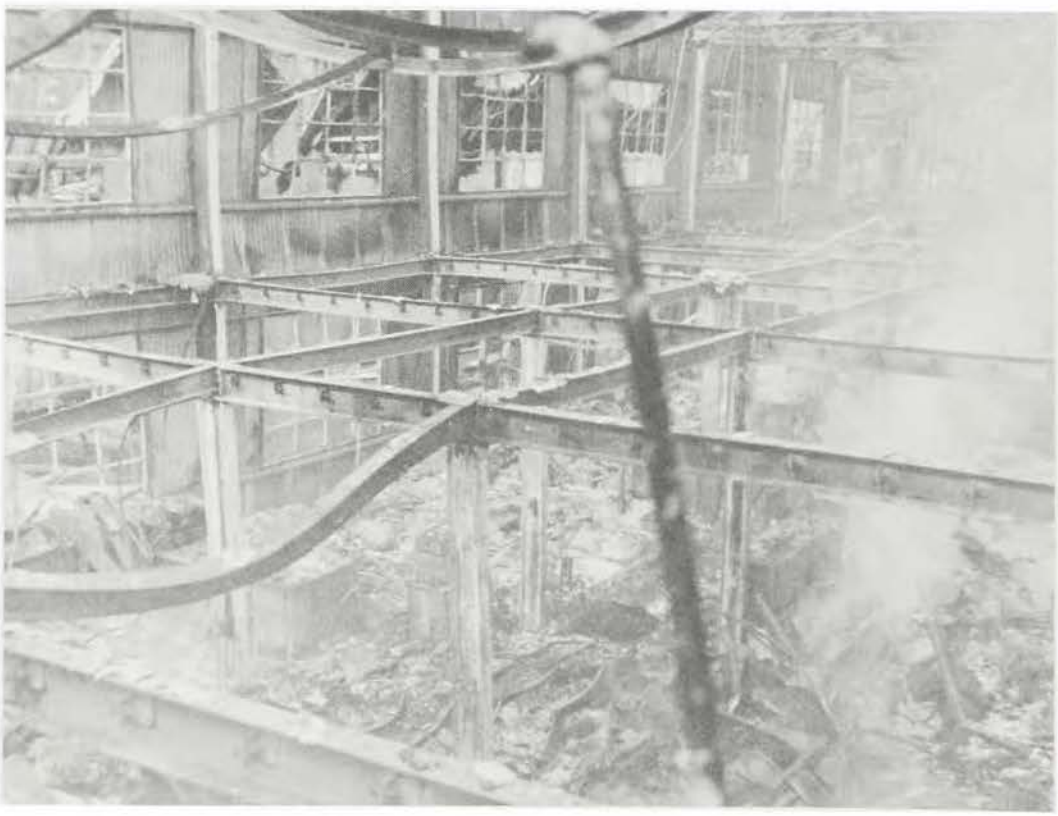
During an era when WES would contribute greatly in both improving peacetime construction techniques as well as in advancements in combat power, a disaster struck in the early morning hours of 3 October 1960: fire gutted the Administration Building.

Front of Administration Building during 1960 fire

Col. Edmund H. Lang, Director, learned of the catastrophe before dawn when W. L. "Bill" Bache pounded on the windows of the Colonel's home to awaken him. The whole sky down toward WES was a red glow when Lang rushed to the scene, and he later recalled the helplessness he felt as the blaze consumed first the roof and then the entire building.[1] Roy B. Jones, fireman-guard at WES, had discovered the fire as he approached the building on his routine rounds. He immediately called the Vicksburg Fire Department, and every available fire-fighting apparatus was dispatched.[2]

Destroyed in the fire in addition to the Administration Building were the following: the IBM 640 computer, owned by the IBM Company and valued at about $400,000; all the printing presses and other equipment in the Print Shop; all the Photography Laboratory equipment including printers, cameras, and other darkroom apparatus; the entire Technical Library collection including over 75,000 items, plus the card index of 275,000 reference cards, published indexes, bibliographies, translations, etc.; practically all of the Mail and Records Section's

Back of burning Administration Building



Interior of WES Library after fire

current files of unclassified correspondence; some of the files of the Personnel Branch and Finance and Accounting Branch; a large number of reports being edited and prepared by the Reports Section; all of the cafeteria equipment (most privately owned); and practically all of the desks, furniture, typewriters, and other equipment in the building.

The building that was destroyed housed the Executive Offices, the Personnel Branch, the Main Conference Room, the Comptroller Staff except for the Property Branch, the Office Service Branch, the Print Shop, the Photography Laboratory, the Drafting Room, all the offices occupied by the Reports Section, the Research Center and Library, the Technical Liaison Branch, the Computer Center, and the Cafeteria.

Fortunately, most classified material was in fireproof containers and was recovered. When it became apparent that the building could not be saved, firemen trained their hoses on cabinets containing practically all the basic files of the Personnel Branch and the most important records of the Finance and Accounting Branch.[3]

Before the fire had been extinguished, Col. Lang appointed a Board of Investigation consisting of G. B. Fenwick as chairman, W. G. Shockley, W. B. Tanner, J. J. Kirschenbaum as recorder, and Capt. J. E. Wagner. They later concluded that the exact cause of the fire could not be determined but that it was probably caused by either the malfunctioning of the ballast in a fluorescent lighting fixture or the development of a short circuit in electrical wiring. There was no evidence or indication of any faulty workmanship or materials in the building or its electrical system.[4]

Another board was also appointed by Col. Lang, one to determine means for continuing operations and to make an immediate survey of space available elsewhere at WES and in the city. Within two days, sufficient space had been found for all 140 employees who had worked in the burned-out building.

On the morning of the fire, some units were moved in order to continue work with the least interruption possible. Within the next few days, relocated offices were housed as follows: the Construction Services Branch in the Forestry Services Building, Finance and Accounting Section to a nearby vacant house, Forestry Service into Mobility Research Center, Travel Section into the Soils Section, Personnel Branch into Hangar #2, Technical Liaison Branch into the Niagara River and Falls shelter, the Technical Library, Photo Lab, Print Shop, and Reports and Drafting Sections into the former visitors' center at the Vicksburg National Military Park.[5]

Technical work operations were in no way affected by the fire as all facilities for research and testing in concrete, soil mechanics, and hydraulics remained intact and work continued without interruption.

In the ruins of the library, efforts to recover any material were unsuccessful. Fortunately, about 10,000 volumes were out on loan in over 40 states.[6] The card catalog index, which represented about 13 years of effort, contained some 275,000 cards, many including abstracts, which were alphabetically arranged by subject, author, series, etc. Without them, the collection could not be properly used. In that one fire, the most outstanding library of its type in the world was reduced to ashes; remaining was only a small collection of unindexed volumes.

Immediately after the fire, the library staff, under the direction of Alan G. Skelton and ably assisted by Marie Spivey, Assistant Librarian, was divided into two groups; one tried to give service with its limited resources to the Corps of Engineers, and another concentrated on the acquisitions and reprocessing program. Funding in the amount of $328,000 was provided by OCE, and during the following months acquisitions ranged from as many as 9,100 in March 1961 to as few as 950 in November 1963. By 1964 approximately 120,000 items had been obtained through gifts, purchases, and exchanges. Many items were given from personal libraries, and gifts were so numerous that only one in every seven publications had to be purchased.[7] Ironically, a group of engineering schools at universities had proposed microfilming the card catalog several years earlier, but lack of funds had been cited for turning down the suggestion.[8]

The Computer Center was relocated in the basement of the Peeples-Newman Building in downtown Vicksburg, and all equipment needed to get the computer back into operation was flown in by IBM, installed, and in full operation within 10 days after the fire.[9] In addition, IBM located over 100 typewriters for loan to WES and had them delivered from all over the United States within a few days.[10] In a short time, equipment obtained on emergency loan from the Engineer Research and Development Laboratories at Fort Belvoir, Va., to enable the Photo Lab and Print Shop to resume operations was on its way to WES in Army vans.[11]

Col. Lang, on 3 October, also appointed a Planning and Development Committee to make plans for the construction of a building or buildings to replace the one destroyed. Space estimates were completed, a preliminary cost estimate prepared, and OCE was notified and asked for funds and authority for construction of two new buildings plus supplemental space for certain units of the Soils Division which were considered to be inadequately and even dangerously housed. Sites were tentatively selected, contacts were made with several architect-engineering firms, and a board was named to recommend the selection of a firm to prepare construction drawings for the replacement buildings. It was estimated that preparation of the plans would take about three months plus a year for construction, and it was proposed to build the new structures on a higher site than that of the old building.

Assigned the mission of examining the qualifications of all of the architect-engineer firms interested in the proposed contract was a committee headed by Joseph B. Tiffany, Jr., and composed of Eugene P. Fortson, G. W. Vinzant, and E. H. Teeter. Aided by Bill Bache, Executive Assistant, the group also acted as a negotiation team for the contract, which was signed on 15 December 1960 with R. W. Naef Company of Jackson, Miss.; the contract for construction was awarded on 25 October 1961 to Sarullo Construction Company. The new million dollar Headquarters Building was occupied in June 1963 and on 30 August 1963, Col. Alex G. Sutton and other staff members hosted an open house to show facilities and work operations to friends and families of employees and to the citizens of Vicksburg.[12]

The new Administration Building and Visitors Facility were not the only construction projects at WES during this period. An extension of the first office building, which had been erected in 1931,

New Administration Building, 1963

was completed in 1962 and another addition was made in 1966. The Soil Dynamics Test facility was completed in 1962, the blast load generator facility in 1963, the Mobility and Environmental Division quarters in 1965, the Nuclear Weapons Effects Division building in 1965, and the Reproduction and Reports Branch building was completed in 1966. Also completed were several big model shelters, the largest containing about 163,000 square feet, and in 1967 the new shops building was completed and occupied. Constructed in 1969 was the new Concrete Division laboratory and office building.[13]

While many changes made were in the forms of physical structures, others were made on paper. One concerned the early publication of reports. Results of work were promptly supplied to those who paid for studies, but for widespread use in the Corps the results of the studies were often unavailable for years. Once a project was completed, engineers found little enthusiasm for paperwork on past assignments. Efforts were made under Col. Lang to speed up and correct this system.[14]

Of significance also was the preliminary work by Colonels Lang and Sutton which ultimately led to the establishment of the graduate training center at WES and a long-range master plan for the development of WES which led to the move of the Concrete Division from Clinton to Vicksburg.[15]

Primary organizational changes occurring while Colonel Sutton was Director included the formation of the Office of Technical Programs and Plans, the

Nuclear Weapons Effects Division, and the Mobility and Environmental Division.[16]

One unique collection at WES was obtained from the Mississippi Geological Survey and contained millions of feet of cutting and core samples taken from over 37,000 oil and water wells in the state. The collection was begun in 1960 with donations from oil companies plus a state building commission appropriation; later samples came from the Corps' own survey test holes. The samples were stored in two forms: Chips, looking like small gravel, and solid core, which was sawed into quarters for more convenient storage. By studying the samples with a machine similar to a geological electrocardiogram, geologists and drillers could determine the probability of locating valuable minerals or water in a particular area.[17]

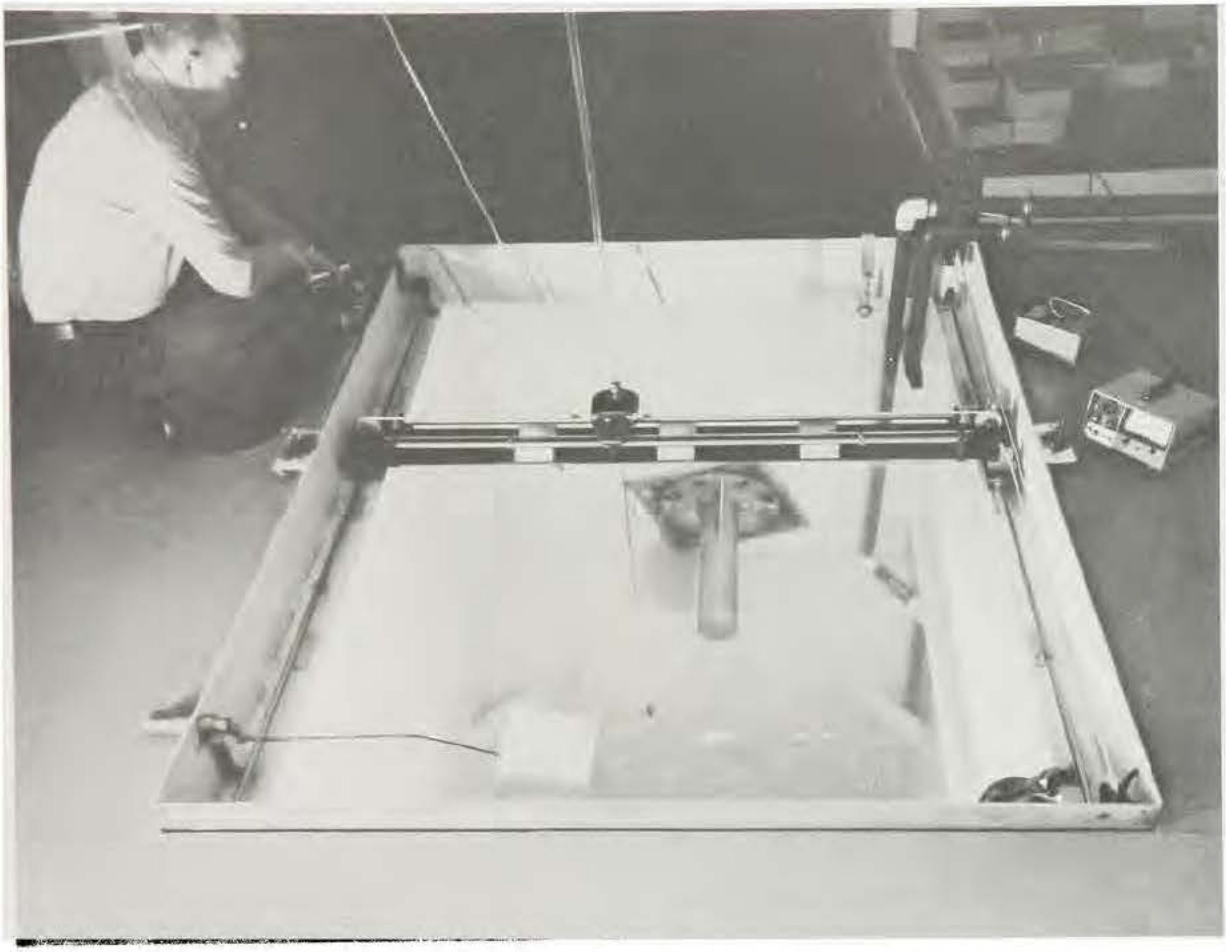
In the late 1950's and early 1960's, work on the deltaic plain of the Mississippi Valley was done by WES geologists C. R. Kolb, J. R. Van Lopik, and R. T. Saucier. A series of comprehensive reports on the deltaic environments of deposition became standard references for investigations of deltas and the influence of deltaic soils on engineering projects. A by-product of these studies was their value in a project designed to locate construction material and building sites in the Mekong Delta in Vietnam.

In addition, the Geology Branch cooperated with the Lower Mississippi Valley Division on numerous projects. In 1964, a sedimentation laboratory was established by the Branch under the direction of Dr. Ellis Krinitzsky to study the effects of depositional environments and postdepositional changes in sediments on their strength properties. X-radiography techniques were also utilized to gain insights into the structural fabric of soils and rock as a means of refining evaluation of engineering properties.

The Geology Branch also provided a quantitative terrain study directed by John Shamburger as a support of the Mobility and Environmental Division. W. B. Steinriede, Jr., conducted a study of rock mechanics, and support was provided to the Nuclear Cratering Group in preshot and postshot studies of the effect of nuclear cratering on rock fracturing and the stability of rock slopes. Two borehole cameras used by the Geology Branch were used in such studies, and the data they supplied were related to joint phenomenology. Dr. Richard Lutton contributed in this area in his work on cratering slopes, slopes in mining excavations, naturally occurring rock slopes, and blasting phenomena.[18]

Another study of the ground was approached in an entirely different way—from high above the earth. In 1961, the Army conducted feasibility studies to determine if an airborne infrared monitor would permit high-speed surveying of the ground below by continuous monitoring of the terrain's infrared reflectance values. The study, conducted at WES, was made to show if such data could be transmitted electronically to a remote intelligence center where technicians could derive accurate indications of the terrain structure and its suitability for heavy traffic such as tanks, trucks, and special weapons vehicles. Officials said if the military objectives were attained, the terrain analyzer project would prove practical in commercial applications for oil, mineral, and other subsurface deposits. Sample plots of terrain were analyzed to determine correlation between infrared reflectance and structural characteristics.[19]

A device in an airplane could possibly



A neutron radiography facility was added to WES capabilities in 1973. Neutron radiation using a Californium 252 isotope source permits nondestructive scanning of density, moisture, and chemical composition of soil, rock, and cementing materials

detect ground conditions, but sensors developed at WES could do the same, after a fashion, and for a different reason. The sensors were planned for service over the southern half of Lake Michigan to report by FM radio the currents from three depths and would assist in the fight against pollution. Health Department officials were studying wastes being dumped in increasing quantities into Lake Michigan; specifically, they wanted to know whether the lower lake could take Chicago's wastes and sewage plant effluent and other waste materials. The findings, to be supplied by the $15,000 sensors, would bear pointedly on the fight to prevent more diversion of lake water to flush Chicago's wastes down the Illinois River.

The master control for the sensing devices was about the size of a steel clothing locker and had an FM sending and receiving unit, electronic "memory" cells, and activating devices. At the Conelrad signal of an air raid, the master control would turn itself off. Most equipment had remote sensing devices to pick up information needed, a receiver for sorting the incoming signals and transforming them into usable information, and a teletype system for sending the information, punched on tape, to the scientists and engineers who used it.

The telemetry setups were also used in the Red Rock Reservoir, at Edwards AFB to measure weather conditions for flyers in vast desert areas, and near Fairbanks, Alaska. They were designed at WES in the Dynamics Section of the Instrumentation Branch by Francis P. Hanes.[20]

One of the unique tests conducted by WES in 1961 concerned shoaling in Galveston Harbor and the search for ways to prevent the shoaling. Keeping the ship channel open in the harbor to the proper depth was costing about $300,000 a year, and WES engineers were constructing a model of the area in order to solve the problem. Tracing the shoaling at Galveston was done with radioactive gold, a process approved by the AEC. About a quart of the material was used and was really a mixture with the texture of fine sand and silt and was made from gold and glass melted together, cooled, and then ground to the proper consistency. It was made radioactive by placing it in a reactor at Oak Ridge, Tenn., and rushed to Galveston for use. Gold was chosen because it is not retained in living organisms, it emits gamma rays which penetrate water for a short distance, and it has a short half-life. The mixture contained about 3/10 of one percent gold by weight, and the radioactive strength of the material reduced to one half in a period of two-and-one-half days, making it ideal for short-term tests.[21]

The substance was dropped outside the jetties at three different depths on 7 June between 8 and 9 a.m. as a Coast Guard boat and an observer from the State Department of Health stood by.[22] Devices similar to geiger counters traced the gold along and around the jetties in search of areas of mass concentration. There was no danger of radioactivity because the substance was dispersed over a large area.[23] The next day, the preliminary results were ready, and Leo F. Ingram of WES reported:

> *Early indications, showing a high peak of radioactivity, lead to the belief that some of the silt which clogs the Galveston Harbor entrance is coming through a small break in the jetty which was made to permit the passage of small boats.*[24]

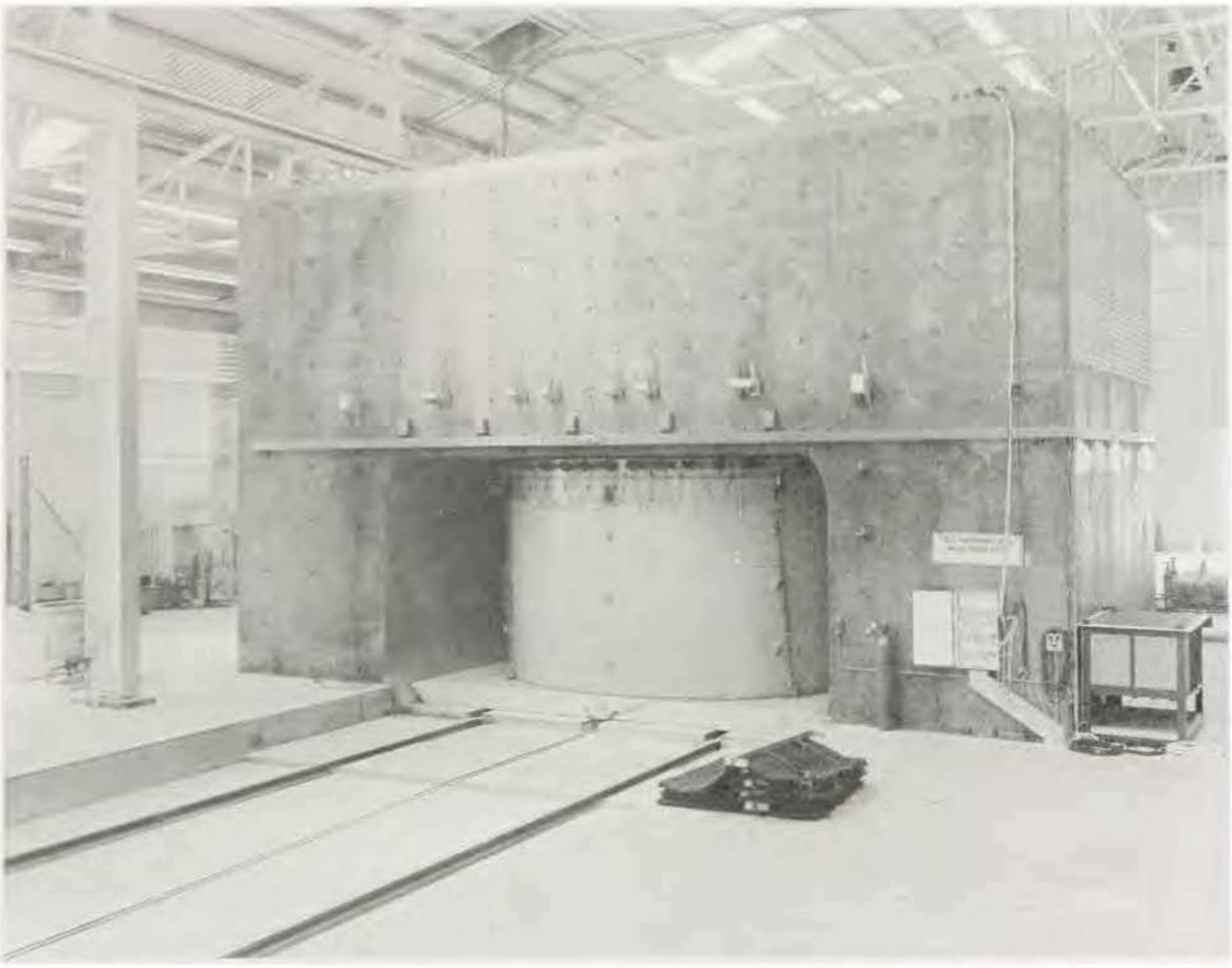
Most of the silt appeared to move around the outer end of the jetty and into the channel. The tests also helped in measuring current flow and force to verify the accuracy of a scale model of the harbor at WES.[25]

The waters of another harbor, New York, presented a different type of problem: how to "bridge" the harbor with runways for La Guardia Airport. The East River completely hemmed in the airport, and extensions were needed for two of its runways in order to accommodate small jet planes. One runway extension would be 2,000 feet, the other 1,035. The Port Authority of New York proposed extending the runways on solid fills, which extended into the East River, and applied to the New York District of the Corps of Engineers for help; the Corps turned to WES.

Engineers at WES, after careful experimentation, proposed a deck across the channel that would be supported on pilings. They discovered that a solid fill between the airport and Rikers Island would have an adverse effect on the harbor, reducing the rate of flushing of pollutants and disrupting normal currents. Other means of keeping water flowing between Rikers Island and the Airport Mainland—such as culverts through the fill—were tried but apparently found to be impractical.[26]

The signing of the nuclear test ban treaty by the U. S. created an immediate need for ways to simulate nuclear explosion blast effects. Thus, explosion-effects simulation played an important and exciting role at WES beginning in the 1960's. In May 1961 WES officials announced that simulation tests and experiments in blasting studies would be conducted in a new $1,500,000 facility being constructed for the purpose; it was the first such facility in the United States. Called a blast load generator, it would permit testing structures and structural components under dynamic loads which would simulate the forces produced by full-scale nuclear explosions. It could test structures of all kinds—steel, aluminum, concrete, or combinations of those materials—under pressures and conditions the same as those that could be caused by an atomic or hydrogen explosion. Thus, the WES studies would provide the needed structural response information without the need for nuclear tests. There would be only a high-explosive detonation within the generator and thus no fallout and no radiation.

The three principal "killing" effects of a nuclear explosion are heat, blast (or air pressure), and radiation; the blast load generator would aid in developing information on blast effects only. Air pressure shock waves, or blast, decrease in



Large Blast Load Generator

magnitude with distance from the explosion; at a certain distance, a pressure of a certain magnitude would exist depending on the size of the explosion. The blast load generator at WES would produce an air pressure of up to 500 pounds per square inch in a heavy steel and concrete chamber. The pressure would be created by fast-burning chemical explosives with a means of controlling the time of the pressure rise, the amount of the pressure, the length of time the pressure was held, and the time and rate of the decrease in pressure back to normal.

The blast load generator consists of two main components, a heavy steel cylindrical chamber and a central reaction station. The heavy steel chamber resembles a pressure cooker and is built of four 2-1/2-inch-thick steel rings 23 feet in diameter. These are stacked one on top of the other with a parallel array of high-strength steel tubes in the top ring, perforated to permit the escape of gases generated by the fast-burning chemical explosives used to develop the desired pressure buildup within the test chamber. The whole device is assembled on a heavy steel-wheeled cart called a platen which rolls on steel rails.

The throat of the test chamber is 23 feet across and about 12 feet high; weight of the chamber is about 350 tons, including the platen. The chamber moves on rails into position in the central reaction station, a massive concrete structure reinforced with prestressed steel rods and cables. Rectangular in shape with a large rectangular opening in the center (its throat), it acts as a clamp or restrainer for the test chamber when subjected to high internal pressures. The central reaction chamber was made of about 3,000 cubic yards of high-strength concrete and was placed on 272 large steel pilings to prevent settlement. They were driven into the earth to depths of 99 to 115 feet.

For testing, the cylindrical chamber is positioned in the concrete reaction station and the fast-burning chemicals are ignited in firing tubes in the top of the steel container. The magnitude of the load is controlled by the amount of gas generated, which is held within the steel container until it is released by small valves located around the periphery of the container's lid. The manner in which the small valves are opened controls the rate of pressure decay and the overall duration of the load within the container. Model structures imbedded in the chamber then experience the load-time history common to the chamber. After a test, the cylindrical chamber is moved along the rails from the reaction station and disassembled and the response of the included model structure is analyzed. Such testing provides information for developing hardened structures to withstand the effects of nuclear weapons.[27]

Another test facility is concerned with finding the characteristics of soils so that atom-bombproof structures and foundations can be built to rest on them. The "ground pounder," or dynamic loading machine, can deliver a shock to a sample of common soil that simulates the effect or ground shock of a nuclear explosion. Driven by a piston and high-pressure gas, the machine can produce loads on soil samples of up to 50,000 pounds in 3/1000 to 150/1000 second. A sample of clay put through the paces looks like it had been hit with a hard fist. Tests showed the superiority of underground missile silos and other such structures.

In addition to the ground pounder, WES also developed a generator with a

100,000-pound force punch that put air pressure up to 100 pounds per square inch on the surrounding soil.[28]

There were a number of interesting aspects to the blast experiments in other departments, such as photography. One was the photographing of "hot air." Using a process called *schlieren* photography, engineers could watch the movements of air, or any gas, on a ground glass or photographic plate just as well as if it were a hard substance. Though the setup could be used for stunts and trick pictures, its prime purpose was to allow engineers to study the exhaust blasts of rocket engines. The effect of the blast on different surfaces, such as materials for missile launching pads, was studied to determine gas flow paths, probable pressure areas, and points of heat concentration. A small rocket engine could burn through solid steel prefabricated landing mats in a few seconds, and a study of the gas flow from engines was needed to develop materials to withstand the heat; photography even showed how the blast could be made to work against itself and form a "cushion" against its own destructive power.

The photographic system worked on much the same principle as seeing a highway reflect the sky on a hot day. A beam of light was played directly on a 48-inch curved mirror. In complete calm, such light was reflected straight back to its source; any gas movement in the beam, however, deflected the rays, forming an image on the mirror which could be photographed. Gases caused by human breath, heat rising from the body, or the glowing ash of a cigarette—all could be photographed. A blowtorch, a soldering iron, or a jet of high-pressure gas would produce billowing clouds that looked like something out of a science fiction movie.

Rocket engine blast test with rocket motor firing on landing mat

Control room for rocket motor firings with closed circuit television for observing operations

Example of Schlieren photography

A small explosion such as a firecracker, the flight of a bullet or a supersonic airstream, normal air movements in a room—all caused enough gas movement to be photographed. Developed in Germany shortly after the turn of the century, the *schlieren* process was used at WES in filming blast tests; at speeds up to 6,000 frames per second, the camera could "stop" a rocket firing or an explosion for analysis in any phase of action.[29]

The man who was conducting the photographic experiments was Francis B. Gautier, who came to WES at its inception in 1930 and stayed for 42 years, retiring in 1972 as Chief of the Photography Branch. He developed numerous and unusual techniques for filming phenomena once invisible to the naked eye, and among his ingenious methods was the use of dye, confetti, ping-pong balls, and floating lights and mirrors. He recorded time-motion histories of surface currents in tidal models and traced the path of a tow entering a lock with multiple-flash photography.

Gautier, assisted by R. M. Rudd and J. W. Turner, recorded the history of WES on film from its beginning as a small hydraulics laboratory to its culmination as one of the world's foremost research complexes, and at the time of his retirement his contributions were reflected in photographs appearing in over 4,000 published reports, a large collection of slides, and 50 motion pictures.[30]

While Gautier and the other WES photographers were taking pictures of "hot air" from blasts, engineers at WES were measuring blasts. Along with the "canned" experiments in Vicksburg, with instruments they made themselves, engineers measured nuclear blast effects at the Nevada Test Site and at Cape Kennedy they installed pressure cells under blast pads to measure the shock and thrust of the Saturn rocket engines.[31]

One series of blast test experiments was conducted in Mississippi in the southern part of the State. Begun in 1960 as part of Project Vela by the AEC and the Department of Defense, the Tatum Salt Dome experiments near Purvis in Lamar County were designed to improve the ability of the Nation to detect nuclear detonations fired underground or in space beyond the earth's atmosphere.[32]

In 1963-64, "Operation Dribble" began in Lamar County and was intended as a yardstick for measuring in comparison all underground nuclear explosions, no matter where in the world they might occur. The project was under the direction of the AEC and the Lawrence Radiation Laboratory of the University of California; WES' services were utilized. The Salmon Event, the first of three planned detonations for Project Dribble, took place on 22 October 1964 in the Tatum Salt Dome. WES' Concrete Division served as consultant and performed technical work in connection with cement grout designed for emplacing scientific instruments in deep-drilled holes and for stemming the hole containing the nuclear device to prevent the venting of gases.

For one detonation, WES developed a series of pumpable cement grout mixtures matching various physical properties of the salt and of the formation overlying the top of the dome. The grouts were used to surround and embed scientific instruments put in a series of deep-drilled holes ranging from 1,000 to 4,000 feet deep and from 100 to 2,500 feet radially from the point

Grouting operations

of detonation. In addition, a high-strength, high-density grout was developed for use in stemming the 2,700-foot-deep hole containing the five kiloton devices.

WES was also called upon to conduct extensive laboratory tests of samples of salt cores obtained from the project site, study stemming materials and procedures for sealing up the device emplacement hole, instrument holes for monitoring the progress and adequacy of the grouting operation, determine downhole temperatures prior to, during, and following each grouting operation, and test field-cast grout specimens in the laboratory on the shot date.

At WES, 104 miles away from the blasts, the Soils Division monitored the Salmon Detonation of Project Dribble in the Soil Dynamics Test Facility. Seismic recordings indicated a time of arrival of the shock wave at 30 seconds after detonation; the shock thus traveled at an average velocity of 18,300 feet per second. Ground motion in terms of amplitude and frequency was determined in both vertical and radial components.[33]

Though nuclear testing projects had been started nearly 15 years earlier, the work grew to such proportions that in 1963 the Nuclear Weapons Effects Division was created; the work had previously been handled by the Hydraulics Division.[34]

Also conducted in conjunction with the AEC were studies of craters made by atomic blasts. Tests conducted by WES engineers as part of "Operation Plowshare" dealt mostly with soil and rock strength and stability after the shock of a nuclear explosion. Weakening at the rim could cause slides, and a massive slide in a canal such as the Panama Canal could close the waterway for a prolonged period. It was necessary to determine the effects of nuclear cratering in different materials.[35]

Surface explosion effects were studied in Cedar City, Utah, in 1968-69 as part of the Mine Shaft Series of blasts. The objective was to determine blast and shock environment near explosions detonated in and on a rock outcrop. Information gathered would be used to improve design criteria for underground facilities. The first test at Cedar City was Mine Under. It involved a 100-ton TNT sphere with the center about 16 feet above the surface of the rock. The second was Mine Ore, positioned with the bottom of the sphere about a foot below the surface of the rock. Measurements were made of ground motions, airblast pressures, and response of certain structural test items. Postshot measurements were made of the craters produced as well as of the ejecta and debris produced by the blast. High-speed photography was again used to record and document the fireball, the cloud, and other effects. Technical direction and management of the tests were the responsibility of WES' L. F. Ingram. Various elements of WES also participated in several technical programs and projects.[36]

Tests of landing mats continued at WES' Expedient Surfaces Branch under W. L. McInnis with mat testing directed by Hugh Green and membrane testing directed by S. G. Tucker. The materials were subjected to every possible condition—they were burned, pounded, frozen, thawed, blasted, ingredients added or taken away, trucks driven over them—all for research. Results were recorded and measured to a hair's breadth. Landing mats tested included those made of steel, aluminum, and plastic, while membranes consisted of nylon and cotton duck fabrics with neoprene and vinyl coatings, various

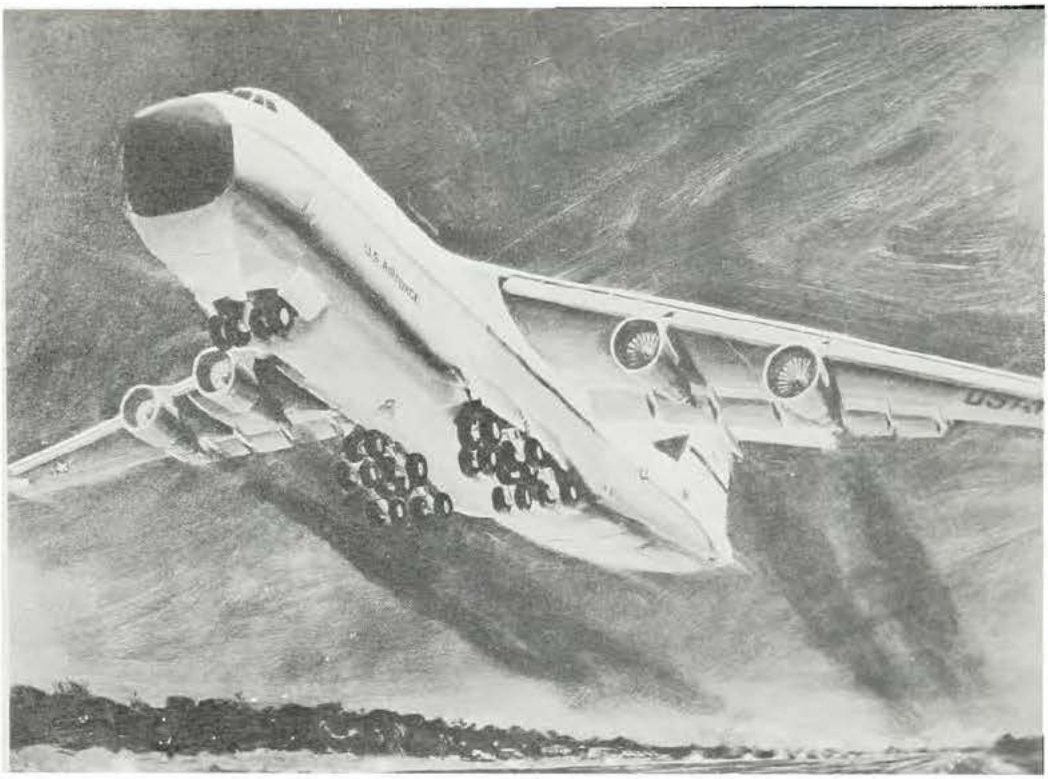
Landing mat display

chemicals, and other substances. While mats were stiff, membranes were flexible and used to waterproof and dustproof areas which were strong enough to support traffic without using mats, or they could be placed underneath landing mats to support weak areas.[37]

One of the landing strip "tortures" was a study to find out what kind of surface it would take to withstand the pressure of a cargo plane bigger than a B-52, the C-5A. Landing mats were improved, and a landing gear was needed that could support such a heavy plane on the mats on existing pavements. Spacing of the wheels, up to 28 in number, was strategic. WES engineers were experimenting on how far apart the wheels should be spaced to better distribute the load. The test vehicles (up to 360,000 pounds) looked like large earth-moving machines that had a test undercarriage with up to 12 large airplane tires and moved around on a modeled landing strip.

The study showed that the C-5A, Boeing 747, and other such planes could land on existing runways despite the fact that they weighed four times more than the weight that such runways were designed to accommodate. The secret was in the design of the landing gear configuration, or the placement of the wheels.[38]

Water and dust were problems in landing areas, and WES developed a membrane of nylon fabric coated with neoprene synthetic rubber which was both dustproof and waterproof and was valuable in forward combat zones for both airfields and helicopter landing sites. Firestone Tire and Rubber Company produced more than 80,000 square feet of the membrane.[39]



Artist's concept of C-5A aircraft

Large test load cart used in designing C-5A landing gear configuration

Dust was also a problem at missile launching sites, and a membrane was developed to resist high temperatures, spillage of fuels and solvents, and abrasive effects from the launching of rockets and missiles. The ground cover was subjected to live tests in the field at White Sands Proving Ground, New Mexico. Constructed of silicone rubber on glass cloth, the developed membrane could withstand the abrasive particles and high temperatures of the rocket engine's exhaust and had the strength under high temperatures necessary to withstand blast forces. In addition, the lightweight material could be easily placed with a 50- x 75-foot launch area being surfaced in about 15 minutes.[40]

Road building is a slower process than laying membranes and mats, but WES studies introduced a new technique of "wrapping" roads in plastic. The process would also apply to airport runways and would be applicable to civilian road construction as well as for military projects. The new concept, developed by James P. Sale, Chief of the Soils Division, was somewhat like wrapping the road in a raincoat. As moisture was the most critical factor to be overcome, the new concept was based on the principle of sealing off moisture which attacked from beneath by seepage and from above by rain, melting snow, and overflow from ditches. The plastic covering worked much as a "baggie" encloses a sandwich.

Construction materials consisted of polyethylene, emulsified asphalt, and polypropylene, a nonwoven synthetic fabric. The manner of construction was simple. The prepared roadbed was sprayed with asphalt, a strip of polyethylene was laid in place, and the road again sprayed

C-130 aircraft operating on membrane-surfaced runway

Final application of asphalt over polypropylene on experimental road at WES

lightly with asphalt. Next was placed a layer of compacted, fine-grained soil which formed the road base, followed by a tack coating of emulsified asphalt, followed by the polypropylene layer, and, in turn, followed by a final asphalt coating. Finally, a light spread of sand was added to provide an abrasive wearing surface to improve traction.

The new method required a minimum of equipment: a standard asphalt distributor, a dump truck with spreader box, and a trained eight-man crew with one supervisor. In a normal working day, they could put down a mile of two-lane road which could be used immediately. Construction time was cut and cost reduced by using native soil for the base course, which eliminated the expensive and time-consuming process of locating, quarrying, hauling, and crushing rock. The test road at WES was placed under realistic conditions. After being subjected to more than 2,000 coverages of military vehicles up to the size of five-ton trucks over a period of two years, it remained in good operating condition.[41]

One of WES' major Divisions, Concrete, had been located at Clinton since 1946 when it was moved there from New York. In 1967, it was announced that because of the large increase in volume of the Division's work and the need for consolidation to improve management and coordination of the laboratory with its companion facilities, it was being moved to Vicksburg.

Construction of an air-conditioned, fireproof two-million-dollar concrete laboratory was started in 1967. It was built of precast, prestressed, and cast-in-place concrete and would house eight separate testing facilities. Special equipment would include: control of temperature and

New Concrete Laboratory, October 1969

humidity, acidproof sinks and related equipment, thermal rooms, freezing rooms, X-ray labs, and other facilities.[42] The move from Clinton to Vicksburg was made in the late fall of 1969.[43]

The other Clinton installation, the giant model of the Mississippi which had been started in the 1940's, was completed in 1966 at a cost of approximately $11,250,000.[44]

As WES was solving problems all over the world, one was created literally right in its own backyard: the WES lake needed dredging. Silt deposits made the job necessary, and 278,000 cubic yards were removed in 1966.[45]

At about the same time, approximately 184 acres of additional land were purchased to provide for future expansion of WES. As a part of that future expansion, the Reproduction and Reports Branch building was completed and occupied in 1966, and in 1967 the new Shops building was finished which provided badly needed space and improved conditions.[46]

Techniques and instrumentation for conducting dispersion, diffusion, and flushing experiments in estuary models were first developed in 1952 under the direction of Henry B. Simmons, and later refinements led to the use of fluorescent dyes as tracers and highly accurate fluorometers for dye detection and analysis. Techniques for conducting thermal diffusion studies in estuary models were developed in 1966 and were refined and improved rapidly as the problem of thermal diffusion was greatly magnified because of construction and design of large steam-generating plants that would use estuaries as a source of cooling water. Hydraulic models contributed much toward defining the effects of such plants on estuaries as a whole, as well as in the specific design of intake and discharge facilities to minimize recirculation of heat.[47]

Continuing education had been a long-standing problem at the Station and work toward a graduate center, started by Col. Lang with further efforts by Col. Sutton, became a reality during Col. John R. Oswalt's tour. A branch of Mississippi State University was created in Vicksburg in 1965. The new branch offered all courses required for the master of science degree in civil engineering and engineering mechanics, and a degree could be earned in three years. The branch was established primarily for the purpose of providing immediate access to advanced education for WES engineers and scientists and for other Corps of Engineers personnel as well. Nongovernment persons could also enroll. Instructors for the courses were selected from qualified persons employed at WES, from other neighboring facilities, and from the regular MSU faculty.[48]

Another educational program begun under Col. Sutton and expanded under Col. Oswalt provided one-year postgraduate instruction at various universities and brought world-renowned lecturers to WES for short courses, further increasing the staff's capabilities.[49]

After the devastating Hurricane Camille hit the Mississippi Gulf Coast in 1969, the WES staff made an on-site study at the request of the Civil Defense Department to try to find why some buildings, many of them frame, withstood the winds and tidal surges while others, often made of masonry, were reduced to matchsticks and rubble.[50]

Another problem tackled by WES

Hurricane Camille damage

concerned clogged water streams—those choked with waterhyacinths. The green scourge of southern waterways was brought to this country from Venezuela in 1884 to the Cotton Exposition in New Orleans. It had a beautiful flower, and everyone wanted a plant. No one knew that a single specimen could reproduce 1,200 new ones in four months, spreading so thickly that they blocked out all sunlight below the surface, killing fish and vegetation.

Efforts to control the waterhyacinth began in 1900 after an 1898 study by the Corps of Engineers. An extensive research program was begun by the Corps in 1934. It was found that dynamite merely spread the plant and that burning was futile. Also, chemicals caused ecological damage, and herbicides were too expensive. The waterhyacinth menace became so acute that it could cause floods and destroy bridges, and no natural enemies of the plant were known in this country.

In 1968, a new possibility for control was revealed at Athens College and at Redstone Arsenal in Alabama when it was discovered that infrared "light" with a wavelength of 10.6 micrometres seemed to reduce propagation and growth of waterhyacinths. WES was given the job of devising a practical prototype laser system that could be used in the field. The configuration eventually chosen used a mixture of 57 percent helium, 39 percent

Waterhyacinth problem

Laser system used to reduce propagation and growth of waterhyacinths

nitrogen, and 4 percent carbon dioxide circulating through the tubes in which the laser action occurred. The system was designed to produce about 4,000 watts of infrared radiation, concentrated in a beam about one-half inch in diameter. The very intense beam was then spread out by a mirror system and directed against the waterhyacinths. The radiation was completely harmless to man or animals, as the heating coil of an ordinary electric range produced approximately the same amount. The device could be transported easily by truck and could be transferred to a barge. The laser destroyed the waterhyacinths' ability to produce chlorophyll, essential to growth, thus eventually killing the plant.[51]

Among other tests at WES were some concerning the wheel and plans to improve it. The Army Mobility Research Center, a small testing facility, sought methods of making wheels roll better and more efficiently and ways to keep them from getting bogged down. Roads had been improved over the years, but the wheel had remained basically the same. WES engineers determined to find out just what happened when a wheel came in contact with various soils. One of the methods of testing included the removal of rocks and other foreign material from the soil so that experiments could be conducted under controlled conditions by knowing the exact composition of the soil, which was placed in large bins 27-1/2 feet long, 5-1/2 feet wide at the top, and 3 feet deep.

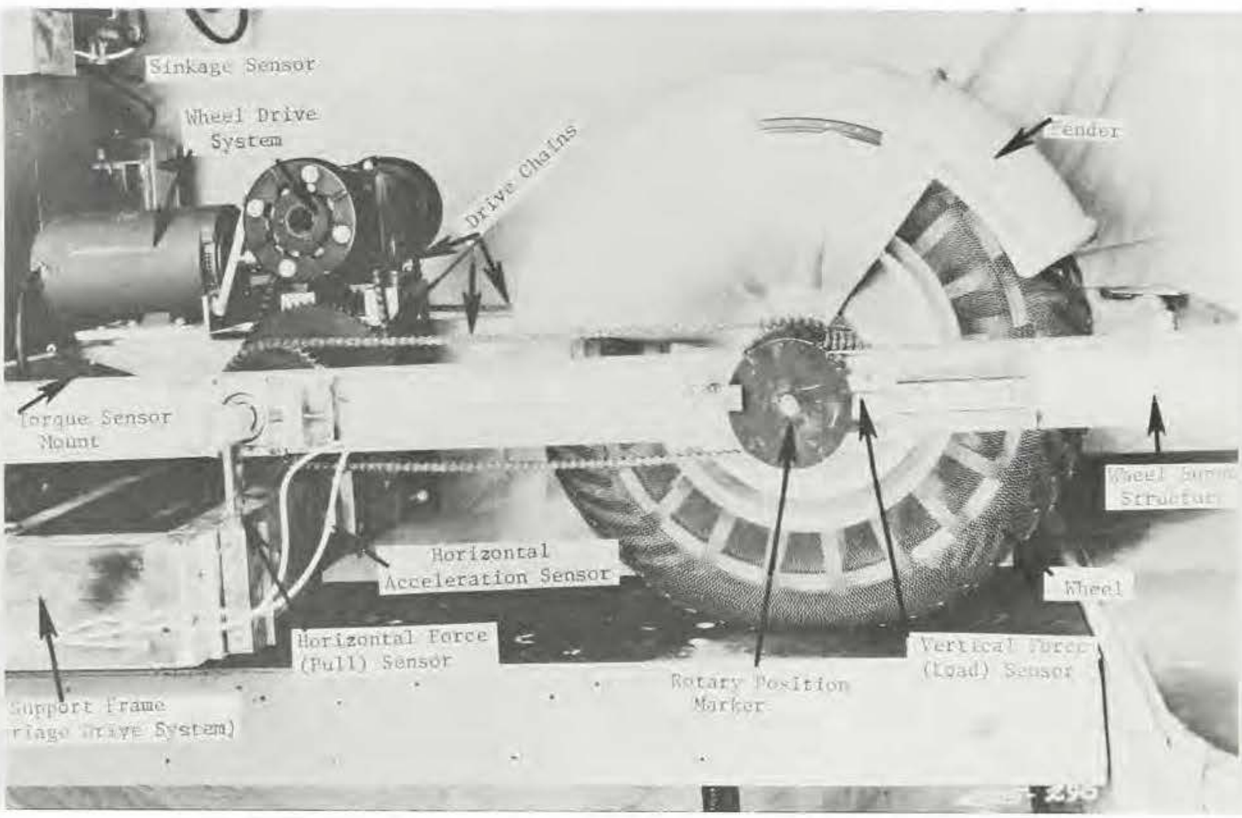
Small scale test facility at Army Mobility Research Center

Sprinkling provided the exact amount of moisture desired. From a cantilever system 165 feet long a carriage was hung, and to it was attached a test model of a vehicle. Under the cantilever the bins were placed, and wheels attached to the carriage were run over the soil and tested for such things as speed, slippage, and torque. The measurements were recorded and data processed and analyzed electronically.[52]

Such research over the years led to a publication in 1969 entitled "Improved Wheel Performance on Sand by Controlled Circumferential Rigidity," a 64-page report that suggested that redesigning of the wheel could solve some mobility problems. Klaus W. Wiendieck conducted experiments to find out if a method of shifting the load and stress on the wheel could improve off-road mobility. In his study he used an admittedly inefficient and impractical wheel which employed hydraulic jacks, pistons, articulated joints, and a sliding "shoe" which moved as the wheel turned. Wiendieck discovered that wheels which could change the distribution of stress performed up to 13 percent better than ordinary ones.[53]

Two significant announcements were made at WES in late 1969, one concerning a new computer and the other outer space. The largest computer system dedicated to engineering design and research, to serve engineers nationwide and to cost about four million dollars, was announced for WES the day before Christmas. Under the direction of Donald Neumann, it would make WES the center of one of the world's largest computer and data communications systems. Several computers had been installed over the decade, each replacement a little more complex and powerful than the preceding one and also of more value to science.[54]

Announcement that WES was entering the Space Age in an important role was made 23 November 1969 when it was revealed that some lunar vehicle testing would be performed at WES. The Mobility and Environmental Research Division, founded in July 1963 and headed by W. G. Shockley, tested wheels proposed for the vehicle that would travel the surface of the moon.[55]



Wheel tested for lunar travel

Though these new tests would deal with man's exploration of space, his primary concern was still the earth; and numerous military tests were conducted at WES in the 1960's in relation to the war effort in Vietnam. Mobility tests were among the most important, and in 1960 the six-wheeled Meili "Flex-Trac" was put through the paces. The 7,000-pound vehicle could carry a 2-ton payload over a right-angled wall 3-1/2 feet high. The machine's wheels followed the slope of any terrain with its flexible frame and vertically joined wheelbase assuming a swayback or arched position, depending on the ground below. At WES, it was tested to determine its capabilities on extremely soft soils.[56] Trafficability tests were also run by WES engineers on a beach in Massachusetts for a civilian vehicle,[57] and studies for the Army were made at WES in the summer of 1960.

The Army study was undertaken to provide scientists with greater knowledge of the way in which the running gear of a military vehicle transmitted its weight, driving, turning, and braking forces to the ground over which it might be moving. Information was sought regarding what stage of continued traffic and under what

Flex-Trac vehicle

moisture conditions a given section of ground structure would break down and refuse to provide traction. Knowledge of off-road mobility of military vehicles would be increased, and the opportunity was provided to study design characteristics of vehicles which enabled them to move on surfaces under unfavorable conditions.[58]

One vehicle which underwent numerous tests was the Marsh Screw Amphibian, developed by the Chrysler Corporation under a contract with the U. S. Navy Bureau of Ships for the Advanced Research Projects Agency of the Department of Defense. The vehicle was designed especially for use in transporting troops and materials in marshy and inaccessible places such as rice paddies in Asia. The Marsh Screw could travel over water, mud, snow, or sand and could move forward, backward, or sideways. It had two counterrotating pontoons, each having screw threads three inches long. The rotors, or screws, were filled with plastic foam so that the Marsh Screw would stay safely afloat even if punctured by a bullet. Testing areas included the boggy land around Eagle Lake north of Vicksburg, the sandbar near the Mississippi River Bridge, and simulated rice paddies at WES. The softer the mud, the better it operated.[59]

The Mobility and Environmental Research Division thrived on tough problems. They tested the "Weasel," an amphibian with tracks, and the "Mule," a small ammunition carrier with tires that looked like volleyballs and a folding steering column so a man could crawl beside it in combat and still steer it.[60]

Military problems with vehicles were nothing new—the Syrians had chariot

Marsh Screw Amphibian in mud

trouble while invading Egypt thousands of years ago, and the Sumerians, the first people known to have used vehicles in war, probably had difficulties with the wagons they used to transport their troops to battle in 3000 B.C.[61] The problems of terrain had not changed, but vehicles had, and some could rush in where others dared not, thanks to the advances in technology made possible by fundamental mobility research.

One unusual military vehicle that underwent tests at WES was the XM759, a marginal terrain vehicle put through the paces for the Marine Corps. Constructed to operate equally well on extremely soft soils or on firm land and in water, it could carry 14 men or 3,000 pounds of cargo. The propulsion system was what made it unique. It had a series of Terra-tires linked together by chains to form a rolling track, giving it a combination of track and wheeled mobility. WES test sites included the WES lake, especially prepared soil, and the Louisiana swamps.[62]

A first cousin to the Marsh Screw, the RUC (Riverine Utility Craft) was tested in late 1969 at WES. It was a larger version of the Marsh Screw and was powered by two 440-cubic-inch V-8 engines which drank a gallon of fuel a minute. Tried out in Terrebonne Parish, La., swamps, it moved with equal ease from bayous to tidal flats to marshes. It was tried out in 28 different types of terrain.[63]

Since many vehicles that WES was testing would probably be used in Asia, their performances in rice paddies were all-important. Rather than test them in Asia, WES constructed its own rice field which was described as "looking like the backyard of a misplaced Vietnamese

XM759 vehicle operating in extremely soft soil

RUC operating in water

peasant."[64] The field was complete with dikes, and few vehicles could traverse the muddy area.

Another problem faced by the military in Asia was the network of tunnels used by the Viet Cong. A team from WES spent four weeks near the front in Vietnam collecting data, and they discovered that understanding the Asian tunnel system required a knowledge of civil engineering, geology, botany, pedology, mathematics, and electronics along with other skills. Living and working quarters were established in a tent about 25 miles northwest of Saigon at Cu Chi, Vietnam. The men stayed with the 65th Engineer Battalion of the 25th Infantry Division. Before venturing out to tunnel areas they went to school for practical instructions in munitions, tunnels, mines and booby traps, and other dangers they might encounter. Their activities were devoted mostly to collecting specified environmental data within and around the Viet Cong tunnel complexes.[65]

Back home, they rapidly put their newly gained knowledge to use. Viet Cong type tunnels were built in Puerto Rico, the site chosen because it had an environment suitable for the particular tests to be run. Construction was with Viet Cong type instruments and in the same manner as the Asian tunnels were built. They were three times as long as a football field and 4-1/2 to 18 feet underground. Included were storage rooms and sleeping quarters. Volunteers lived in the rooms and ate special diets. Weapons and munitions were stored in the tunnels.

One of the tests conducted was that of a sensor which the engineers called a "people sniffer." Military science had perfected the "artificial nose" to sniff out characteristic odors of people who lived in a specific environment, ate a specific diet, wore specific types of clothing, and practiced specific habits of body cleanliness.

Before, during, and after the tunnel testing, existing sensor systems were evaluated to determine their capabilities for detecting tunnels. Also planned were multispectral visible and infrared flights to be made over the tunnel areas. Electromagnetic and seismic surveys were also conducted, trace gas experiments and geochemical analyses were made, and the reflectance and emission properties and the visible and infrared regions of the spectrum evaluated. Meteorological data were also collected. At another primary tunnel site, ecological factors were studied; and at a third site, mines and booby traps were installed and sensor systems evaluated to determine their capability. Though several organizations participated in the studies, WES wrote specifications for the tunnels, monitored construction, evaluated reflectance and emission properties, and collected meteorological data.

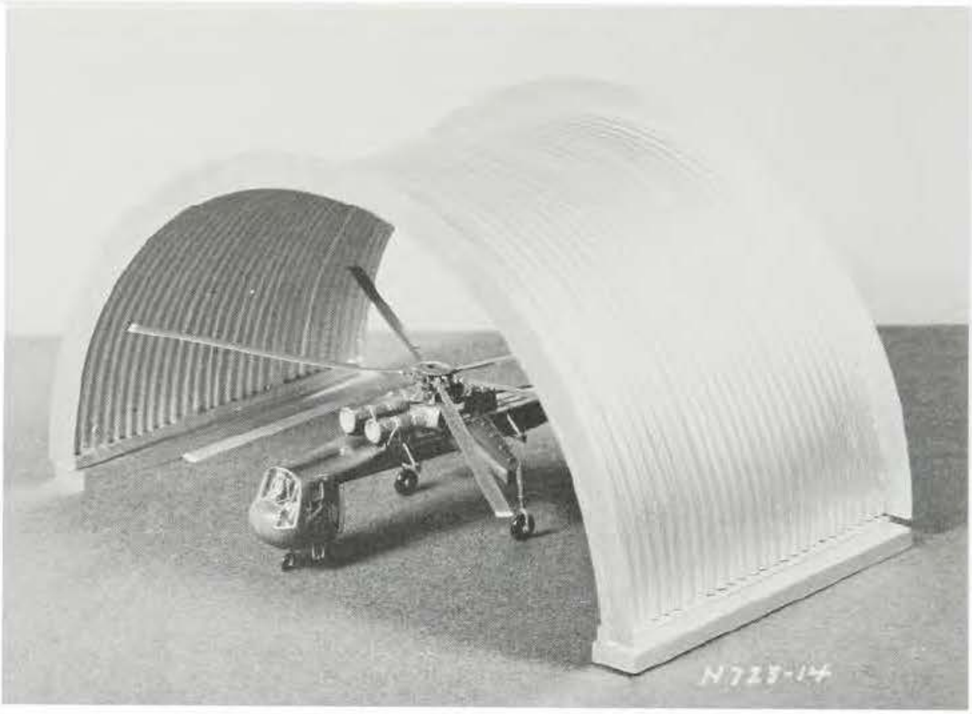
Viet Cong tunnels were also difficult to destroy, and Leo F. Ingram and J. Donald "Don" Day of the Nuclear Weapons Effects Division supervised a project in which advanced types of explosives were used in an attempt to blow up tunnels at different depths underground. Tests were made in South Carolina on actual tunnels that were built similar to those found in Vietnam. Assisting on this project were Mark A. Vispi, Wallace M. Gay, and Pat A. Shows.[66]

One result of the study in Vietnam by WES was the development of the "tunnel tracker." It was a modified two-way, battery-powered solid-state circuit radio unit. Light in weight, it

Tunnel explorer locator system, developed and built at WES, is a modified two-way communication unit capable of tracking and pinpointing the location of someone inside and also provides a two-way communication between personnel outside and those working inside the tunnel

required a minimum of power and was adapted for use in jungle environments. It could track and pinpoint the location of men in underground complexes and also provided two-way communications with observers outside the tunnel. The unit transmitted continuously to permit pinpointing the explorer's location in case an injury prevented him from keying the microphones. To test the device, three tunnel shafts were dug in Vicksburg. Each about 60 feet long, they had depths of overburden of 5, 10, and 20 feet, comparable to the Viet Cong tunnels. A "tunnel tracker" system sent to Vietnam proved so successful that six more were ordered almost immediately.[67]

Another Vietnam War effort by WES was helping to devise shields to protect helicopters. The machines were especially vulnerable to enemy attacks when parked. The Army launched a search to find a "quick and dirty" method of providing protection for them from shrapnel, small firearms, rockets, mortars, and satchel charges. The "quick and dirty" term referred to something that could be constructed quickly from materials at hand with a minimum of engineering effort. To find such a method, WES conducted field tests at Camp Shelby near Hattiesburg. Large and small vertical billboards and screens were arranged at various distances from prepositioned mortar and rocket shells. The rounds were fired remotely to produce the desired fragment density



a. Model shelter

b. Prototype shelter

Several structures were designed, constructed, and evaluated to determine their potential in protecting parked Army aircraft distribution at various ranges. Each round had its own unique footprint, or spray pattern.

Foreign rounds similar to those encountered in Vietnam and American rounds were tested for comparison. Fragments were captured in fiberboard boxes to determine sizes and velocities at various ranges. At the same time, materials tests were in progress to accumulate data on the effectiveness of ballistic nylons, plywood, concrete, and soil bin revetments. It was discovered that a standard item, landing mat, was the most effective. Two plank steel mats, erected as an A-frame shelter, would stop as much as 75 to 80 percent of the fragments at 30 feet, a significant amount of protection from a simple construction effort involving readily available materials.

The tests also revealed that metal or plywood bins, filled with soil and placed around helicopter parking areas, could be reduced from 5 feet to 1 foot in thickness and still give the same amount of protection. This would make a tremendous difference in the effort required to build and fill the bins. Another shield, a lightweight protective device that could be easily carried by the helicopter to areas near the front, was a flexible curtain made up of layers of special type nylon cloth. The tests, under the direction of W. J. Flathau, J. V. Dawsey, W. H. Sadler, and John H. Stout, were conducted at Aberdeen Proving Ground in Maryland.[68]

An additional military study, one to assist the Navy much closer to home than Vietnam, was made of the harbor at Point Loma, Calif. A model of the harbor and a wave maker were constructed at WES in order to develop a breakwater to protect a special Navy ship. A medium-size aircraft carrier equipped with an electronics laboratory for the development of antenna systems and other electronic projects, it could not be jarred by waves over 3 feet in height during tests if results were to be accurate, and storm waves at Point Loma sometimes rose as high as 15 feet. The WES model reproduced the coastline and a large offshore area as well as the moorings. A 60-foot plunger-type wave machine was used in the model to produce the artificial waves equivalent to the real ones.[69]

Design of military protective shelters was another project at WES during the Vietnam War. Experiments were made using corrugated steel arches, aluminum arches, and reinforced concrete arches as roofs for troop shelters, command posts, first aid stations, etc. Though reinforced concrete was selected, shipping made it impracticable so portable steel forms were designed and used in Asia to construct the concrete arches. Experimental shelters were first made and tested at Ft. Benning, Ga., by the 43rd Engineer Construction Battalion. Ben F. Blansett of the Construction Services Division went to Vietnam where he directed the manufacture and building of the shelters while under enemy fire. The shelters were so designed that portions of them could be turned on their sides and made into fighting bunkers. Designs were also developed for constructing concrete log bunkers which proved far superior to other types.[70]

The use of concrete in Vietnam called for new efforts on the part of the Concrete Division. Materials such as barbed wire and bamboo, readily available on the war front, were used as reinforcement in experimental concrete members and structures.

Support was also given in solving problems related to the mineralogical characteristics of the soils; the studies were under the direction of Katharine Mather.[71]

Numerous WES personnel gave on-the-field assistance in Vietnam. R. G. Ahlvin of the Flexible Pavement Branch of the Soils Division visited Vietnam on two occasions to help in the solution of problems involving airfield construction, and G. R. Kozan assisted in setting up a training program to show villagers how to build and repair small airfields. A. H. Joseph, one of the first WES men to go to Vietnam, visited Cam Ranh Bay in 1965 relative to a sand stabilization study. H. B. Simmons of the Hydraulics Division went to Vietnam as a consultant to the Navy in connection with the design of a model to study harbor problems. N. R. Oswalt went twice to assist in setting up hydraulics laboratory facilities. Other personnel frequently were called upon to review reports and research proposals related to construction or military efforts in Vietnam.[72]

There was an urgent request for landing mat for use in Southeast Asia in 1966, and WES was made the procuring agency in order to expedite production. Its experience in the development and testing of landing mat brought a directive for $50,000,000 worth of the materials. Negotiation and execution of these very large sole source contracts posed unique problems for WES. The Expedient Surfaces Branch of the Soils Division under W. L. McInnis, assisted by Hugh Green and Robert Turner, aided the Contract Branch of the Procurement and Supply Office, headed by J. J. Kirschenbaum, in the endeavor. WES also served as technical advisor for other government agencies in the procurement of landing mat.[73]

Stabilizing sand around troop structures was also a problem that WES tackled. Erosion at such buildings and bunkers by wind and rain was a serious problem. Chemicals in a liquid form were selected which would harden when sprayed on loose sand and prevent erosion. G. R. Kozan, Royce Eaves, and Capt. A. M. Hardstein were major contributors in developing the material, and G. W. Leese designed several types of spraying equipment to be used in placing it on the loose sands. In the experiments, a partially buried structure was prepared and covered with sand and then the effectiveness of the material was tested. J. W. Carr was sent to demonstrate the use of the substance and equipment to troop units in Vietnam.[74]

Hundreds of dust suppressants were also tested during the 1960's, for one of the most critical problems in Asia was dust on airfields; it caused jet engines to wear out at an unusually rapid rate.[75]

In January 1966, responding to a directive from the Chief of Staff, the Chief of Engineers appointed Col. Oswalt to the position of Army Project Manager for Dust Control in the Republic of Vietnam, with

Tests of potential of three liquid dust control palliatives were conducted at Yuma Proving Ground offices in OCE. For an eight-month period, Col. Oswalt supervised all Department of Army actions to correct a serious helicopter maintenance problem throughout Vietnam. As a result of Col. Oswalt's actions, the Chief of Staff in October 1966 expressed satisfaction to the Chief of Engineers that the dust problem at heliports in Vietnam had been effectively solved. The Army Aviation staff in USARV estimated that the dust control measures taken reduced the annual helicopter engine and rotor blades maintenance and report cost by $100,000,000.

Other work was connected with the Vietnam War: Soils Division personnel prepared instruction manuals for soldiers in the field with "do it yourself" directions on the proper methods for use of landing mat and dust palliatives; C. R. Kolb and W. K. Dornbusch made major contributions in connection with geology problems, especially in the Mekong Delta; and many instruments made by WES personnel were utilized. Eugene H. Woodman, Francis P. Hanes, Leiland Duke, George Downing, and Homer Greer of the Technical Services Division were the instrumentation specialists who made many important contributions to a variety of projects.[76]

The work of WES was now indeed worldwide in scope. The Soils Division's first major overseas project was an evaluation of all U. S. Air Force airfields in other nations; the study was begun in 1951 and was accomplished by teams including a military liaison officer, an engineer in charge of the party, a geologist, and various technicians. Ten trips made to foreign countries included visits to the Arctic, Western Europe, the Middle East, North Africa, and West Pakistan.

Airfields were evaluated in Korea by P. J. Vedros, and A. H. Joseph spent several months in Japan assisting with reconstruction of an airfield. Two WES personnel, W. C. Sherman, Jr., an engineer, and W. B. Steinriede, a geologist, went to Eniwetok, a South Pacific island, to examine and report on features of the underwater craters which had resulted from atomic explosions. The data were needed in connection with important studies on the stability of cratered slopes being conducted for the Nuclear Cratering Group, a Corps of Engineers agency located at Livermore, California, an organization which would later become a part of WES.

The foundation of an unusual building on Kwajalein Atoll in the Pacific presented problems and it was decided to install instruments in the foundation in order to observe the stability under operating conditions. Personnel from WES designed the instruments and incorporated them in the original building construction. Dirk Casagrande, an engineer of the Soil Dynamics Branch, visited Kwajalein Atoll on two occasions to supervise the installation of the instruments and later to observe foundation performance.

Others worked on data needed for the possible construction of a new canal in Panama or some other Central American region, and some studies, mainly in trafficability, took WES men to such places as Guam, the Philippines, and West Germany.[77]

When plans were made to build the high Aswan Dam in Egypt, many historic temples and other edifices were threatened. A protective dam was planned to save Abu Simbel Temple, built about 1265 B.C. by Rameses II and considered the most important in Nubia. W. J. Turnbull, Chief of the Soils Division, was called to Paris to consult with the engineers and UNESCO officials about the project. He had previously assisted with the Souapiti Dam in French Guinea, Africa, and the Serre-Poncon Dam in France.[78] Also, Fred R. Brown, current Technical Director of WES, spent a month in Egypt during 1963, advising on problems that might be expected to develop in the Nile River after construction of the Aswan Dam.

Thailand requested advice in the 1960's on dredging a harbor channel, and WES sent Ernest B. Lipscomb, Jr. Later, a three-man team from WES worked in Thailand in connection with Mobility Environmental Research studies; they were Lt. Col. Arthur R. Simpson, E. E. Garrett, and C. A. Blackmon. These studies were sponsored by the Advanced Research Projects Agency of the Department of Defense. The Thailand Detachment was the principal field agency of the Corps of Engineers in the Far East for conducting engineering investigations to establish the relation between the various features of the physical environment as they affected surface vehicle mobility.[79]

Much of the world, however, didn't wait for WES to come to them—they came to it by the thousands. In a 15-year period, 1954-1969, about a quarter million people visited the Vicksburg installation, and they ranged in rank from high Government officials to school children.

If the visitor didn't speak English, the man to see was Jan C. Van Tienhoven, who understood French, German, Dutch, Greek, Spanish, Italian, Portuguese, Flemish, Afrikaans, and English. Van Tienhoven, born in Holland in 1893 and a graduate electrical engineer from the Institute of Technology at Karlsruhe, Germany, had also studied at the Lyceum in Anshem and at the Institute of Technology in Delft, Holland. He had worked in The Hague and in Argentina, and had come to the United States in the 1930's. At WES, he translated reports and kept files on international engineering terms.[80]

Two other WES men with whom foreign engineers could converse freely, men who had achieved worldwide fame, were Dr. M. Juul Hvorslev and Dr. Garbis H. Keulegan, consultants on the staff at WES who remained with the Corps of Engineers by special request after reaching retirement age. Hvorslev, born in Denmark and educated at the Technical University, came to the United States in 1921, later returning to Vienna for his doctorate. From 1937 until 1946 he served on the faculty at Harvard University and then came to WES as Technical Consultant to the Soils Division. Dr. Keulegan, born in Armenia, was educated in Asia Minor and came to the United States in 1912 in pursuit of higher education. He received two bachelor's degrees at Ohio State, his master's degree, and then his doctorate at Johns Hopkins. He was one of the original staff members when the National Hydraulics Laboratory was established by the Bureau of Standards in 1932 and served as a consultant for WES. Upon retirement in 1962, he joined the Hydraulics Division at WES as a consultant. Both Dr. Hvorslev and Dr. Keulegan have authored numerous papers in their respective fields in which they are considered the world's foremost authorities. Both men were honored in 1969 with the Army Research and Development Achievement Award, one of the most prestigious forms of recognition for rewarding notable contributions to the Army's broad program of scientific investigations.[81]

Visitors to WES included Chiefs of Engineers from Argentina, France, Australia, England, India, Korea, Paraguay, Pakistan, Thailand, and Vietnam. Reasons for coming were as varied as the work at WES.

Dressed in flowing white robes, the Minister of Transportation from Nigeria came for information on flood control and commercial development of river systems for applications to the Niger and Benue Rivers. The General in charge of the Army Engineer Corps of Pakistan was particularly interested in vehicle mobility research (he also took time out to fulfill a lifetime ambition: he saw a football game); two Engineers-In-Chief of the British Army saw a "great deal here to prevent our (British) government from duplicating experiments on airfield landing mats;" the Inspector General of the Mekong River Development Plan for Cambodia, Laos, Thailand, and South Vietnam was interested in overall river basin development and administration; and the Chief of Engineers of Vietnam was fascinated by the laboratory which duplicated conditions in his homeland in order to plan for construction projects there.

The Provisional President of Argentina was interested in Army facilities and wanted assistance in planning a project on the Rio Negro River; the General in command of Greek engineer troops was interested in both civil and military projects since the Greek Army had similar missions; the Commander and 12 officers of the Paraguayan Navy created a mystery at WES as Paraguay is an inland nation with no coastline (they explained that their navy operated on lakes).

A 10-man team of highway engineers from the Soviet Union came for discussions on flexible pavement design as applicable to highways and was followed by a group of hydroelectric specialists who gave away small souvenir medals of national landmarks, a Russian custom showing approval.

The first use of an earphone hookup to enable quick interpretation was made with a group of German dredge experts, and an Icelandic engineer studying airfield pavements found the only similarity in Vicksburg to his homeland to be the hospitality. Similarities of the loess soil in Vicksburg and that in Israel were noted by an engineering geologist from the Holy Land; one of the 12 women engineers in India studied soil mechanics techniques for a month and fascinated WES employees with her saris, for she wore a different one each day. When a teacher in Scotland assigned her history class a project for material from other countries, she became so interested that she came to WES on vacation; a French Jesuit missionary with a degree in engineering planned to apply the knowledge he gained at WES to help the people of Thailand; and an Indonesian engineer in charge of that country's harbors was amazed to find more people of his profession at WES than his entire nation could boast.

Nobility has been represented with visits to WES by Sir David Ormsby Gore (later known as Lord Harlech); Sir Donald Bailey, whose designs of the pontoon and fixed bridges for use in Europe during World War II brought him knighthood; and Count Alfred Cornett de Peissant, Major General in the Belgian Army and dean of a group of 47 military attachés from 46 different countries.

Representatives of various international engineering organizations came as did delegations from NATO and the United Nations. High-ranking officials from abroad also included key government personnel from Bolivia, Turkey, Brazil, Canada, Egypt, Jordan, Italy, Hungary, and Cuba. Some gave lectures on the hydraulic engineering in their native lands in addition to studying at WES.

Thousands of articles on WES have appeared in publications throughout the world including the leading newspapers of France, England, Sweden, Denmark, and Yugoslavia. All major TV networks have made films at WES, and cabinet and congressional visitors have been legion. Thousands of other people have come while participating in conferences.

There was something for everyone—highly complex studies for the most learned scientists and engineers down to picture postcards of the Mississippi River Flood Control model and WES' version of Niagara Falls for the tourist.[82]

As WES was separate from other Corps of Engineers installations, a distinctive emblem was designed for WES in 1968 by the Institute of Heraldry of the United States Army at the instigation of Col. Levi A. Brown. The Institute explained that the colors of scarlet and white referred to the Office of the Chief of Engineers; the wavy blue and white represented water, standing for WES' primary function; the atomic symbols were for nuclear research, especially in soils, concrete, and water; the three orbits of the symbol were for WES' threefold mission of research, testing, and development; and the gold rays alluded to light and knowledge which was disseminated at WES.[83]

The Waterways Experiment Station was 40 years old in 1969, and open house and a celebration was held on 18 June with Major Gen. Frederick J. Clarke, who had been designated by Pres. Richard Nixon as the new Chief of Engineers, as the principal speaker. Various projects were on display for the public to see, and tours were conducted throughout the day. Before Gen. Clarke spoke at evening ceremonies, Mississippi's Lieutenant Governor Charles Sullivan told the crowd:

> *Not only from an economic standpoint in contributing to scientific research and development but socially and culturally, you people at this installation have made the State of Mississippi a much better place in which to live.*[84]

On a special press tour, two media representatives get a lesson on how to drive a "Mule," a standard military vehicle to transport weapons and equipment used in mobility research

Also on hand for the event was John M. Hayes, Vice President of the American Society of Civil Engineers, who called the operations of WES "civil engineering in action" and presented WES with an inscribed plaque in recognition of its distinguished contribution to engineering; it was accepted by Col. Levi A. Brown, the Director of WES.

Gen. Clarke noted that challenges of the future would call for even additional special talents and capabilities at WES. To be dealt with would be water resources, pollution, conservation, underground construction, canalized waterways, further navigation development, and technologies relating to terrain data, soil mechanics, and mobility.[85] He said that investments in research at WES had paid off, noted some of the many achievements, and predicted that "future water conservation projects will have to meet high aesthetic standards if they are to win acceptance for a public demanding preservation of the natural environment."[86] The future promises greater challenges, Clarke said, and he believed that WES would continue to act with the same distinction which characterized its service during the past four decades.[87]

WES' "dynamic blending of construction and combat power" was invaluable in peace and war, and Col. Brown expressed confidence in the future by stating that "the Nation could hardly afford to be without the services of this installation."[88]

All former living Directors except Mr. Lindner, who was in Europe at the time, returned to Vicksburg and WES for the celebration.

Maj. Gen. Frederick J. Clarke delivering keynote address at the evening ceremony

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45. Ibid., p. XI-8.
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53. *Army Times* (October 8, 1969).
54. Jackson *Daily News,* December 24, 1969; also see Tiffany, *History of WES,* pp. IV-23, 24.
55. Vicksburg *Evening Post,* November 23, 1969.
56. Ibid., March 31, 1960.
57. North Scituate, Mass., *South Shore Mirror,* June 23, 1960.
58. "Increase in Army Mobility," *Armor Magazine* (May-June, 1960), p. 48.
59. Vicksburg *Evening Post,* September 22, 1963.
60. Vicksburg *Sunday Post,* November 3, 1963.
61. Ibid., April 15, 1964.
62. Vicksburg *Evening Post,* April 16, 1967.
63. Ibid., November 30, 1969.
64. Ibid., October 20, 1963.
65. Ibid., May 20, 1967.
66. Jackson *Clarion Ledger,* May 5, 1969, and Vicksburg *Evening Post,* June 17, 1969.
67. "Tunnel Tracker," *Army Digest* (July 1969).
68. Vicksburg *Sunday Post,* September 21, 1969, and Vicksburg *Evening Post,* June 17, 1969.
69. Vicksburg *Evening Post,* January 2, 1964.
70. Ibid., June 17, 1969.
71. Ibid.
72. Ibid.
73. Ibid.
74. Ibid.

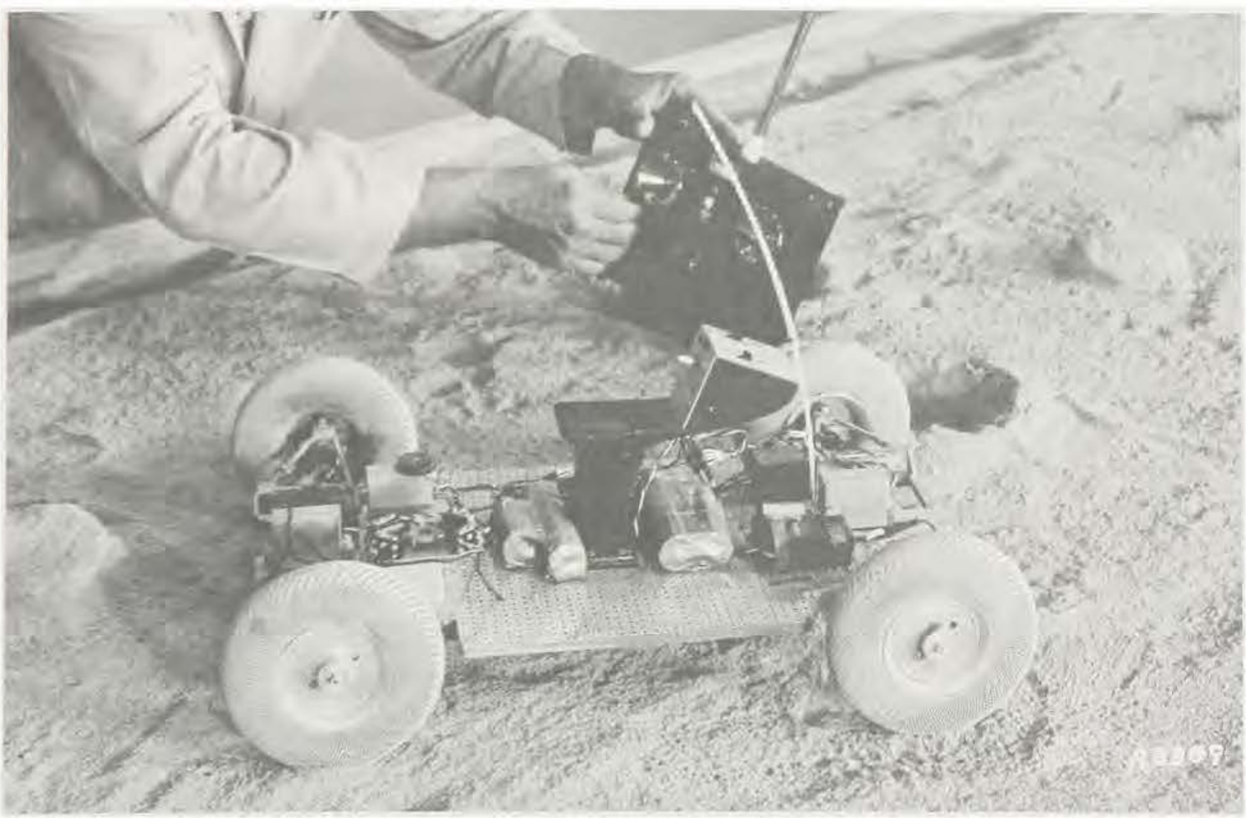
75. Ibid.
76. Ibid.
77. Ibid.
78. Ibid., August 9, 1960.
79. Ibid., December 11, 1958, and February 16, 1964.
80. Ibid., January 16, 1964.
81. Ibid., October 31, 1969.
82. Ibid., June 17, 1969.
83. Letter from the Institute of Heraldry, U. S. Army, Cameron Station, Alexandria, Va., October 23, 1968. In WES archives.
84. Vicksburg *Evening Post,* June 19, 1969.
85. Ibid.
86. WES letter, October 23, 1968; Institute of Heraldry indorsement, April 23, 1969; and OCE indorsement, July 7, 1969. In WES archives.
87. Vicksburg *Evening Post,* June 19, 1969.
88. Ibid., June 18, 1969.

CHAPTER VI: SOLVING PROBLEMS ON EARTH AND MOON: 1970–1979

Millions of people watched on television as the first lunar roving vehicle traversed the hills and valleys of the moon on 26 July 1971, and no one was more interested than a group of engineers and scientists at WES. For two years they had researched the venture in the Mobility and Environmental Division as they conducted tests of wheels and modifications of wheels which eventually would be used on the moon vehicle.

Three of the men, D. R. Freitag, Klaus-Jurgen Melzer, and A. J. Green, all experts in vehicle mobility, stood by in the control room at the Marshall Space Flight Center in Huntsville, Ala., as the Apollo 15 sped toward the moon. They had been instrumental in research and testing to obtain soft soil performance data from which the ultimate range of the mission was determined. At Huntsville, they were part of a 60-man operations support team. They were on hand to advise Operations Control on the power consumption rates and traction capabilities in the event of trouble with the dune buggy moon car; they also received information on its performance and ran computer programs to verify the prediction system.

The fact that the vehicle didn't encounter any problems was partially due to the thorough testing performed at WES. The wheel selected to make the first tire prints on the moon was made of



Model testing of lunar vehicle wheels and lunar rover zinc-coated wire mesh to avoid problems of inflating it in the lunar atmosphere. Design of the wheels was a critical factor in overcoming unusual environmental conditions of the moon such as temperatures which range from 343 degrees Fahrenheit in the day to 279 degrees Fahrenheit below zero at night, a total variation of 622 degrees. Also confronting designers was intense radiation from the sun, a highly rarified atmosphere, and the possibility of meteorite impact.[1] The tire had a 32-inch diameter, weighed 12 pounds, and had a life expectancy of 112 miles, although only 22 miles were on the tour route covered during the three separate 7-hour exploratory trips.

The astronauts not only rode in a vehicle with WES-approved tires—to test the soil on the moon they had with them a modified version of the cone penetrometer which WES had perfected years before.

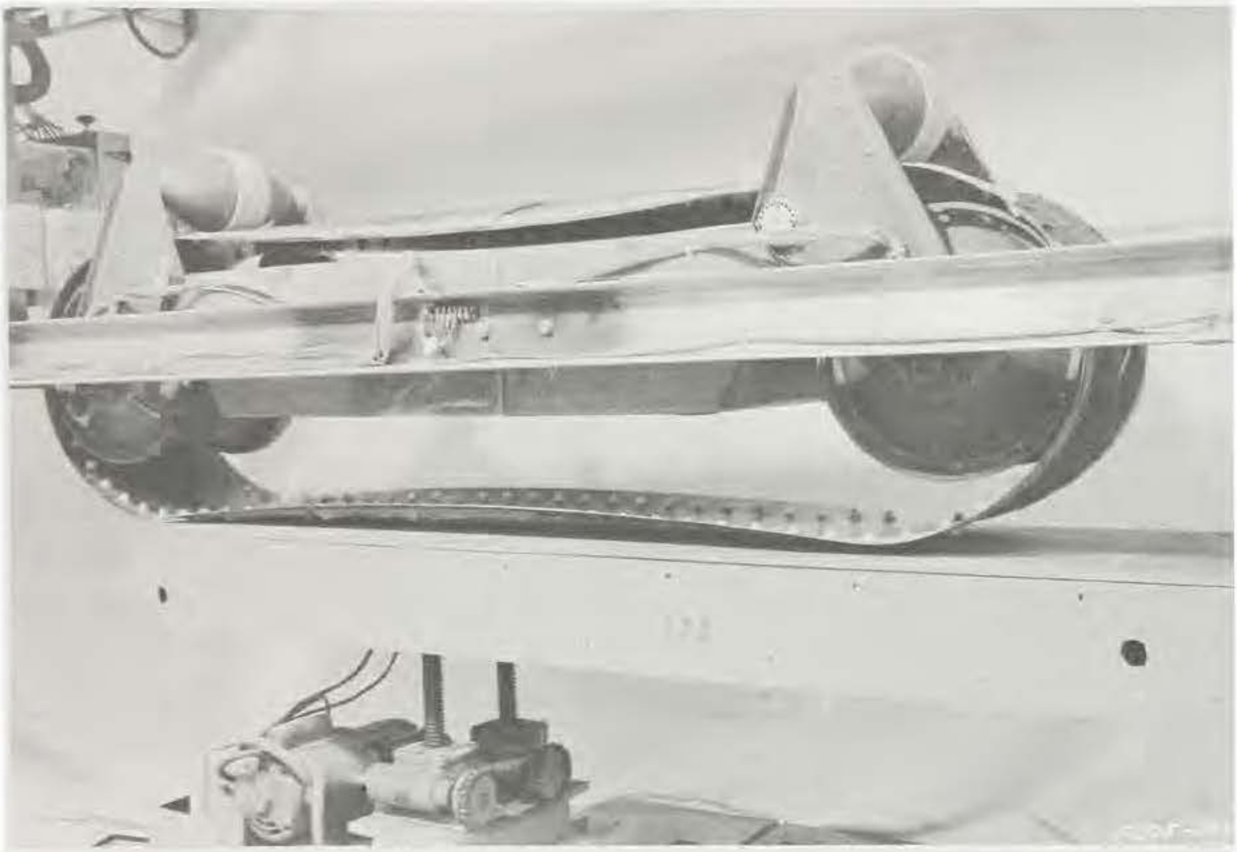
Extensive filming of the lunar vehicle wheel testing was done at WES, and some special footage of the Rover traversing a preselected run was dubbed by the Astronauts during their training as the "Lunar Grand Prix." NASA photographers, before the test, made a photographic evaluation at WES of the single-wheel performances in a simulated lunar soil to prove the usefulness of the vehicle test and help establish photographic techniques for the actual shots.[2]

Scale-model tests had been started at WES in the late summer of 1970. Simulated moon soil was made of crushed basalt with the same grain size distribution as that of samples collected on earlier moon missions and was thought to have the same shear behavior as lunar soil. The model vehicle was 11 inches wide and 22 inches long, or six times smaller than the real one.[3]

Testing was begun with a moon boot rather than a moon tire, for a counterpart of the boot that made "one giant step for mankind" was used at WES in 1970 in the soil testing program. NASA furnished the boot for WES engineers and scientists who were working on the program. The boot was weighted with 33 pounds of lead, the equivalent weight of an astronaut on the moon. Bootprints were then made in the simulated soil, and the similarities and differences in the real and the simulated moon bootprints were used as a basis for evaluating traction characteristics.

Following the successful ventures on the moon, scientists and engineers turned their attention to explorations of Mars and other planets with the use of unmanned vehicles. Two landings had been made on Mars by 1976, but the Viking crafts were immobile. WES personnel, working with the Marshall Space Flight Center's Science and Engineering Directorate and the Lockheed Missiles and Space Company's Huntsville Engineering and Research Center, proposed the Elastic Loop Mobility System, an outgrowth of the lunar roving vehicle used on the moon during the Apollo landings. Engineers said that such a vehicle could provide a mobile laboratory for missions on Mars for up to two years and cover up to 300 miles on the planet's surface. An elastic loop track would be used in place of the three landing pads on the lander, distributing the vehicle weight uniformly over a relatively large area while at the same time combining the suspension and drive systems of a spacecraft into one compact, lightweight package.[4]

The space program also opened a new dimension in remote sensing with the

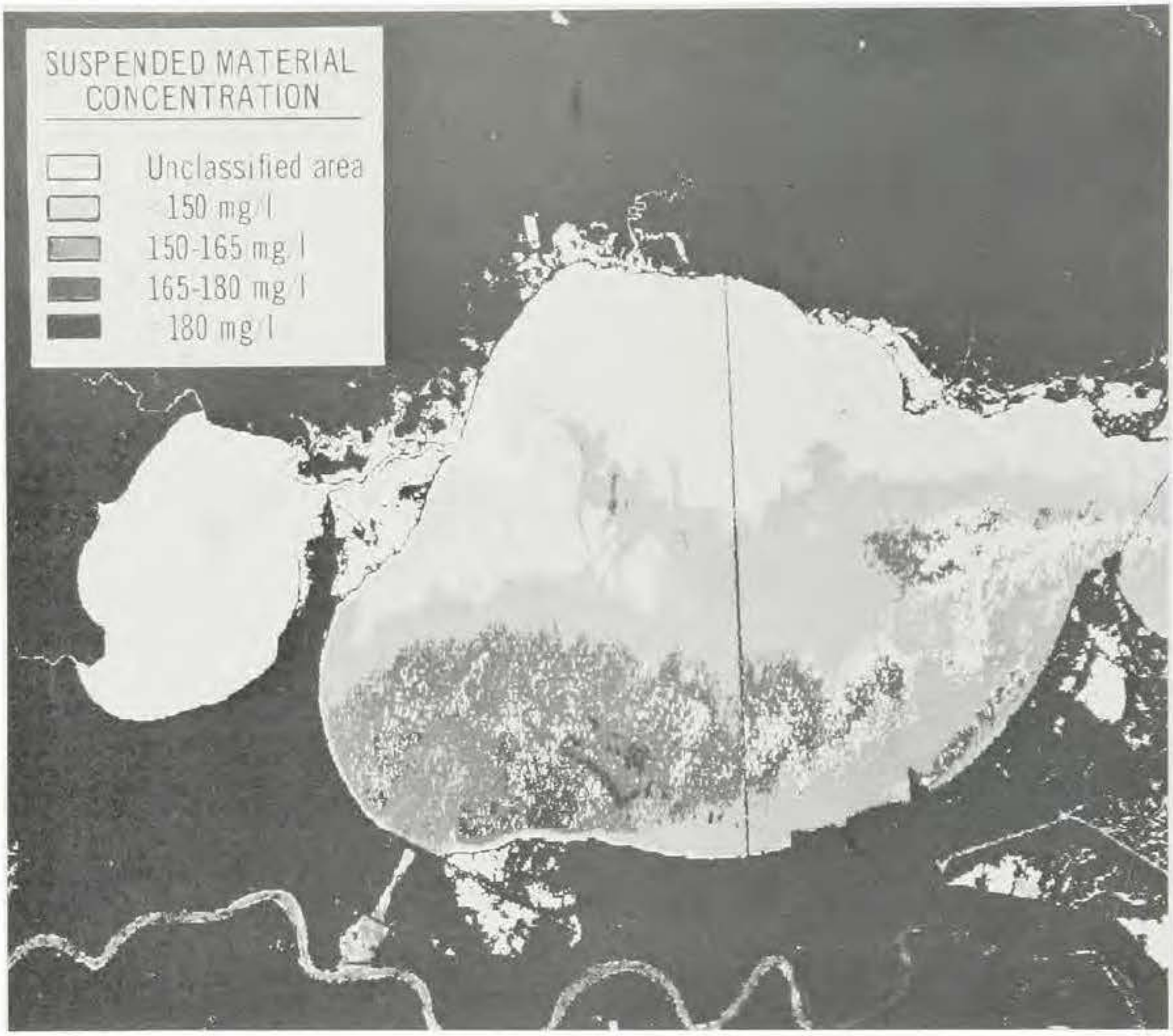


Elastic Loop Mobility System tested at WES for possible use in extraterrestrial explorations (such as unmanned spacecraft to Mars)

launch in 1972 of the Earth Resources Technology Satellite (now called Landsat). A multispectral scanner aboard the satellite provides digital data from which an image of the landscape beneath the satellite can be reconstituted. The satellite's orbits and altitudes are so arranged that it passes over the same area at the same time of day every 18 days. Each image covers an area of about 34,225 square kilometres, and consists of about 30,000,000 bits of numerical data.

It was clear to the research teams at WES that such enormous amounts of data could not be used effectively unless much of the work of interpretation could be done by computer. If that problem could be solved, then the Landsat images offered, for the first time in human history, a way of obtaining environmental information on a whole geographic region through entire seasonal cycles. One of the more pressing problems facing the Corps of Engineers, for example, was that of determining the distributions of suspended materials (either natural materials, such as silt or clay, or pollutants, such as wastewater discharges) in very large water bodies like Chesapeake Bay or Lake Pontchartrain, or other water bodies.

Within two years of the launch of Landsat I, computer programs at WES were processing the digital data from the satellite and drawing maps of, for example, the distribution patterns of suspended sediments in Lake Pontchartrain during the time that the Bonnet Carré floodway was open during the great Mississippi River



Sediment distribution map for Lake Pontchartrain

flood of 1973. Extensions of the basic procedure were quickly developed, so that within a short time it became possible to very quickly map land use, the extents of flooding, and a number of other things by an almost completely automatic system using computer programs.

While some WES studies were ensuring smooth traveling on the moon, others continued experimentation on landing mats for use on earth. A new use for the landing mat was found in the spring of 1971. A series of tornadoes had devastated sections of the Mississippi delta, and mobile homes were placed in the stricken areas for emergency housing. Mud was a hindrance in placing the mobile homes, and on 1 March 1971 the Office of Emergency Planning at Inverness, Miss., requested help from WES. A stockpile of aluminum mat was sent, and 135 mobile homes were unloaded and moved into place quickly and easily.[5]

Improvements in landing mat and membrane design continued in the Soils and Pavements Division, and in 1971 a new product was tested made of four-ply nylon fabric impregnated with neoprene, a synthetic rubber highly resistant to oil, gasoline, sunlight, and adverse weather. Foot-long reinforcing rods with 8-inch circular steel-plate heads pinned the

Aircraft operating on unsurfaced soil

Aircraft operating on membrane-surfaced soil material down, and a liquid adhesive was used to seal it where the sections met and where pins were driven, to prevent moisture from getting between the membrane and the soil. Techniques for preparing the subgrade and for placing and anchoring the membrane were worked out at WES where the material was subjected to simulated traffic using special loading carts. A 3,700-foot-long landing strip and associated turnaround facilities were covered with the material at Fort Bragg, N. C., for further testing under real conditions.

Military personnel from several engineer, construction, and equipment battalions prepared the subgrade to conform to the most sophisticated of the three types of tactical assault landing strips. It was comparable to clearing and grading a very dry pasture of vegetation and placing the membrane directly over the natural dirt. A sheet of membrane 53 feet long and 66 feet wide, along with the anchors and adhesive, could fit in a box 4x4x6 feet, for it was folded accordion-style. For installation, one strip was placed at a time, anchored in ditches with the huge pins, then the next strip which overlapped it was sealed with adhesive and further stabilized with a row of anchor pins across the two strips, and so on until the overall membrane was the desired length. Testing, which started in December 1970 and continued until June 1971, included landings and takeoffs by a variety of fixed- and rotary-wing aircraft. In addition to landings and takeoffs, the aircraft performed maneuvers such as locked wheel braking and turning to determine if the mats would stand up under all conditions. After months of testing, they looked just as good as when they were new.[6]

Field testing of landing mats was also carried out in Army, Navy, and Air Force training exercises in North Carolina in 1973. The training event, "Exotic Dancer VI," provided a week of strenuous use of aluminum mat developed by WES. A strip 3,500 feet long and 60 feet wide was placed over a deteriorating World War II asphalt landing strip in three days. WES engineers assisted in the planning phases of the airfield installation and the placement of the landing mat, and they were invited to observe the actual exercise. The landing mat field proved successful, even though it was used during an 8-inch rain and one plane, making an instrument landing, dragged its tail down the field with visibility less than 400 feet. Over 250 takeoffs and landings were made on the mat runway during the week of high-intensity landings, in which combat-loaded C-130 aircraft delivered supplies as part of a military training exercise. Items delivered consisted of jeeps, cargo trucks, communications equipment, and other items along with troops used in conjunction with the program.[7]

Not all testing was done in the field, for an automated rig at WES was used in developing design criteria and construction techniques for military roads and airfields. The circular test facility made possible the rapid evaluation of a large number of membrane materials and pavement surfaces subjected to continuous traffic under various wheel and load conditions. Traveling at a speed of 40 miles per hour, the rig would spin around the circular track every 10 seconds, applying rolling wheel traffic on pavement surfacings. In one hour it could apply loads equivalent to 360 aircraft landings or the same highway traffic as six heavy trucks passing over any spot each minute. The inside radius of the

Circular test track

track was 28 feet with the outside radius 49 feet. Test sections were constructed 22 feet wide. Traffic with maximum gross weights up to 50,000 pounds could be applied in uniform coverages or in fixed wheel paths at any speed up to 30 miles per hour. Carefully controlled engineering tests gave valuable guidance on paving mixtures, total thickness, compaction requirements, membrane strength, and other aspects of design for military roads, heliports, and airfields constructed by the Corps of Engineers.[8]

Not all membrane was made of solid substances—one was a spray-on foam. The rapidly reacting polymeric foam, which could be applied to the subgrade with hand spray equipment or sprayed from a helicopter and used as a dust-free helicopter landing pad less than an hour later or serve as a hard surface for truck traffic, was demonstrated successfully at WES. It could prove invaluable in Asian rice paddies or swampy regions.[9]

Landing strips on the Alaskan tundra presented another problem, for during a thaw the fine-grained soils of the usually frozen region would not support loaded aircraft, and the oil fields at Tunalik and Inigok had to be kept open year-round. The U. S. Geological Survey, responsible for petroleum exploration on the North Slope, was in a dilemma: drilling test wells would take a year, requiring uninterrupted air support activities; gravel for airfield construction in Alaska was expensive; and the airfields had to be built in winter months when the tundra was frozen and safe from damage by heavy equipment (the sand and gravel would also be frozen). Temperatures of 40 degrees Fahrenheit below zero to 60 degrees Fahrenheit below zero presented many new challenges, and the USGS called for the expertise of WES's

A completely nondestructive evaluation procedure has been developed by WES that provides determination of overall strength of the pavement structure. The technique uses an electrohydraulic vibrator to perform tests without closing the runway and cutting into the pavement, which interrupts traffic for several days or weeks

Experimental Pavements Research (EPR) Branch.

Cecil Burns, Chief of the EPR, explained that some airfields had been constructed in Alaska by building gravel fills 6 to 8 feet over the permafrost, which prevented it from thawing and provided a strong foundation. But gravel was too far away from Tunalik and Inigok, so a more economical means of building the airfields had to be found. Since some fine-grained sand was available at the two sites, methods of using it for construction were tested first. A hard clay surface simulated the frozen soil that would underlie the airfields and a test load cart equipped with a 70,000-pound single tandem axle represented the aircraft's landing gear.

Tests at WES showed that frozen sand was impractical because of the spring thaw when the sand lost its stability. Confining sand in reinforced paper grids was also unsatisfactory, and permafrost protected with polystyrene did not have the strength to support a loaded C-130 airplane. With gravel or landing mats over the insulation, however, the system worked well.

Gravel-over-insulation was selected as more economical than landing mats, and subsequent tests at WES determined the amount of gravel required to prevent the aircraft loads from crushing the polystyrene, which would cause it to lose its insulating qualities. After tests were completed and recommendations were made and followed, Burns visited the airfields at Tunalik and Inigok and found them performing as well as had been predicted.[10]

Explosion effects tests at WES ranged from above the earth to on the earth to beneath its surface, with one study being concerned with the ability of precast concrete manholes to withstand pressure. WES was commissioned to systematically destroy one of the manholes used to house electronic gear that amplified telephone signals. Such manholes were buried along underground cable routes, and the routes were hardened to withstand natural disasters or nuclear attacks. At WES, the concrete manhole was tested in the Large Blast Load Generator facility. The manhole, made of two sections of steel-reinforced concrete, each weighing 14,000 pounds, survived blast pressures of 100 pounds per square inch.[11]

Tests of concrete had a new home at WES, for on 12 June 1970 Bryant Mather, Chief of the Concrete Division, cut the ribbon on a new $2,200,000 testing facility. The ribbon itself was significant, for it was made of concrete reinforced with polyester fiber.[12]

The concrete industry has been revolutionized because of studies conducted by WES scientists and engineers. One substance developed by WES was both "hard as concrete" and "light as a cork." Testing at WES had perfected two extremes of concrete—some that could float on water and other types that were much heavier than normal. Such unusual concretes were designed to fit special requirements and to meet special needs, and testing covered a wide range of uses in many different situations of interest to the largest users of concrete in the world, the Corps of Engineers, and other Government agencies.

In many cases investigations were performed merely to make sure that the best concrete for the purpose was made using locally available materials at the

Roller-compacted concrete

lowest cost and with the greatest assurance of adequate strength and durability. In other cases, quite unusual materials were used when concrete of very unusual properties was needed. As cement was the most costly ingredient in concrete, cost could be cut drastically by replacing a portion of the cement with a substitute material, or pozzolan, so named because the first such material was a volcanic ash from a locality in Italy named Pozzuoli. The most widely used substitute material was fly ash, the dust that is collected at smoke stacks where powdered coal is burned to generate electric power. Studies showed that concrete made with portland cement plus fly ash is in some ways better and always of lower cost than concrete without pozzolan.

One type of concrete studied by WES and used in most of the Corps of Engineers flood control dams is made with aggregate in particles of all sizes up to six inches. Concrete weighing almost twice as much as normal was perfected to provide protection for people against nuclear radiation or against X-rays; iron ore and pieces of iron and steel were used for the aggregate. Cellular concrete, the other extreme, contained no aggregate except a little sand. Foam was substituted instead, and this type of concrete was used around underground buildings and instruments to protect them from explosively generated shocks.

Reinforcement materials for concrete were as varied as the substance itself: fiberglass rods were found to be stronger than steel as well as being noncorrosive and nonmagnetic, and split bamboo stalks were found to work quite satisfactorily where long life was not a requirement.

Experiments were also conducted on perfecting slow- and rapid-hardening concretes as well as one that would expand.[13] A test of rapid-hardening concrete, which would also gain strength, was made when a simulated bomb crater, 30 feet in diameter and about 7 feet deep, was repaired within two hours using a seven-man crew with portable pumping and mixing equipment. Pumping the material

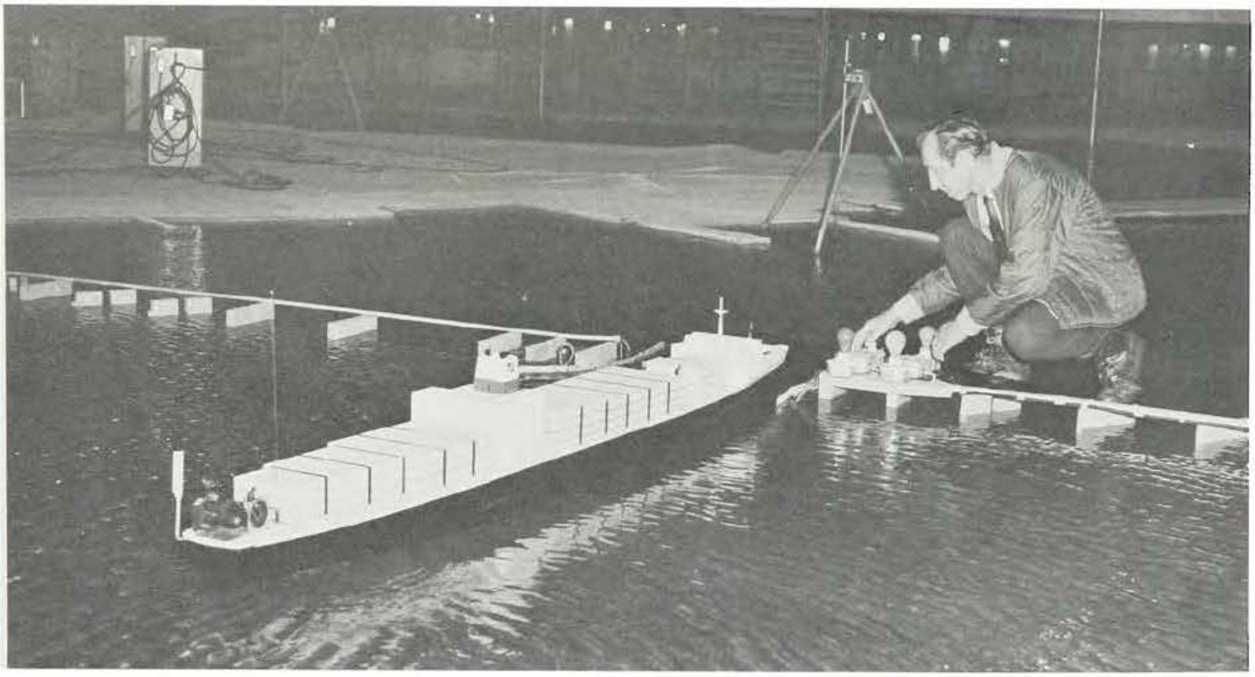
Grouting equipment at Nevada Test Site in support of weapons testing through plastic lines from 200 feet away, the lower portion was filled with foamed concrete made from cement, water, and air plus the debris from the crater. The top 1/2 foot was filled with cement grout with no air and no rock to form the pavement surface. The concrete set up in 10 minutes and within one hour was as strong as conventional high-strength concrete is after curing from one to three days.[14]

Research at the WES Concrete Laboratory also showed that there was a use for old concrete. Metal, glass, paper, and other forms of solid waste were being recycled, so why not portland cement concrete? Recycling of waste concrete could be especially advantageous because supplies of mineral aggregates were becoming exhausted in many areas (over 600,000,000 tons of aggregate were required annually in the United States for highway construction alone), and waste concrete removed during demolition of obsolete concrete structures required disposal.

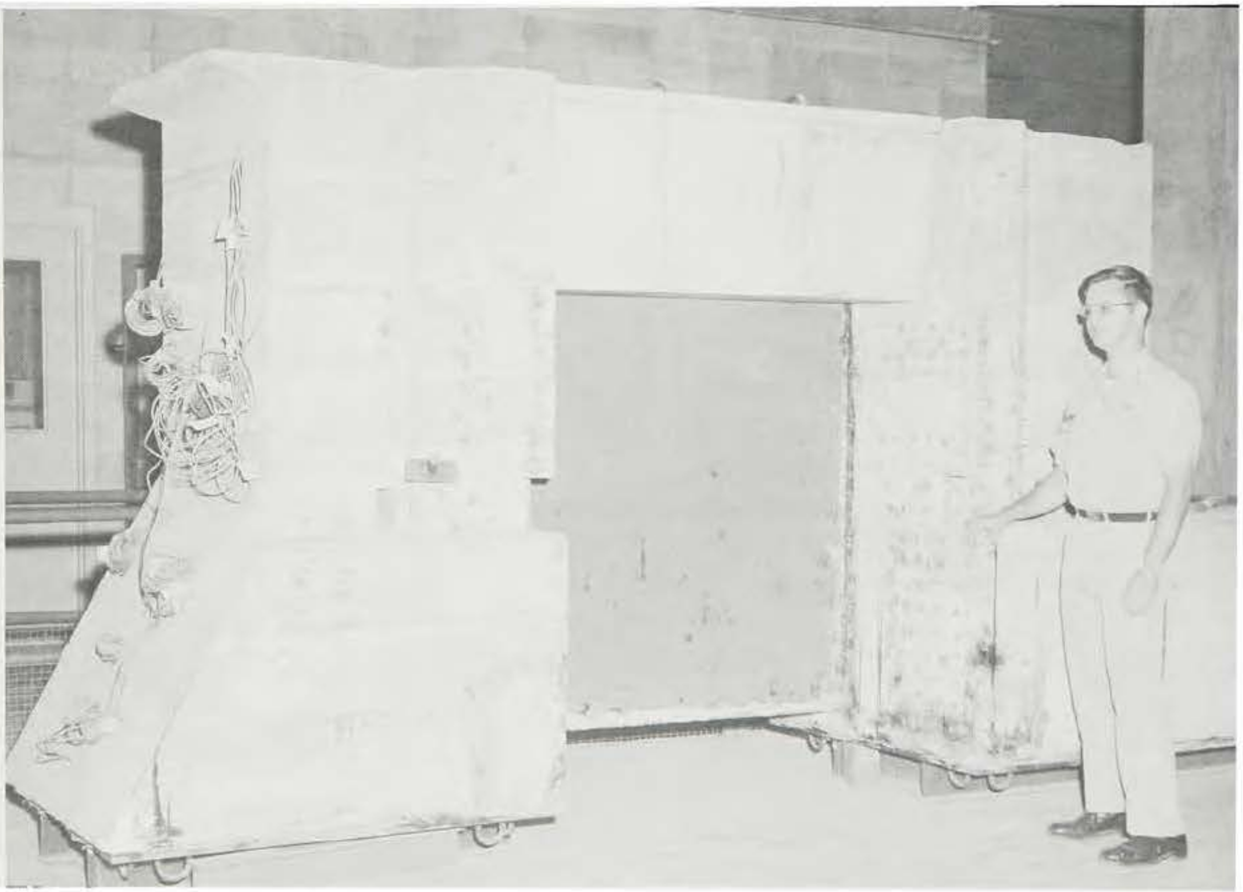
Recycled concrete. The concrete specimen shown on the right was made using discarded concrete as aggregate while the specimen on the left was made with the usual chert gravel and natural sand as aggregates. The intent of using waste concrete as aggregate is to conserve our supplies of natural aggregates and to reduce the amount of solid waste that must be disposed of daily. The specimen made with waste concrete as aggregate compares favorably with normal concrete. Based on results to date, this new usage appears feasible and desirable. The particles indicated by "x" represent fragments consisting of both mortar and coarse aggregate from the recycled concrete

At WES, several large fragments of 6-inch-thick pavement that was being removed and a large unreinforced concrete flexural test specimen were salvaged, and tests showed that the crushed waste concrete could be successfully used as concrete aggregate.[15]

Testing in other fields also continued, and one of the most unusual tests was the use of models to train river pilots to navigate the watery maze between Lower New York Harbor and the Elizabeth Port Authority Marine Terminal. Berths for 946-foot-long SL-7 containerships owned by Sea-Land Service, Inc., were reproduced to give pilots of the giant vessels advance opportunity to hone their skills under actual tide, wind, and current conditions using a 9-foot-long scale model built by Stevens Institute of Technology and shipped to WES. The hydraulically powered model was equipped with individually controlled twin screws and could be operated at two, five, or eight knots by remote control. Four tugs pushing the ship were simulated by fans built on the vessel—two at the stern and two at the quarterpoint forward. The pilot controlled the ship by radio from a platform built above the navigation channel. All predominant forces of nature, such as amount and rate of flow, currents, silting, salinity, tidal action, and waves, were reproduced; but the trials in the model happened 10 times faster than in real life.



Model ship built by Stevens Institute of Technology



A miniature version of Ice Harbor Lock on the Snake River in Washington was used to develop a modeling technique to determine internal stresses on mass concrete structures

When the pilots later handled the real vessels in New York Harbor it was evident that their training had assured mastery of their jobs.[16]

Scale-model testing was also conducted with miniature vehicles to predict their performance as related to geometrical surface irregularities such as logs, boulders, steep banks, and ditches. The self-propelled models included a tank and truck, which were standard Army equipment, and a new vehicle called the Gama Goat. The studies were made to verify the results of full-scale tests and for performance comparisons with other vehicles when the same obstacles were encountered. The surface geometry was flexible enough to cover a wide range of obstacle sizes, shapes, and spacings to simulate irregularities encountered when moving cross-country where there are no roads. The tests were part of research that was done to design military vehicles to meet and overcome nearly every extreme of the environment.[17]

Mobility data were collected by a WES team headed by B. G. Schreiner at Aberdeen Proving Ground, Maryland, in March 1976, and the XM-1 tank was chosen over competing designs on the basis of mobility, durability, fire power, and survivability on the modern battlefield. The WES team further tested the tank to determine if modifications were required before initial orders were placed by the Army, and a special instrumentation system developed by Newell Murphy and Gerald Switzer of the Mobility Systems Division of WES was used to evaluate the XM-1. The system measured and recorded the dynamic responses of the XM-1 at various speeds over a range of surface

Small-scale mobility models

XM-1 tank

roughness. The data gathered were used to evaluate the new tank's ride and agility on road and off, essential in determining how fast the vehicle can be operated effectively over certain types of terrain.[18]

Mobility testing wasn't confined to tanks and other military vehicles, for the "all-terrain" vehicle was popularized by outdoorsmen as well as companies concerned with timber harvesting, mining, surveying, and other earth-related activities. Accompanying the increased use of wheeled vehicles in off-road activities was the increased need for an ability to predict vehicle performance.

WES utilized a balanced program of basic laboratory research and field testing of full-scale vehicles with tires ranging in size from 2 to 15 inches wide and with diameters from 8 to 41 inches. Two principal soil types that, in most cases, present the severest problems to wheeled vehicle mobility were used: air-dry sand and near-saturated clay. WES expertise in predicting tire performance took the guesswork out of tire selections.[19]

A method for predicting ground vehicle performance in cross-country and on-road operations was developed jointly by WES and the U. S. Army Tank-Automotive Research and Development Command by utilizing speed prediction plots from a computer placed directly into a photo scanner-printer to create mobility overlays for use with standard topographic maps. The overlays could be rapidly reproduced in various colors by means of a dry-process printer, using commercially available printing foils. Such overlays could be useful in identifying probable enemy thrust lines, planning placement of minefields and barriers, and organizing mobile attacks.[20]

Ordinary driving of Army trucks also had a role in WES experiments. For 24 hours a day, 7 days a week for a month, a driving marathon was conducted in 1971 to determine how long a clay soil road would hold up under heavy truck traffic during dry and rainy weather. A half-mile loop road near the Yazoo Drainage Canal north of Vicksburg was laid out, the grass was removed and ditches were dug, but the soil was left in its natural state. The road was built near a levee so steep grades could be incorporated, and the loop shape provided the needed severe curves. From 5 to 10 trucks ran continuously over the track with 28 drivers operating in shifts to represent 100 or more heavy trucks passing over a clay soil road each day. It took more than 15,000 passes to develop behavioral patterns for dry, moist, and wet soil conditions. Results from the month-long testing program provided the military with a better system for estimating the capability of moving traffic on substandard roads. The tests were sponsored by the U. S. Army Transportation Engineering Agency.[21]

Just as landing mat and membrane had proved useful in various projects, a product developed for the military to control dust was also tried as an erosion preventive measure along the banks of Halls Ferry Road, which borders the WES grounds on the west and south sides. Stabilizing slopes along newly constructed roads until vegetation could take hold was a chronic problem for engineers, and several techniques were tried by WES. One method was to spray asphalt in combination with hay; the method provided a blanket which would hold newly planted seed in place until germination. Another method was to use PVA, an emulsion of chemical modifiers such as a plasticizer, surface active agents, and other organic constituents. By comparing the test sections, it was discovered that the dust control agent was quite effective in preventing erosion and in waterproofing the soil.[22]

A continued project at WES was the development of sensors, first begun in the 1960's, to detect tiny seismic waves set off in soil by the movement of men and machines. They were first used in Vietnam, but later equipment based on different physical principles was developed. The newer sensors "listened" as men whispered while walking along a jungle trail; others picked up the sound of a vehicle moving down a hidden road. They could detect changes in the earth's magnetic field caused by passing metal objects ranging in size from vehicles to men carrying rifles.

Actual use of sensors was extremely complicated. Models could not discriminate among the many things that created waves because they reacted only to the presence of seismic impulses and not to what caused them. The instrument did not tell the nature of the target from the number and frequency of activations. Terrain features such as vegetation, soil conditions, and the shape of the ground surface, even weather conditions, affected the operational performance of that type sensor, making it necessary to very carefully deploy it to obtain the best performance.

WES researchers attacked both problems with emphasis on understanding the interaction of the sensors and the environments where they were deployed. Teams of mathematicians and physicists worked to design sensors that would discriminate between soldiers and vehicles and even between different types of vehicles. Environmental elements greatly affected the sensors, causing them to work well in some areas and not perform satisfactorily in others. Even plowing a field changed the seismic properties of the area, and seismic waves moved differently before and after a rain.[23]

Tests of earth vibrations were conducted from one extreme to the other, for earthquake studies were also under way at WES in the 1970's. For years WES scientists and engineers had simulated disasters such as floods, tidal waves, hurricane surges—all in miniature. Their model earthquakes were of such magnitude that they might cause a dam to collapse and spread millions of gallons of water over the countryside. Such an event had never happened, but it was possible. One of the preventive measures was a study at the Big Black River test site where vibrations were created under the foundation of a scale model dam to simulate vibrations under real dams during earthquakes. Such tests pinpointed the critical stresses that could possibly lead to failure of structures during severe tremors.

Engineers made a model of the North Fork Dam on the American River in California, which had been built in 1939 to trap sediments from gold mining operations upstream. Vibration equipment had to be selected to induce forces in the model which would make it respond in much the same way that a real dam would respond to an actual earthquake. The vibrator had to excite the foundation of the model dam, plus the mass of the dam structure, plus the mass of an unknown volume of water behind the dam which would tend to dampen the vibrations of the structure. Twin electromagnetic vibrators were mounted on opposite sides of the center of the crest of the dam; by operating them out-of-phase as well as in-phase, a seismic motion of the dam abutments could be simulated to examine the responses of the structure to twisting or torsional motions.

The second and most important vibration system was a large electrohydraulic vibrator installed downstream from the model dam and coupled

Response of the North Fork Dam model to the effects of a nearby upstream explosion

North Fork Dam, prototype

into the foundation block to vibrate the foundation as a rigid body. The third method was to detonate a small explosive charge buried in the ground near the model basin to create the random, nonstationary ground motions characteristic of an earthquake. Such testing would allow prediction of the response of the real dams to earthquake vibrations.[24]

Another problem with shifting soil—one much less noticeable than earthquakes—was also studied at WES: the deposits of sand and silt in harbor entrance channels. One area where WES expertise was put to work to alleviate such a situation was at Mexico Beach in Florida. Sand drifting down the beach collected in the canal entrance. Constant dredging at considerable expense was necessary to keep the canal open to service the marinas and fishermen who kept the town economically alive. That's why the Town Council agreed to experimental testing of the WES sand bypassing system to suck in sand before it reached the canal and release it down the coast past the canal entrance. To achieve this suction, an intake pipe sucked water from the canal through a 6-inch pipe at the rate of 600-800 gallons per minute to a jet pump on the floor of the Gulf.

Project engineer William B. Fenwick of WES explained that a 1.25-inch nozzle in the jet pump caused water to shoot past a 2-foot suction pipe at a high velocity. The velocity created a low pressure, and like a vacuum, the suction pipe drew in sand and water, which was added to the water already supplied. All was returned at a rate of 900-1,200 gallons per minute. The flow was measured by a magnetic flowmeter at the centrifugal pump, and a nuclear density meter measured sand concentration. After the sand and water mixture was pumped through the nuclear density meter, it was

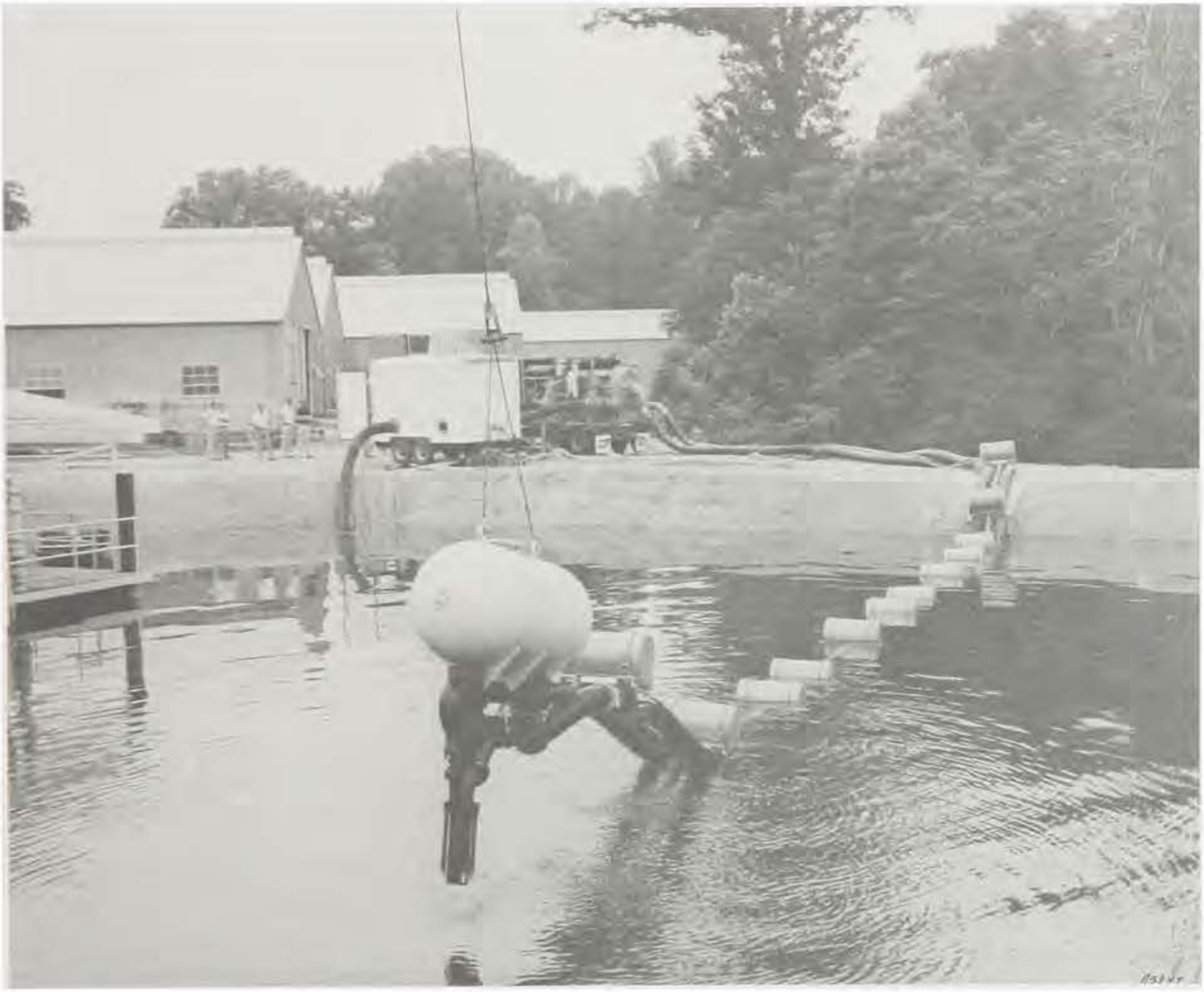
Sand bypassing system

then discharged onto the downdrift or the east side of the channel where it was redistributed to rebuild the beach where natural erosion had taken away the sand. The project, an experimental one, was not designed to clean out the canal but to bypass the natural drift of sand, thereby keeping the canal open.[25]

A portable sand bypassing system was also utilized by WES to combat shoreline erosion caused by small-craft harbor structures in the Great Lakes area and was delivered to the Detroit District of the Corps of Engineers in September 1978.

The problem in the Great Lakes area was caused when structures on the beaches impeded the movement of sand, the downdrift beaches suffering as sand collected on the opposite side of the barriers. The bypassing system moved the sand around obstacles to improve the navigation and to replenish the downcoast beaches.

The Great Lakes system included several special considerations: it had to be easily transportable, as it would be used at several different sites each year; it had to operate self-sufficiently without expensive large-capacity power hookups; and it had to operate with minimum manpower. A stock 43-foot lowbed semitrailer was used to make the system portable. The centrifugal and dredge pumps were at the back of the trailer, and a 1,500-gallon diesel tank which powered the system for about 55 hours was placed on the trailer



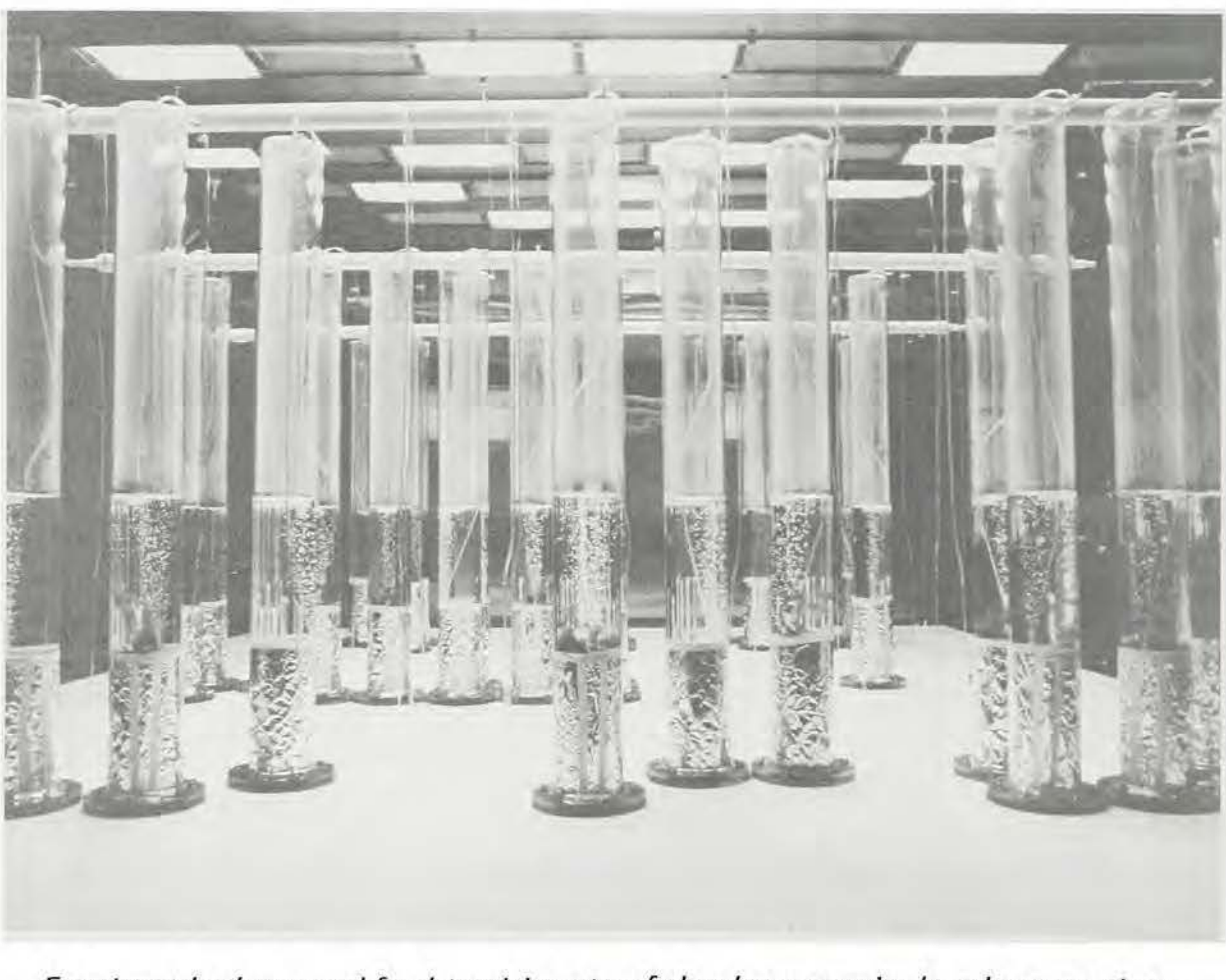
A portable sand bypassing system was developed by WES to combat shoreline erosion caused by small-craft harbor structures in the Great Lakes area. Sand bypassing is a unique method of dredging, using a centrifugal pump and a dredge pump on the shore and a jet pump in the water at the dredging site

front deck. Over the fuel tank, a diesel generator supplied all electrical requirements, and between the pumps and the fuel tank a small cab housed a 10-hp air compressor and a small room for shelter and storage space. A ladder from this room connected it to the control tower where one man could operate the entire system. Instruments for monitoring the system were self-contained in a separate 8x12-foot van type trailer. The jet pump could be operated up to 275 feet away from the trailer and the discharge site could be as much as 2,600 feet away. The system could move an average of 120 cubic yards of sand per hour.[26]

WES personnel also conducted tests to find a way to get an abundance of fresh water from the sea without contaminating the source. For every ten gallons of salt water converted to fresh, one gallon of brine went back into the sea; and to ensure that no harmful effects resulted, it had to be mixed properly. Research was conducted for the Office of Saline Water, Department of the Interior, to find how and where the brine waste could be discharged to get adequate mixing and to prevent detrimental effects. Tests were made in a flume built to a scale of 1 to 20, reproducing a level ocean floor 140 feet wide and 600 feet long. A dyed brine solution with a density higher than that of the flume water was pumped through the model outfall system, and the geometric characteristics of jet dispersion were determined by photographic methods. Both conductivity and temperature probes were used to define downstream dilution. When the time comes for desalting water to play a larger role in supplying the needs of man, WES' basic research and testing will have paved the way to getting the water without polluting the source and destroying marine life.[27]

Concern for the environment was nothing new for WES in its projects, for ecological effects had been taken into consideration for many years before public awareness became a factor.[28] "Environment" became the watchword for engineering projects in the 1970's, and efforts were made to try to balance the need for preservation of the landscape and ecological values against the needs of industry. Reservoirs, for example, were built for man's pleasure and needs, but environmental quality was kept in mind.[29] WES used hydraulic models as tools to study and plan environmental protection, pollution control, and ecological considerations in the water resources development program.[30]

One of the problems studied was that



Experimental columns used for determining rates of phosphorus pumping by submergent plants

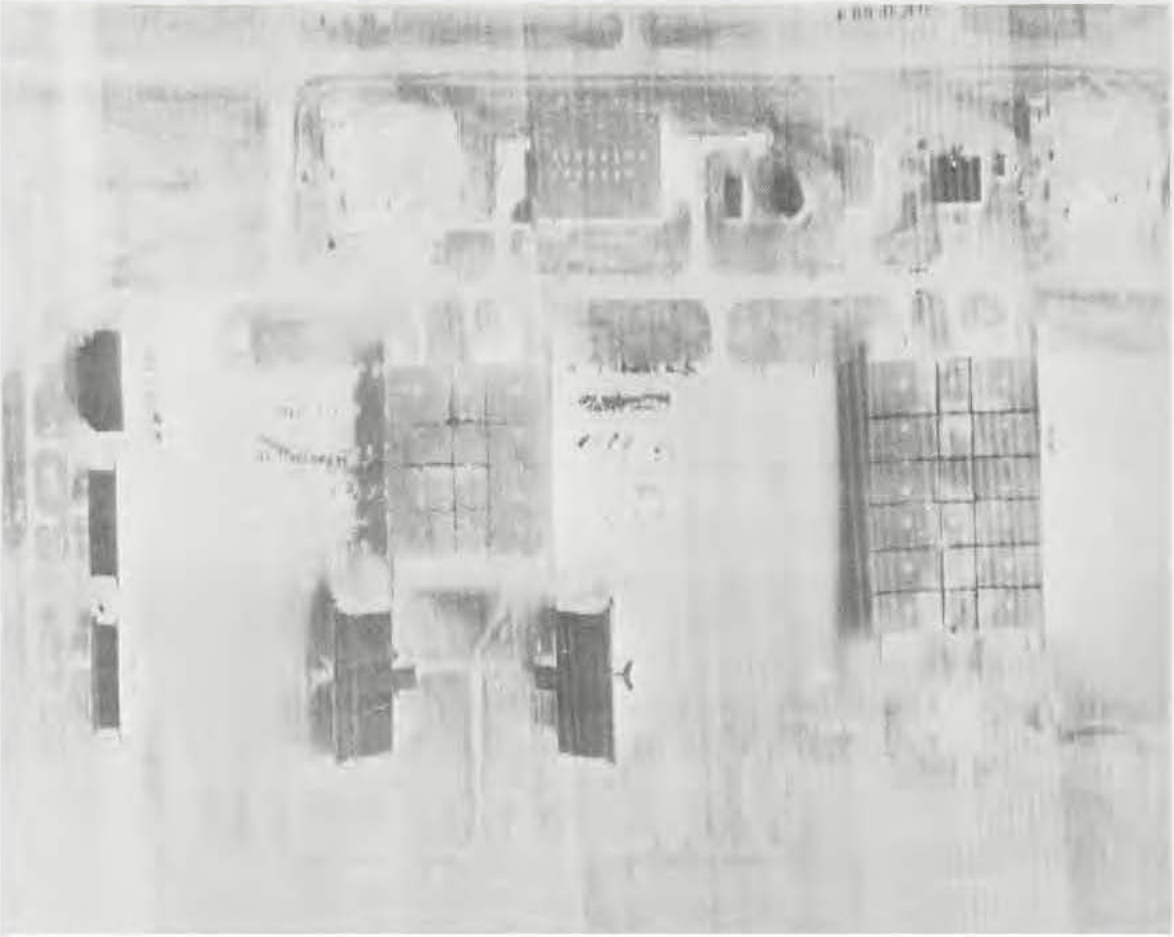
The selective withdrawal study is being conducted to improve the capabilities of the Corps to control and predict the quality of water released from impoundments

of oil spills on the sea. Though ancient mariners may have spread oil on troubled waters to calm them, they didn't realize that such oil might eventually wash ashore and pollute the beaches and destroy wildlife. How to sink oil was a problem studied at WES, for even sinking the substance with a variety of sorbents, or absorbents, offered by manufacturers could cause more problems. When applied to floating oil, the sorbents created, by chemical or physical action, a lump with a density higher than that of water so that the newly created lump would sink. Such sinking agents were used only after all other control methods proved to be inadequate and oil was in danger of polluting the shoreline. Sinking sorbents were not used in marine waters less than 11 metres deep because of the danger to shellfish and other marine life. WES scientists and engineers experimented with over 25 different types of materials marketed as sorbents. Each was tested with six different oils in both fresh and sea water and at various temperatures in order to evaluate the effectiveness of each.[31]

An example of the environmental data supplied by experiments with a model was that of Mobile Bay. Tests could determine the impact of a proposed ship channel and its resultant displaced bed material on the oyster industry at the lower end of the bay; and potential uses of the model included the effects of deepening the main ship channel; alterations in the pattern or quantity of freshwater inflow; possible changes in dredging practices; construction of causeways, bridges, and landfills; pollution abatement; wildlife enhancement; and shoreline development.[32]

Environmental-related knowledge and experience were formulated by the Office of Special Assistant for Environmental Coordination which formed, managed, and supported interdisciplinary teams to attack the many problems associated with today's environment. A wide variety of systems analysis methods was applied by WES to obtain solutions to problems including traditional techniques of mathematical modeling as well as rapidly developing methods of computer simulation and study. Data storage, using computers, made it possible to gather and preserve for quick use vast amounts of information. An instrument package was capable of collecting and transmitting to a computer the data on current velocity, discharge, water temperature, dissolved oxygen, pH, turbidity, and conductivity.

WES carried out extensive research in the use of remote sensing in environmental studies. Examined were the results of infrared and radar imagery, radiometry, gamma radiation, magnetometry, airborne



Airborne thermal infrared sensor systems have proved to be a valuable means of rapidly surveying the roofs of an entire installation. Lighter spots indicate areas of entrapped moisture that may have to be replaced or repaired laser profilometers, and laser surveying devices.[33]

At the request of the Office, Chief of Engineers, an interdisciplinary team was formed at WES to define problem areas and to direct and conduct the research needed to solve the nationwide dredging problem. Through the preparation and review of Environmental Impact Statements, extensive experience was gained and was extended into the development of a general systems analysis approach for the preparation of such statements. WES had the capability to predict physical consequences and associated impacts on ecosystems, endangered species, water quality, and such interrelated hydraulic or sedimentation phenomena as tides and tidal currents, wave action, littoral currents, movement and deposition of beach sands, and the intrusion and mixing of salt water.[34]

Data sources included both laboratory and field studies of all Government agencies, domestic and foreign university investigations, and professional periodicals and literature. Analysis of the data was done in accordance with accepted modern theories, procedures, and techniques, and the results were normally illustrated in dimensionless parameters correlated and published in chart form for use in the solution of design programs.[35]

Such rapid accumulation and dispersal of information would not have been possible without the large computer system at WES. Computers had been used at WES for more than a decade when the largest one devoted to engineering and the only such system in the Corps of Engineers was dedicated in mid-1973. The 30 seconds it took WES Director Col. Ernest D. Peixotto and Technical Director Fred R. Brown to cut the ribbon at the ceremonies was equivalent to the day's calculating efforts of 50 people.[36] Plans for this Honeywell G-635, which had twin processing units, 192,000 words of memory, and 170 million characters of random access memory, began in April 1967; final installation took place in the spring of 1973. The WES Automatic Data Processing Center provided services to about two dozen Corps of Engineers offices, and hundreds of engineers and scientists could use the system, operated by WES and housed in the specially designed and constructed computer room of the ADP Center.

Computer power at WES again took a giant step forward in February 1979 when the newest acquisition, the Texas Instruments Advanced Scientific Computer, went into operation. The $8 million computer system is one of only seven Advanced Scientific Computers in existence. It has the potential to be as much as 80 times as fast as the Honeywell G-635 also used at WES and provides the opportunity to explore new frontiers in civil engineering research.

Very special housing and handling were provided to protect the $3 million investment in computers and supporting communications equipment. Around-the-clock humidity control and air conditioning were required, and a specially designed motor generator supplied the system with over 200 kilowatts of electricity. In case of a power failure, the computer could close down without damaging itself. Fire and smoke detectors would automatically close doors to the room and alert WES security forces when activated. All cables and utility services were connected to the equipment from underneath the special raised floor.

The large computer, capable of

performing one million operations per second, could produce 15 different jobs simultaneously and send the calculated information back to the user over telephone lines direct to his office. In addition, the computer constantly analyzed itself and typed out messages on the local operators' console when one of its components was not properly functioning.[37] The big machine was used in conjunction with the standard GE-225 and GE-400 computers. It proved to be a totally responsive, efficient, cost-effective system unparalleled in civil engineering practice.[38]

An example of the computational capability of the ADP Center computers is the dynamic structural analysis of the North Fork Dam, a concrete arch-type dam located on the American River near Auburn, California. Mathematical models of the dam's response to impulsive loadings were solved using the computers. The computational procedures involved over a thousand degrees of freedom for describing the response. These results were used in conjunction with model and prototype vibration tests to evaluate the dam's response to earthquake loads and to water shock loadings from underwater explosions.[39] The computational efforts were under the direction of Dr. J. P. Balsara and Mr. C. D. Norman, both of the Weapons Effects Laboratory.

Use of computers and other rapid scientific advancement made some recent engineering projects practically obsolete, and on 1 January 1968 part of the property at the Clinton installation had been declared surplus. Forty acres were offered to the City of Clinton for use as a sewage lagoon.[40] Several years later, additional land at the big river model site was offered to Mississippi College at Clinton.[41] In 1973, when the school took possession of 220 acres, Dr. Lewis Noble, President of Mississippi College, noted that 85 acres would be used for field research in biology, botany, and chemistry and studies in air, water, and land pollution as well as fisheries biology. An additional 85 acres was planned by the college for physical education including a golf course, lake, and picnic area.[42]

However, at about the same time the transfer was being planned, use for the model was again found. By the middle of 1973, with floods inundating the entire Mississippi Valley, engineers turned to the model for information on what to do about the situation. It was placed on 24-hour duty, and MRC President Major Gen. Charles C. Noble noted:

> *Intricate relationships between the Mississippi and its tributaries do not always lend themselves to computer analysis. A computer is only as good as the data you input. There usually comes a time, in these situations, when you feel a lot better if you can put the problem on the model and get an empirical answer.*[43]

The first problems put to the model in a series of crash tests that were begun on 16 April 1973 dealt with the Atchafalaya Floodway. James Foster, engineer in charge of the big model, commented that "Computers have not been able to duplicate what this model can do."[44]

The 1973 flood, however, was unique in that one like it had never before occurred in recorded history. Should such a flood occur again, or even one that is more intense, the WES computer has the needed information stored away for easy retrieval and utilization.

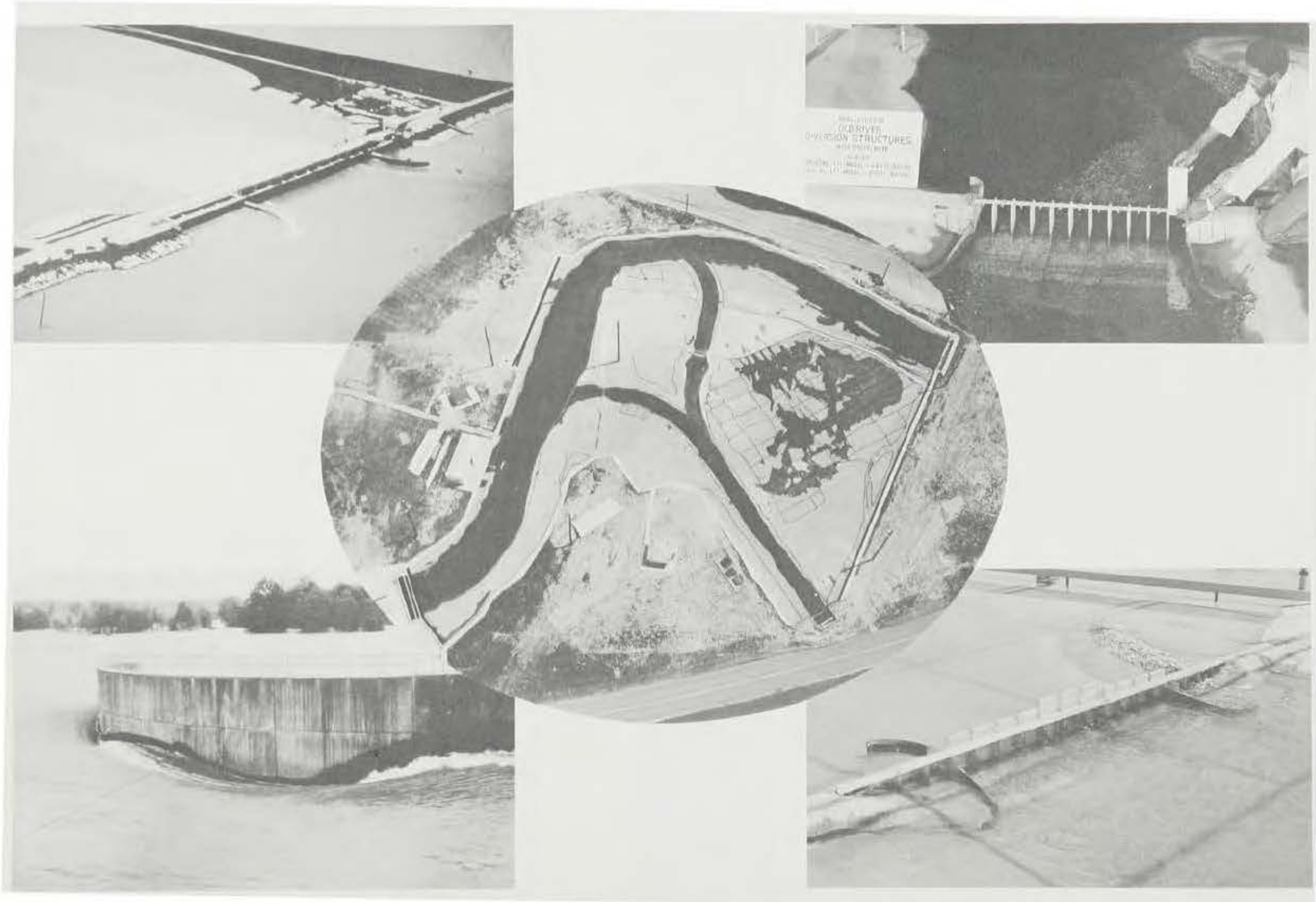
Two control structures at the junction

Mississippi Basin model, 1973 flood

of the Mississippi River with the Red and Atchafalaya Rivers did not survive the 1973 flood unscathed. Thirty days before the flood crest reached Old River, a vortex formed beside the left guide wall of the low-sill structure, and the vortex and the high-velocity flows combined to undermine the guide wall, which subsequently collapsed. With the guide wall gone, the turbulent flow scoured a deep hole upstream of and beneath the low-sill structure itself, and the Corps of Engineers immediately began to dump stone riprap into the hole; a rock dike was hurriedly constructed to prevent further scouring near the end of the structure.

In May 1973 as the flood crest passed, WES gave priority to construction of a fixed-bed model of the control structures and the nearby river system in order to reproduce the conditions which caused the failure and to test possible remedies. Testing began as soon as the model was complete, and several types of dikes and levees were designed and tested in an effort to find the optimum replacement structure for the missing wing wall. In February 1974 the model was extended downstream and remolded to postflood surveys in order to test possible sites for a new low-sill control structure and diversion channel.

Grout mixtures for repair of the Old River low-sill structure were tested at WES, and approximately 30 were analyzed before recommendations were made; 33,000 cubic yards of level-seeking grout



Aerial view of Old River Control Structure model. This study of a section of the Mississippi River between Natchez, Mississippi, and Baton Rouge, Louisiana, was requested as a result of the collapse of the south wing wall of the structure during the spring flood of 1973. Views of models shown in insets at right; prototype shown in insets at left were placed under the structure to fill the voids. Location and spread of the grouts used were determined by electronic grout detection gages developed especially for the project by personnel of the Engineering Physics Branch of the WES Concrete Laboratory. The gages determined when and where to switch grout pipes and when to start and stop grouting.[45]

While many efforts were made to keep streams within their natural beds, other tests were conducted to determine the best methods to construct canals and reservoirs through the use of explosives, or cratering. In 1971, WES successfully conducted its first explosive ditching experiment after broadening its capabilities in the nuclear and conventional weapons effects area to include development of actual construction techniques.[46]

On 19 July 1971, the U. S. Army Engineer Nuclear Cratering Group (NCG) at Livermore, California, was discontinued by the Chief of Engineers in Washington; it was put under the direction of WES, and on 30 July 1971 Col. Ernest D. Peixotto, WES Director, issued General Orders #5 assuming the work at Livermore.[47] The installation had been created as a Class II activity under the command of the Chief of Engineers on 23 May 1962 with headquarters at the Lawrence Radiation Laboratory (LRL) at the University of California at Livermore. Its mission was to participate jointly with the LRL in the technical planning, management, and

Demonstration of explosive ditching

execution of a research program on nuclear methods of excavation, a part of "Operation Plowshare." One of its major projects was to investigate and provide basic information for examining the question of, the need for, and the method of construction, location, and cost of a sea-level interoceanic canal in the Isthmian region of Central America.[48]

The primary activities included the following:

> *Execution of high explosive cratering experiments to develop cratering characteristics data for geologic media of interest and serve as calibration experiments for large-scale nuclear experiments; participation in and joint planning of AEC nuclear craters; development of civil works nuclear construction technology; accomplishment of engineering studies to identify and solve engineering and construction problems involved in the use of nuclear explosions in construction of civil works projects; and execution of joint CE/AEC Civil Works nuclear construction experiments.*[49]

NCG also conducted military-funded research and laboratory experimentation in order to develop engineering data and emplacement techniques for using nuclear explosives for military engineering purposes.[50] Studies provided a feedback to the research program on specific problem areas encountered in real application, served as a training ground for a large pool of talent in the new technology, and provided data for developing nuclear cratering experiments which could be conducted in conjunction with the construction of actual civil works projects to demonstrate the viability of nuclear excavations.[51]

By 1969, a dozen studies on the use of explosives had been completed, including spillway excavation, quarrying, creation of dams, and harbor excavations.[52] Many problem areas had been identified during the studies. One of the major ones concerned explosive placement, determining the best techniques and ways to minimize costs of drilling large-diameter (30-inch) emplacement holes in various geologic media, in disturbed materials, and within (or near) existing nuclear craters for enlarging excavation.[53]

High-explosive quarrying for rock fill on Buchanan Dam on the Chowchilla River near Merced, California, resulted in a $550,000 savings. Studies on a similar project for the Twin Springs Dam on the Boise River showed a possible savings of 1.2 million dollars exclusive of the nuclear devices needed and public safety costs. Not all such projects are amenable to explosive excavation techniques, e.g., the study of an improvement project for Yaquina Bay and Harbor at Newport, Oregon, showed that oyster beds in the area would be harmed, so the project was abandoned.[54]

WES and NCG had often worked in cooperation. In Project Danny Boy, a low-yield nuclear cratering experiment conducted in the basalt of Buckboard Mesa in Nevada, WES personnel conducted extensive postshot geological and engineering investigations of the crater to determine the change in engineering properties of the rock media adjacent to the crater and to determine the engineering properties of the important physiographic features of the crater.[55]

Nuclear cratering could break up and eject large quantities of rock and soil for excavations such as channels, harbors, dams, and spillways, or the method could be employed simply to break up rock media to produce aggregate for quarrying purposes. Cratering could also be utilized in highway and railroad construction, and it proved to be both a time and money saver.[56]

Naturally, a great deal of study preceded the actual use of nuclear cratering, for those in charge had to possess knowledge of the phenomenology of crater formation with regard to the immediate geologic environment surrounding the site, be familiar with detailed data on the characteristics and emplacement requirements for nuclear explosives, and understand the safety implications of the radioactivity, the airblast, and the ground shock effects, all of which were by-products of nuclear cratering detonations.[57]

The first project conducted after NCG came under the jurisdiction of WES was at Trinidad Lake, Colorado, where two experiments were made to demonstrate the feasibility of making railroad cuts with high explosives. When the work was complete, the cuts were very nearly perfect.[58] After the Livermore Group became a field office of WES, the name was changed to Explosive Excavation Research Office, and in October 1974 the announcement was made that the work was being further consolidated with the movement of EERO from California to Vicksburg, where it became a division of the Weapons Effects Laboratory at WES.[59]

During the fall seasons of 1973, 1974, and 1975, extensive field tests were conducted at Fort Polk, Louisiana, for the purpose of determining the effects of subsurface explosions. This test series, known as Project ESSEX, was under the direction of John N. Strange.

Railroad cut made by explosives

The main purpose of the ESSEX experiments was to evaluate the capabilities of low-yield nuclear weapons, whether they be atomic demolition munitions or earth penetrating warheads, to create obstacles and/or barriers to mobility and to destroy generic classes of structures that might be targeted in a tactical war environment. Mainly, the targets of interest were: bridging, earth-covered precast concrete aircraft shelters, POL (petroleum, oil, and lubricants) storage and pipeline distribution systems, and underground command and control centers.

Each of the ESSEX detonations, nine in all, involved nominal 10-ton yields of gelled nitromethane. The centers of gravity of the various charges were positioned at varying depths below the ground surface ranging from 3 metres to 12 metres. This spread in the charge depth of burial established an optimum depth of burial for cratering. The results obtained have provided a realistic data base for inferring the effects of low-yield nuclear events by having a quantitative knowledge of the effects of their high explosive equivalents or their modeled high explosive equivalents.

Not all tests were on such a large scale. In the late spring of 1976 preliminary tests, made for the Federal Aviation Administration, gathered data on the effects of homemade or terrorist bombs detonated in airport baggage lockers. Results were used to redesign lockers and

Project ESSEX detonation

the locker storage space within air terminals to minimize damage from these and other explosive threats.[60]

Explosives were also used by the Weapons Effects Laboratory to obtain information on lava flow structures on the flanks of the world's largest active volcano, Mauna Loa, on the island of Hawaii. The tests were devised and directed by John E. Shaler and Sherman Price, both of the

Smoke and volcanic dust billow in the air as two 40-pound charges are detonated over a lava tube located on the flank of giant Mauna Loa Volcano on the Island of Hawaii on 24 May 1976

This opening was blasted into a lava tube on the flank of Mauna Loa Volcano. The analysis of tests such as these will help scientists to evaluate potential use of explosive charges to hinder or stop volcanic flows in the event of an eruption on the giant mountain

Weapons Effects Laboratory. The purpose of their investigations was to determine the feasibility of redirecting lava flows away from habitation by altering the down-slope terrain along the flanks of Mauna Loa and by explosively constructing dikes to divert lava flows.

Past eruptions had resulted in the formation of lava tubes for undetermined distances through Mauna Loa; should the lava form new tubes as an escape route, it would remain in a molten state longer and could flow unimpeded with no knowledge of where it would eventually surface. Collapsing the lava tubes could have the effects of rubble stopping the flow or changing the force of the flow to other directions and also allow the lava to surface, disperse, and solidify.

During preemergency tests, 47 charges were exploded at depths from 3 to 8 feet against 10-foot spatter cones and levee walls and against 10-foot lava tube ceilings. Breaching spatter cone walls and lava levees could change the flow of lava to a desired direction, and charges in or ahead of lava flows could be useful in creating new channels, lava dikes, or lava lakes.[61]

Another function created at WES in 1974 was the Environmental Effects Laboratory (EEL), which combined the Office of Environmental Studies (OES) and the Office of Dredged Material Research (ODMR), both of which had been organized in the early 1970's and had worked in conjunction with one another. Their establishment was brought about by an ever-increasing concern over environmental factors, particularly those related to dredging operations.

Chief of EEL was John Harrison, who had three special assistants: R. T. Saucier, Dredged Material Research; J. W. Keeley, Program Development; and Major F. H. Griffis, Jr., Program Management. There was a manager and staff for each of the four major project areas, and personnel from several other WES technical laboratories worked closely with EEL.

Dredging of the nation's channels, harbors, and facilities that accommodate the huge tonnages of domestic and foreign waterborne commerce and serve maritime interests is both important and necessary; and the principal responsibility for such work is shouldered by the Corps of Engineers, which, with its own equipment or by contract, periodically must dredge much of the 25,000 miles of waterways, 107 commercial port facilities, and 400 small-boat harbors assigned to it by Congress for maintenance. Annual cost is almost $200 million, and each year dredged materials exceed 350,000,000 cubic yards.

Traditionally, dredged materials were disposed of in the easiest and most economical manner. However, during the 1960's and early 1970's, environmental concern became a significant factor, perhaps the controlling one in regard to many dredging projects. Such concern, both private and public, led to the creation by Congress in 1970 of a nationwide research effort as part of the Rivers and Harbors Act (Public Law 91-611, Section 123i), and the job was assigned to the Corps of Engineers. The Corps turned to its problem-solving center, WES; and in May 1971 WES began defining and assessing the problems and development of the research program, completing these two parts of a four-phase program in 1971-72.

In March 1973, the third phase of the program was augmented to discover cause-effect relationships pertaining to all modes of disposal and a search for new or improved methods and/or alternatives was begun. The purpose was not to prescribe disposal methods for any particular project or location but rather to identify, test, and evaluate a list of disposal options representing a wide range of applications. Rather than seeking to establish the precise effects of a contaminant on water quality or particular organisms, the program instead endeavored to understand the processes involved so that effects could be measured and consequences predicted.

The final phase, along with continued work of the Dredged Material Research Program (DMRP) begun in 1973, concerned prototype tests and the application of results. Research projects fell into four categories: aquatic disposal, habitat development, disposal operations, and productive uses. Twenty separate tasks to be researched were incorporated into these projects.[62]

Funding for the program was authorized by the Office of Management and Budget (OMB) in February 1973, and both Congress and OMB approved continuation of funding for the fiscal years 1974 and 1975. It was estimated that the program would require five years and $30 million; it was completed in March 1978. Incremental funding by OMB was contingent on production of results justifying continuation.

Field test sites were established in such diverse locations as Texas, Oregon, Michigan, New York, Ohio, and Connecticut, and carefully controlled and analyzed studies were conducted by WES engineers and scientists as well as by contract with private organizations.

Research into disposal and use of dredged materials concluded that there are productive uses that will benefit both man, bird, and beast. Historic Fort Massachusetts, located on Ship Island, presents a good case history of the use of dredged materials. Built 12 miles off the Mississippi coast in 1856, the old brick fortification stood on a small peninsula that slowly eroded away over the years, leaving the walls unprotected from the water. Rock jetties were only partially successful in protecting the popular tourist attraction from the ravages of hurricanes and other storms.

In the early 1970's, the site was acquired by the U. S. National Park Service (NPS) as part of the Gulf Islands National Seashore, and the NPS requested the Mobile District to consider placing dredged material from the nearby Gulfport Channel around the fort to isolate it from structurally damaging constant wave action.

Sediment removed periodically from the navigation channel in maintenance dredging operations is largely clean sand. In the past, the sand had been disposed of in open water on the downdrift side of the channel; the progressive buildup, however, was considered environmentally undesirable because it reduced the circulation and flushing of the shallow Mississippi Sound. Despite the increased cost that would be involved in placing a portion of the dredged material around Fort Massachusetts, the Mobile District agreed to the NPS request as being the most satisfactory disposal alternative and one with direct tangible benefits, both sociological and economic. After construction of a low dike to prevent the spread of dredged material into an adjacent marsh, about 500,000 cubic yards of dredged material was placed around the fort in March 1974. Once again the fort is on land, protected from wave action. Future dredging will make possible the replenishment of the sand around the fort and the restoration of other shoreline areas.[63]

A DMRP study in 1975 showed that aesthetic development could be an integral part of any disposal project. Examples included the Portland, Oregon, Port Authority which developed and maintained pleasant parks on land created by disposal of dredged material; Times Beach, a large diked disposal facility near the central business district of Buffalo, New York, which was being developed for recreational use; Vacation Island in Mission Bay, California, part of a land and water recreation complex created by dredging and disposal of dredged materials; and East Potomac Park in Washington, D. C., built on dredged materials. Along Lake Ontario near Toronto, Canada, the Harbor Commissioners have used construction fill and some dredged material to create a shoreline park system, and one of the parks, Ontario Place, has been extensively developed with theaters, lakes, and facilities for a variety of recreational experiences. The use of dredged materials for such projects could alleviate both the problem of disposal and that of where to locate needed recreational facilities.[64]

A century of active dredging and disposal operations by the Corps, state agencies, and private industry resulted in the creation of over 2,000 manmade islands throughout the U. S. coastal, riverine waterways and the Great Lakes, and in 1976 the DMRP made an initial assessment of the existing use of dredged material islands by wildlife, primarily by colonial nesting sea and wading birds. It was found that 36 colonial nesting waterbird species, 17 noncolonial waterbird species, and 32 other noncolonial bird species were nesting on dredged material islands in U. S. waterways in numbers estimated to total

Port center development on dredged material, Portland, Oregon

Terns on island made of dredged material, located off the coast of Florida

two million adults. Where natural sites were not available, colonial nesters used dredged material islands; and in some cases where both types of habitations were available, some species preferred the dredged material habitats.

In several instances, islands created from dredged materials were providing habitats for rare, threatened, and endangered species. Black skimmers, gull-billed terns, and least terns found homes on Core Sound Islands in 1976-77, only a year after the Wilmington District of North Carolina had created the islands.[65]

Sidney Island, located at the head of Sabine Lake in Texas and made from dredged materials from the Sabine-Neches Canal, the Sabine River Channel, and the Neches River Channel projects, has become the home of a number of wildlife species including colonies of herons, egrets, cormorants, and the coveted and endangered roseate spoonbill; over 300 of the spoonbills in the early 1970's made it the largest known colony in Texas.[66] In 1975, rare spoonbills were again nesting in Florida's Tampa Bay for the first time in 63 years—on an island created by deposition of dredged material.[67]

Though many such islands had been accidentally beneficial, WES studies showed that planned marshes and manmade islands were not only feasible but also desirable. An example was the area along Alameda Creek in California where dredged material from a flood control channel was used to create a marsh in a salt pond, and marsh grasses were planted.[68]

Another planned habitat development was on Nott Island in the Connecticut

Salt marsh development on sandy dredged material, Galveston Bay, Texas

River where dredged material was utilized as a base for reclaiming six acres of barren, coarse sand in the middle of a 100-acre island.[69]

In 1976 researchers from Old Dominion University in Norfolk, Virginia, joined with the Corps in studying possible problems of a manmade island on the James River. The 11.5-acre site near Hopewell, Virginia, was a watery milieu enclosed by soil dikes. Pathways cut by insistent river currents flowing in through a few breaks in the dike walls penetrated the mass of vegetation which often towered 10 feet above the water level. Wildlife quickly found the island. Migrating ducks and geese stopped after some experimental grasses planted by project workers had sprouted (natural seeding of native grasses made further planting unnecessary). Soon muskrat, frogs, and fish turned the manmade habitat into a normal wildlife community.

The process of building such an island was simple: dredges pumped the dredged material inside the perimeter of sand dikes. Pipes at either end of the oblong island allowed the water from the dredged material to flow through, and the heavier particles settled to form a marshlike environment inside the dikes.[70] Being inhabited does not preclude additional use of the site for disposal, for studies showed that new periodic deposits of dredged material on manmade islands would prevent excessive vegetation and preserve the island for the desired species.[71]

Uses for dredged material, not necessarily oriented to wildlife, were also studied. Though some concepts were limited by the variation in the quality and supply of dredged material, shrimp raised in ponds and sustained by the nutrients in one foot of dredged material on the bottom grew to be larger than those in similar ponds with no dredged material. On the basis of these tests, shrimp farming was attempted at a conventional disposal site near Freeport, Texas, and proved to be feasible.[72]

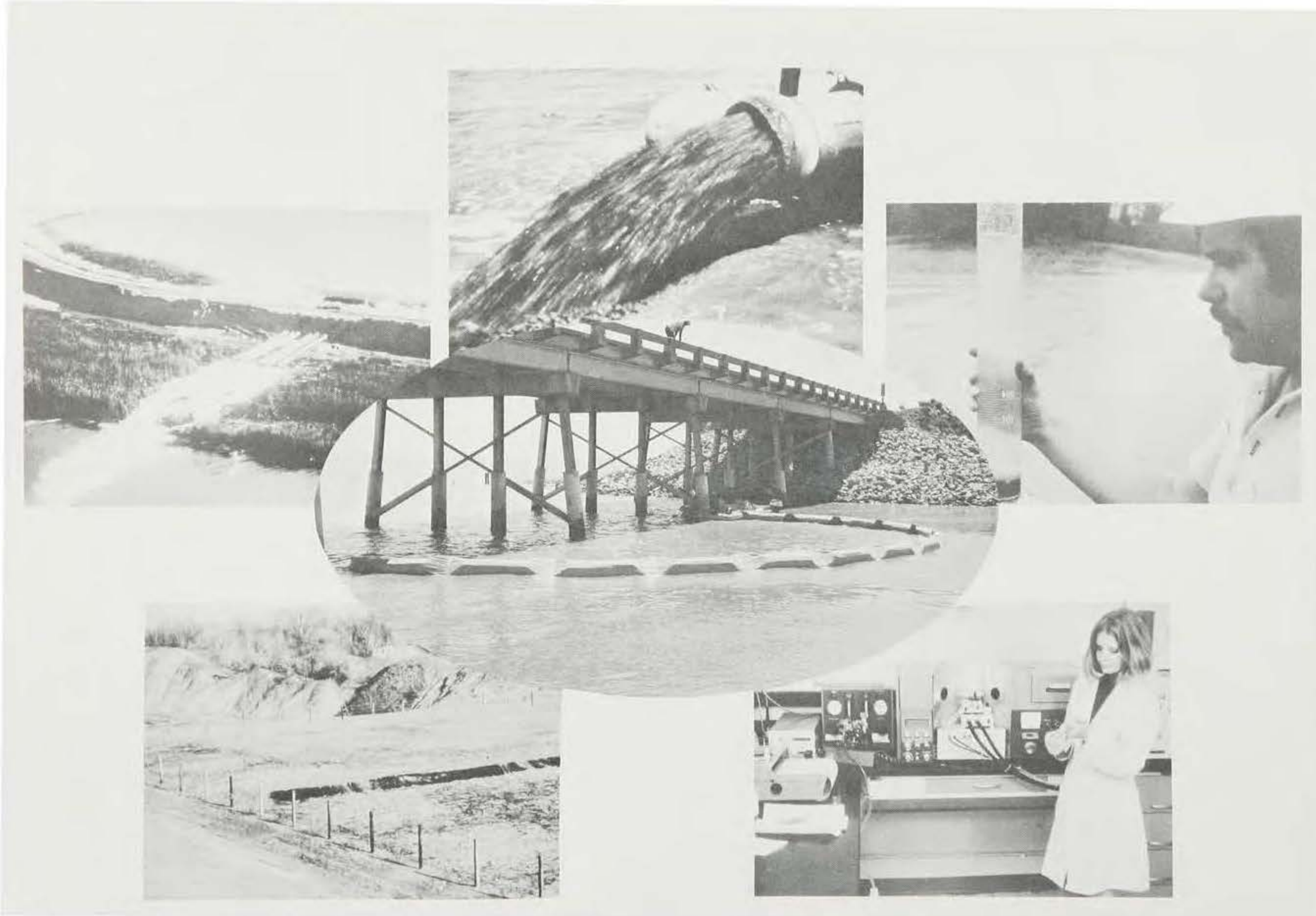
Studies were also made of long distance transportation of dredged material and the costs involved for use in inland areas. If dredged material could be moved economically over several miles, it could perhaps be used to improve agricultural soils, to fill abandoned pits and quarries, and to reclaim stripmined lands. Intensive research on dredged material during the period March 1973 to March 1978 proved that, with proper management, dredging could serve the environment as well as the economy. There are disposal alternatives that are safe for the environment that can be established at reasonable costs by using dredged material as a natural resource.[73]

One of the most expensive aspects of confined containment areas for dredged material is land acquisition. A solution to this problem would be to increase storage capacity of existing sites or make them reusable. Since most dredged material is at least 80 percent water when it is placed in a disposal site, removing the water would increase storage capacity. Through tests conducted by WES, it was found that a modified Marine Corps vehicle, the Riverine Utility Craft (RUC), tested earlier by WES for military purposes, would be an inexpensive and effective way of creating trenches to provide natural drainage. In addition to increasing storage capacity, dewatering also improved the engineering value of dredged material. The consolidated material could be used within the site for dike raising or haul roads, or offsite for landfill or construction.[74]

Shrimp farming in a disposal site

Pollution effects of disposing of both raw and chemically fixed industrial wastes into a municipal solid waste landfill were also studied at WES in tests begun in 1977. Thirty tons of household refuse from the Vicksburg area were used in the project, sponsored by the Solid and Hazardous Waste Research Division of the Environmental Protection Agency in Cincinnati. Five tons of industrial sludges (chemically fixed to provide a stable material) were added to the municipal waste. The material was weighed and then compacted into large cylinders. Raw sludge was placed in some, fixed sludge in others, and four cylinders were filled with municipal waste only; these latter four would be used to monitor gas production rates and gas composition.

Samples were to be collected and analyzed for four years to determine the potential for contamination of



Silt curtains were tested in Heron Bay, Ala., to evaluate their effectiveness in containing turbid water. Other Dredged Material Research Program activities shown in insets

Sanitary landfill simulation

groundwaters by industrial sludges buried in sanitary landfills; gas data would be analyzed to determine the volume and quality of gas per pound of the municipal waste released during composition. Concurrent with the project, WES conducted studies to determine the feasibility of using chemical fixation to reduce the release of pollutants from sludges produced when coal-fired boilers were used for energy production.[75]

WES also assisted the EPA in a program designed to eliminate the high cost of wastewater treatment systems. The combined effort was the result of an EPA Office of Water Program Operations and the Corps' Urban Studies Program involvement in water resources planning for metropolitan areas. The Federal Water Pollution Control Act of 1972 allowed both agencies to assist regional governments in developing long-range plans for their water and wastewater requirements.

WES developed the Computer-Assisted Procedure for the Design and Evaluation of Wastewater Treatment (CAPDET). The idea for CAPDET originated when the Office, Chief of Engineers, asked WES in 1972 to develop a design manual for wastewater treatment systems. By the use of CAPDET, planners could consider existing wastewater treatment facilities, community growth patterns, and future restrictions when developing designs and costs for plant upgrading. One of the major attributes was the preparation of the design and calculation of the capital and operating-maintenance costs for thousands of possible designs. The system also permitted the large-scale design and cost analysis of wastewater treatment systems. Other uses for an expanded CAPDET system as a planning tool were wastewater routing alternatives, optimization of staged construction of facilities, and other alternatives for management of water and wastewater required to meet the needs of the growing population.[76]

At the nearby town of Utica, Mississippi, an experimental testing program to clean up wastewaters to advanced levels before discharging them into streams was initiated by the Ecosystems Processes Research Branch of the Environmental Effects Laboratory at WES. The concept was to use soil as a purifier for water. Slow and rapid infiltration systems remove such elements as nitrogen and phosphorus from water, but trace elements of predominantly heavy metals such as lead can be toxic, and WES' testing was to determine if the water-soil treatment system was safe and effective for both man and the environment. Testing was pioneered at WES in 1972 with greenhouse models to see if the system was confined to any particular locality or if it could be used universally.

At Utica, on a field adjacent to the town's sewage lagoon, three slopes of varying degrees were constructed. The areas, 150 feet long and divided into sections 15 feet wide, ranged in slope from 2 to 8 degrees. The wastewater was

Overland flow treatment of wastewater, Utica, Miss.

pumped to the top and then discharged by an automated process. After the water passed down the slope it was caught in a drainage ditch and checked for contents. It was noted that low operating and maintenance cost was an asset of the operation, and that side benefits included irrigation of the soil and an improved quality of the grass.[77]

A six-year program of applied research to provide new or improved technology to solve selected environmental quality problems associated with civil works activities of the Corps was also initiated under the sponsorship of the Office, Chief of Engineers, in October 1977 at WES. Called the Environmental and Water Quality Operational Studies, the principal goal was to solve specific environmental quality problems.[78]

Another problem tackled by EEL was that of clogged waterways which were choked with hydrilla and waterhyacinths. As mentioned earlier, no natural enemies of the waterhyacinth were known in this country; dynamite spread it, burning was futile, chemicals would cause ecological damage, and herbicides were too expensive.[79]

A way to control such aquatic plants which could be used efficiently on a large scale without the risk of producing environmental problems was the main goal of the Aquatic Plant Control Program at WES. A variety of techniques gave the operations groups flexibility in choosing a control measure with regard to its predictable effectiveness, its cost, and its compatibility with the environment.

Considerable evidence suggested that proper management of biological agents (fish, insects, and others) would provide an environmentally compatible technique for the large-scale operations needed to control some of the Nation's pest plant problems.

Verification of one phase of this evidence was begun in a test in cooperation with the U. S. Army Engineer District at Jacksonville, Florida, when 87-acre Lake Conway was stocked with white amur in September 1977. A native of eastern Asia, the white amur had been introduced into other parts of the world both as a food fish and for controlling aquatic plants. Another common name for the white amur, "Asian grass carp," indicated its natural preference for a vegetable diet. From all available evidence, including experimental pond studies, the white amur is exclusively vegetarian and feeds greedily, sometimes consuming twice its weight daily; it showed a decided preference for hydrilla, a plant that grows rooted to the bottom of waterways with its stems remaining underwater. It is one of the most undesirable submerged aquatic plants in many of the lakes, ponds, and waterways located in the Gulf States.[80]

In a previous test of white amur conducted by the Florida Department of Natural Resources, Bell Lake near Ocala was stocked with the Asian fish in 1974. The lake had become wall-to-wall muck; hydrilla covered it and then decayed, giving off a horrible odor. Some had warned that there was no cure for the Lake's problems and that drastic action could create an ecological imbalance within the lake system, but residents of the area persisted in seeking a solution. Two years after Bell Lake was stocked with white amur, the waters were so clear that people could once again water ski on the lake.[81]

Evaluation of chemical controls for aquatic plants was also made. Specific interest was centered on the development of controlled release herbicide formulations of chemicals which have proven to be

The Waterways Experiment Station is the lead laboratory in the Corps of Engineers Aquatic Plant Control Research program. One of the methods considered is use of the white amur (grass carp) fish for control of the submerged aquatic plant hydrilla

valuable for such operations.

Research using insects and pathogens (or fungi) for control of aquatic plants was conducted in cooperation with the U. S. Department of Agriculture Biological Control Laboratory and the Plant Pathology Department at the University of Florida. Tests were made at Lake Concordia, Louisiana, for control of waterhyacinth by combining an insect and a pathogen. As a result of this research, alligatorweed has been successfully controlled in most areas of the southern United States with the use of the flea beetle.[82]

A combination of chemicals, insects, and fungi was tested on waterhyacinths at Brickyard Bayou at Gulfport, Mississippi, in 1976. First, herbicide 2-4, D was used to eradicate most of the plants. Then a waterhyacinth weevil, a natural enemy of the plant, was introduced. The weevils bored holes in the plants, and fungi then attacked the plants through the holes left by the weevils. The test was approved by the U. S. Department of Agriculture.[83]

Mechanical harvester tested for waterhyacinth control in the St. Johns River, Florida

Neochetina eichhorniae, a weevil tested for waterhyacinth control

Effect of Cercospora pathogen on waterhyacinth leaf

WES tests also showed that remote sensing proved to be both a rapid and economical method for detecting and monitoring plant infestations. The remote sensing techniques considered to have the most immediate potential for reconnaissance surveys of aquatic plant infestations were Landsat, high-altitude aerial photography, and synthetic aperture radar imagery. The operational procedures were tested at Lake Marion in South Carolina, Ross Barnett Reservoir in Mississippi, Lake Theriot in Louisiana, and Lake Seminole and Lake Tohopekaliga in Florida.[84]

Along with the Corps' development of water resources came a product of unexpected value, for the American public soon discovered that the lakes and surrounding areas offered unlimited recreational opportunities including swimming, boating, fishing, water skiing, camping, picnicking, and other outdoor activities. To accommodate public use of project lakes, basic facilities were provided with the dual goal of safe recreation and preservation of natural resources.

With ever-increasing numbers of visitors, however, the Corps found that such programs could no longer be administered as a sideline. The Recreation Research Program, administered by WES, was designed to improve the effectiveness and efficiency of the Corps' outdoor recreation services on 11 million acres of Federal lands and water. Research included design of facilities, prediction of use by the public, natural resource preservation, environmental problems, economic impact, social impact, cost-effective sanitary facilities and access road, law enforcement, and visitor safety.[85]

Though hydraulic models built by WES were ordinarily housed at the Vicksburg facility, a model of Chesapeake Bay was constructed in 1976 in Maryland for the Baltimore District. Chesapeake Bay is the largest of over 500 estuaries in the United States. Ranging from 3 to 40 miles wide and 195 miles long, the Chesapeake Bay area is the home for over 11 million people. More than $30 million worth of fish and shellfish are harvested there each year, and over 83 million tons of import-export trade are handled, about 11 percent of the total foreign commerce of the United States. The 6.3-acre model, the largest estuarine model in the world, represents a 4300-square-mile area including a portion of the ocean and bay,

Recreation Research Program

The Chesapeake Bay Model located in Matapeake, Maryland, reproduces such physical characteristics as salinity, current speeds and directions, and tides

10 main tributaries, and the Chesapeake and Delaware Canal. A 14-acre building on a 60-acre tract, given by the state of Maryland, houses the model, which is capable of reproducing all pertinent prototype phenomena including tides and tidal currents, salinity, temperature changes, percentage and movement of sediments, and dispersion of pollutants. Information as to tidal heights, current velocities, and salinity collected from the model can be used to study water utilization and control of the bay basin, including such related items as navigation conditions, fisheries, flood control, control of noxious weeds, water quality control, and recreation areas.

An interesting feature of the model is the use of Solar Salt which was evaporated from sea water obtained near South America. The normal operation of the model expends 20 tons of salt per day, and the model can contain 50,000 cubic feet of water that would match the fresh to briney mixture of the bay. Fresh water is provided to the model by a one-million-gallons-per-day-capacity water treatment plant. On the average, the plant provides 120 gallons per minute during model operation.

Another feature of the model is that it has two tide machines as there are two openings to the bay under tidal action influence—one at the mouth of the bay and the other at the Chesapeake and Delaware Canal at the upper end of the bay.[86] WES employees helped in construction, and five engineers from WES moved to the area to help staff the model. The Chesapeake Bay Model was chosen by the National Society of Professional Engineers as one of the 10 outstanding engineering achievements of 1976.[87]

Other scientific and engineering achievements also brought honors to WES from professional and civic organizations. The WES Concrete Laboratory was awarded the American Concrete Institute's Charles S. Whitney Medal for Engineering Development in 1974. Bryant Mather, Chief of the Laboratory, accepted the award from Robert E. Philleo, President of the American Concrete Institute, "for research and development effort leading to better understanding of the basic properties of concrete and its principal ingredients."[88] In February 1976, WES Director Col. G. H. Hilt accepted the Professional Development Award presented to WES by the National Society of Professional Engineers at the annual meeting in Albuquerque, New Mexico.[89]

WES also captured an Honorable Mention in the Chief of Engineers' Environmental Award Program in 1977 for its Wildlife Information System, a computer program that provides data on the habital requirements of protected species of mammals and birds. Use of the system can alert land managers and project design engineers to the possible presence of valued wildlife populations on the land area of a proposed project.[90]

Commendations also came from other sectors. An editorial in the Alabama Wildlife Federation magazine in 1976 hailed the Corps' efforts through WES research "to come up with environmentally acceptable alternatives to open water disposal of dredged material—particularly where the alternatives made productive use of the dredged material...."[91]

During the Bicentennial, WES was the second Corps of Engineers installation to win the honor of being designated by the American Revolution Bicentennial Administration as a Bicentennial Army Installation.[92]

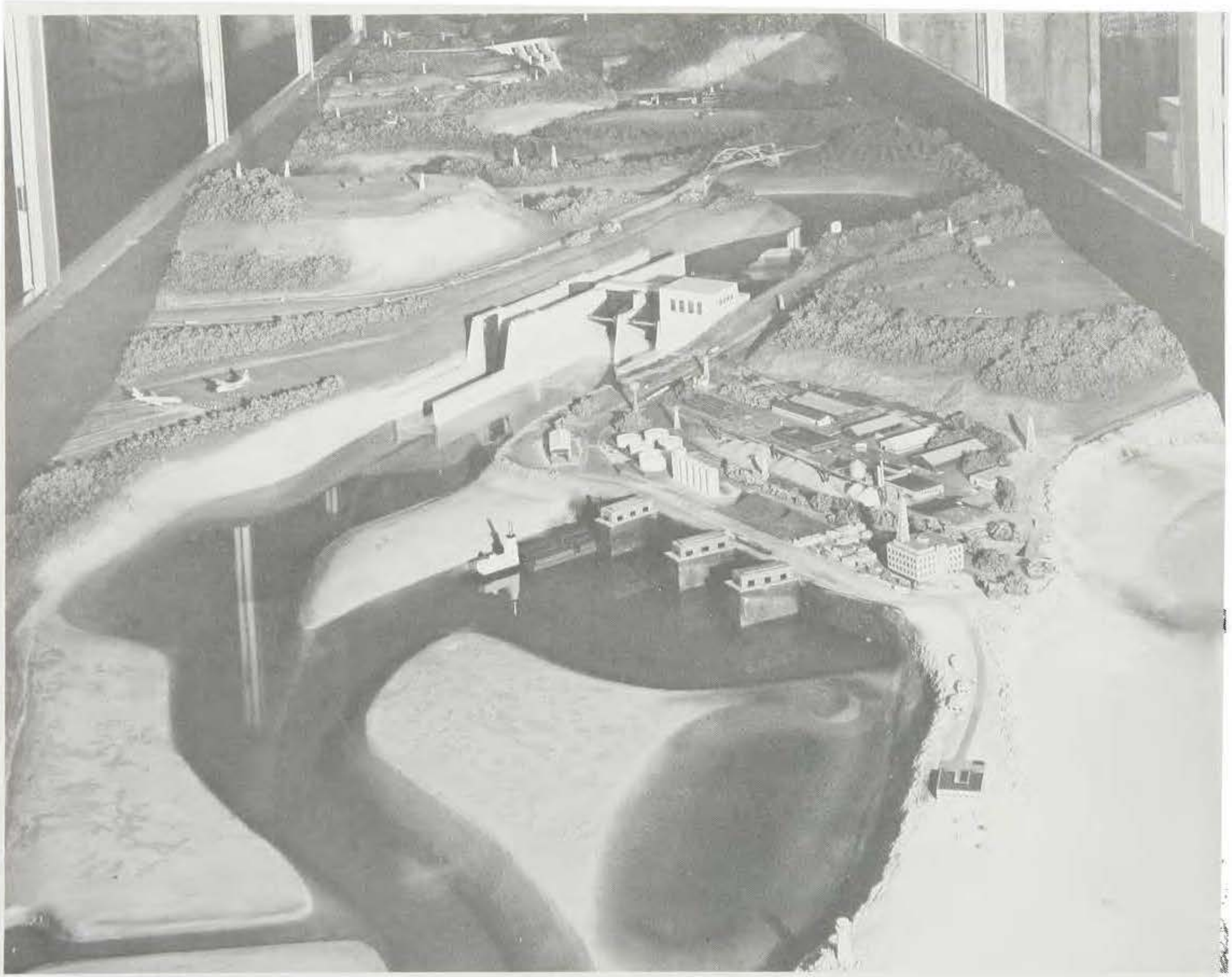
In designating WES as an official arboretum for the state of Mississippi in December 1976, the Garden Clubs of Mississippi cited "the beauty of the reservation during various seasons" and commended WES for its designation of trees on the grounds with common and botanical name plates.[93]

In the spring of 1978 the arboretum program was expanded by WES with the construction of a nature trail southwest of the Headquarters Building. The Young Adults Conservation Corps performed much of the work, which included identification of the flora along the trail and construction of a gazebo in the wooded area.[94]

Another addition to WES was the construction of a model just for visitors; it is a tiny reproduction of a river flowing to the ocean. Visitors can view most of the water resources activities of the Corps of Engineers in a 10-minute visit. The model is designed to show the effects of rainfall on a stream where flood controls are used. Dams on the river automatically release water through spillway gates, and a small-scale model towboat demonstrates the use of locks. Farther downstream, the effects of tides and waves in a harbor are demonstrated to explain various methods used by the Corps of Engineers for harbor protection. The area surrounding the river and harbor was carefully landscaped to

Mrs. Thomas Lacey, President of the Garden Clubs of Mississippi, presents the plaque to Col. John L. Cannon, Commander and Director, designating WES as official arboretum for the State of Mississippi. Others shown are Mrs. J. E. Jagger, Arboreta Chairman, from Forest; Mrs. Charles Kolb, Conservation Chairman, GC of Miss., who nominated WES; and A. G. Skelton, Chief of the Technical Information Center at WES, who was responsible for identifying the trees

Girl Scouts from Troop 83, Vicksburg, toured the newly constructed Nature Trail at WES July 17, 1978



Automated water resources model. By the mere push of a button, a visitor can start the rain in the mountains and watch the many ways it affects our everyday life until it eventually empties into the ocean. Model includes flood control, river channel stabilization and navigation, hydroelectric power production, harbor protection, conservation, recreation, watershed management, etc. It is open to the public year round scale with tiny towns and cities, trucks, cars, houses, industries—even a tennis court.[95]

Groundbreaking and dedication ceremonies for a new facility for the Geotechnical Laboratory were held 28 June 1978 with Lt. Gen. John W. Morris, Chief of the U. S. Army Corps of Engineers, on hand for the events. The $4.5 million building was named for Dr. Arthur Casagrande, Professor Emeritus of Harvard University and a principal consultant for the Corps since 1938. The world's foremost authority in soil mechanics and foundation engineering, Casagrande had contributed a large portion of his collection of books, files, technical papers, and soil and rock samples to WES in March 1976. At the groundbreaking ceremony, he was presented a plaque commemorating the occasion by Gen. Morris.

The Casagrande Building, still under construction in 1979, houses the Soils Testing Laboratory, Soils Research Center, and parts of the research group of the Soil Mechanics Division, and when completed will cover about 78,000 square feet and will house the remaining elements of the Soil Mechanics Division as well as the Engineering Geology and Rock Mechanics Division and Pavement Systems Division. The first portion of the facility was

Ground breaking ceremonies of the Arthur Casagrande Building were held on June 28, 1978. From left to right: Gary Hathorn, Architect-engineer; Fred R. Brown, WES Technical Director; C. L. McAnear, Geotechnical Laboratory; J. P. Sale, Chief, Geotechnical Laboratory; Dr. Arthur Casagrande; Lt. Gen. John W. Morris, Chief of Engineers; Col. John J. Moellering, Vicksburg District Engineer; and Col. John L. Cannon, WES Commander and Director

Artist's conception of completed Arthur Casagrande Building

completed in 1976; phase two construction (the major portion of the center) is expected to be completed in June 1980.[96]

A group of water resources experts from the People's Republic of China spent two days at WES in 1973 during a seven-week tour of the United States. The visit was the first of several exchanges of scientific and culturally oriented groups between the two Nations.

In September 1978, James E. Glover participated in a trip to the People's Republic of China as a member of a U. S. team of specialists in river control and sedimentation organized by Prof. H. W. Shen of Colorado State University. Col. Cannon was a member of a similar trip in October sponsored by the American Society of Civil Engineers. Both trips resulted in return visits to WES by Chinese dignitaries for technical information exchange on the topics of hydraulics and hydrology.

WES became a participant in the US/USSR Scientific and Technological Exchange Program in 1974. Several groups from the U.S.S.R. visited WES under the auspices of this program with the latest visit occurring in May 1979. WES employees serving as project coordinators and/or U. S. team leaders included F. R. Brown, Bryant Mather, J. M. Scanlon, Jr., W. C. Sherman, Jr., R. C. Eaves, and C. R. Styron, III. Primary areas of interest at WES were water resources development projects, the use of polymer concrete in hydraulic structures, and plastic films and soil stabilizers. WES program participants have, in turn, visited projects of similar interest in the U.S.S.R. Mr. J. B. Tiffany visited the U.S.S.R. in September 1961 as a member of an exchange group of U. S.

Visitors from the People's Republic of China at WES Mississippi Basin model, 1978

Hydraulic Laboratory directors.

In February 1979, His Excellency Romeo Lucas Garcia, President of the Republic of Guatemala, and eight of his ministers visited the Station. They were primarily interested in meandering of rivers, bank stabilization problems, and aquatic plant control. Although WES had received numerous prominent visitors, this was the first time the head of a country had visited.

The diversity of capabilities and growth of WES over its 50-year history brought about a number of changes in organization, some of which are shown in the organization charts in Appendix I.

To control the diverse WES program, a Management Information System was developed under the Office of Technical Programs and Plans headed by William R. Martin. Pertinent cost information was provided on a daily basis, enabling project engineers to plan and operate their projects on a current basis. The program also provided data involving personnel, procedures, formats, data elements, project definitions, and scheduling. Assisting Martin in the development of the system were Jack Hilderbrand and Don E. Eicher. This system provided a much-needed planning, programming, and progress reporting capability.

Guatemalan President Romeo Lucas Garcia (at right in dark coat) visited WES in February 1979 to tour hydraulic models and soils testing facilities. Frank Townsend (at right, back to camera) demonstrated liquefaction and explained the phenomenon in fluent Spanish

While the technical laboratories have been directly responsible for the accomplishment of the overall mission of WES in their respective fields of endeavor, other facilities provided the essential technical support in electronic computation and data processing, instrumentation, special library services, technical report preparation and publication, etc., and have performed additional work for the Corps within their capabilities. (See Appendix II.)

Likewise, the administrative support organizations were vital to the success of the technical laboratories and a history of WES would not be complete without recognition of the services provided by the Resource Management Office, the Procurement and Supply Office, the Office of Technical Programs and Plans, the Public Affairs Office, the Office of Administrative Services, the Equal Employment Opportunity Office, and the Safety Office. Individually and collectively these elements have been an important part of the reputation which WES enjoys as a "can do" organization responsive to the needs and demands of the American people.

Various members of the staff have been honored by awards given in many areas of accomplishment. The number and variety of these awards reflect highly upon WES and its personnel. Those receiving the Department of Defense Distinguished Civilian Service Award, the Department of Army Exceptional Civilian Service, Meritorious Civilian Service, and Patriotic Civilian Service Awards, the Army

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION STAFF
Vicksburg, Mississippi
20 July 1978

Seated, from left to right: F. R. Brown, Technical Director; John L. Cannon, Commander and Director; Douglas A. Hughes, Deputy Commander and Director. Front row, from left to right: Alan G. Skelton, Chief, Technical Information Center; August J. Breithaupt, Chief, Procurement and Supply Office; David H. Myers, Chief, Personnel Office; William R. Martin, Chief, Office of Technical Programs and Plans; William J. Flathau, Assistant Chief, Structures Laboratory; Bryant Mather, Acting Chief, Structures Laboratory; Henry B. Simmons, Chief, Hydraulics Laboratory; James P. Sale, Chief, Geotechnical Laboratory; John Harrison, Chief, Environmental Laboratory; Woodland G. Shockley, Program Manager for Military Engineering; Jane C. Cotton, Chief, Public Affairs Office; Thomas J. Money, Chief, Equal Employment Opportunity Office; William M. Pace, Chief, Office of Administrative Services; James M. Daniel, Chief, Safety Office. Second row, from left to right: Donald L. Neumann, Chief, Automatic Data Processing Center; Francis P. Hanes, Chief, Instrumentation Services Division; James M. Peterson, Chief, Engineering and Construction Services Division; Thomas B. Rosser, Chief, Publications and Graphic Arts Division; Count G. Evans, Chief, Resource Management Office.

Research and Development Award, and others are listed in Appendix III.

The Gallery of Distinguished Civilian Employees was established in 1966 to recognize particularly outstanding service by former civilian employees of WES. To be selected for this honor, an employee must have accomplished assigned duties in a clearly outstanding manner; developed or improved knowledge, methods, or procedures which produced extraordinary benefits to WES or the Corps; or contributed substantially to the reputation and honor of WES or the Corps. Candidates for the Gallery are nominated by the Deputy Director, Technical Director, and Chiefs of laboratories and separate staff elements, and selected by the Special Recognition Committee. Employees included in the Gallery are pictured in Appendix IV.

The worldwide WES reputation for excellence in research and engineering is built on a broad base of hard-working and dedicated individuals. A listing of WES employees as of March 1979 is included in Appendix V.

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2. Vicksburg *Evening Post,* July 26, 1971.
3. Vicksburg *Sunday Post,* September 27, 1970.
4. Huntsville *Times,* October 24, 1976.
5. Vicksburg *Evening Post,* March 29, 1971.
6. Ibid., April 15, 1971.
7. Vicksburg *Sunday Post,* April 15, 1973.
8. Vicksburg *Evening Post,* August 21, 1971.
9. "Spray-On Landing Pad A 'Foaming' Success," *Army Times* (May 6, 1970). Science fiction has often become fact, and the spray-on landing mat is one example. It was a mere coincidence, but shortly before the process was perfected and the details made public, a popular comic strip, "Steve Canyon," ran a series where the hero used a similar material in his daring exploits.
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12. Vicksburg *Evening Post,* June 13, 1970.
13. Vicksburg *Sunday Post,* June 7, 1970.
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16. "SL-7 Pilots Trained at Vicksburg, Miss.," *Florida Journal of Commerce* (1972).
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18. *Station Break,* June 1978.
19. G. W. Turnage, "Tire Selection for Off-Road Vehicles," *Engineering and Scientific Research at WES* (February 1974). Misc. Paper 0-74-1.

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24. Vicksburg *Evening Post,* September 6, 1971.
25. Panama City, Fla., *Herald,* October 17, 1973.
26. *Station Break,* October 1978.
27. Vicksburg *Sunday Post,* March 28, 1971.
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30. "Hydraulic Models Predict Environmental Effects," *World Dredging and Marine Construction* (December 1972), p. 38.
31. Jackson *Daily News,* February 28, 1971.
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33. Ibid., p. 40.
34. Ibid., p. 41.
35. Ibid., p. 42.
36. Vicksburg *Sunday Post,* July 5, 1973.
37. Ibid.
38. Donald L. Neumann and Mary S. Hine, "Centralized Scientific Computation," *The Military Engineer* (March-April 1973), p. 97.
39. *Engineering Computer Notes* (March 1975). Misc. Paper K-75-3.
40. Letter to Mayor A. E. Wood, Clinton, Miss., February 12, 1968, from W. H. Sanders, Regional Administrator. Copy on file in WES archives.
41. Memphis *Commercial Appeal,* October 27, 1971.
42. Jackson *Clarion Ledger,* April 22, 1973.
43. Vicksburg *Evening Post,* April 26, 1973.
44. Ibid.
45. "The Old River Diversion Model," *Engineering and Scientific Research at WES* (October 1974). Misc. Paper 0-74-7. See also "Grouting Repair of Old River Low-Sill Structure," *Engineering and Scientific Research at WES* (November 1974). Misc. Paper 0-74-8.
46. Vicksburg *Evening Post,* November 1, 1971.
47. General Orders #21, regarding discontinuance of the U. S. Army Engineer Nuclear Cratering Group and transferring everything to WES; signed by Col. Richard F. McAdoo, Corps of Engineers, Department of the Army, Office of the Chief of Engineers, Washington, D. C., July 19, 1971, to be effective July 31, 1971; and General Orders #5, signed by Col. Ernest D. Peixotto, Corps of Engineers and WES Director, July 30, 1971. Both documents are on file in the WES Archives.

48. *History of the U. S. Army Nuclear Cratering Group,* Lawrence Radiation Laboratory, Livermore, California. (January 1969), p. 1.

49. Ibid., p. 3.

50. Ibid.

51. Ibid., p. 39.

52. Ibid.

53. Ibid., pp. 39-40.

54. Ibid., p. 43.

55. Ibid., p. 47.

56. Ibid., p. 78.

57. Ibid.

58. Vicksburg *Evening Post,* November 1, 1971.

59. Ibid., October 12, 1974.

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61. Vicksburg *Evening Post,* July 5, 1976.

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66. Ibid. (October 1973). Misc. Paper D-75-5.

67. Tampa *Tribune*—Tampa *Times,* June 1, 1975.

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82. *Aquatic Plant Control Research Program* (No number, no date; located in WES files). Information Exchange Bulletin.

83. Jackson *Clarion Ledger-Daily News,* May 23, 1976.
84. *Aquatic Plant Control Research Program* (March 1978). Information Exchange Bulletin.
85. Vicksburg *Evening Post,* November 7, 1977.
86. Vicksburg *Sunday Post,* August 8, 1976.
87. Vicksburg *Evening Post,* May 19, 1977.
88. Vicksburg *Sunday Post,* February 15, 1976.
89. Vicksburg *Evening Post,* November 21, 1977.
90. Ibid., September 30, 1977.
91. *Alabama Wildlife Federation Magazine* (October 1976).
92. *WES Activities Summary,* 1976, p. 93.
93. Vicksburg *Sunday Post,* December 5, 1976.
94. *Station Break,* April 1978.
95. Paper in WES files, July 7, 1976.
96. *Station Break,* August, 1978. Also see Vicksburg *Evening Post,* March 11, 1978.
97. Ibid., April 1978. See also WES organizational chart, November 1, 1978.

CHAPTER VII: CONCLUDING REMARKS

From its inception in 1929, WES has been a unique establishment in many respects. Outstanding is the fact that it was founded and continues to operate on a free enterprise basis. No direct congressional allocation keeps it going, for work is performed, whether it be for another government agency, for private industry, or for a foreign nation, on a cost reimbursable basis.

Experiments performed at WES in its 50-year history are too many to enumerate, and the untold millions of dollars which it has saved the American taxpayer can only be estimated. The rapid advancement of technology indicates an even brighter future.

The U. S. Army Engineer Waterways Experiment Station has proved its worth many times over, not merely within the Corps of Engineers, but more broadly to the total Army and to the Nation.

WES is the principal research, testing, and development facility of the U. S. Army Corps of Engineers. Located on 685 acres in southeast Vicksburg, its mission is to conceive, plan, and execute engineering investigations and research and development studies in support of the civil and military missions of the Chief of Engineers and other Federal agencies. The headquarters building is located between the road and the lake on the left; other buildings house the administration buildings of the four technical laboratories, hydraulic models, and other test facilities. (December 1978)

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Interview with Charlie Faulk, Managing Editor, Vicksburg *Evening Post,* August 14, 1974. Vicksburg, Mississippi.

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Letter written by Major Gen. Edgar Jadwin, June 18, 1929.

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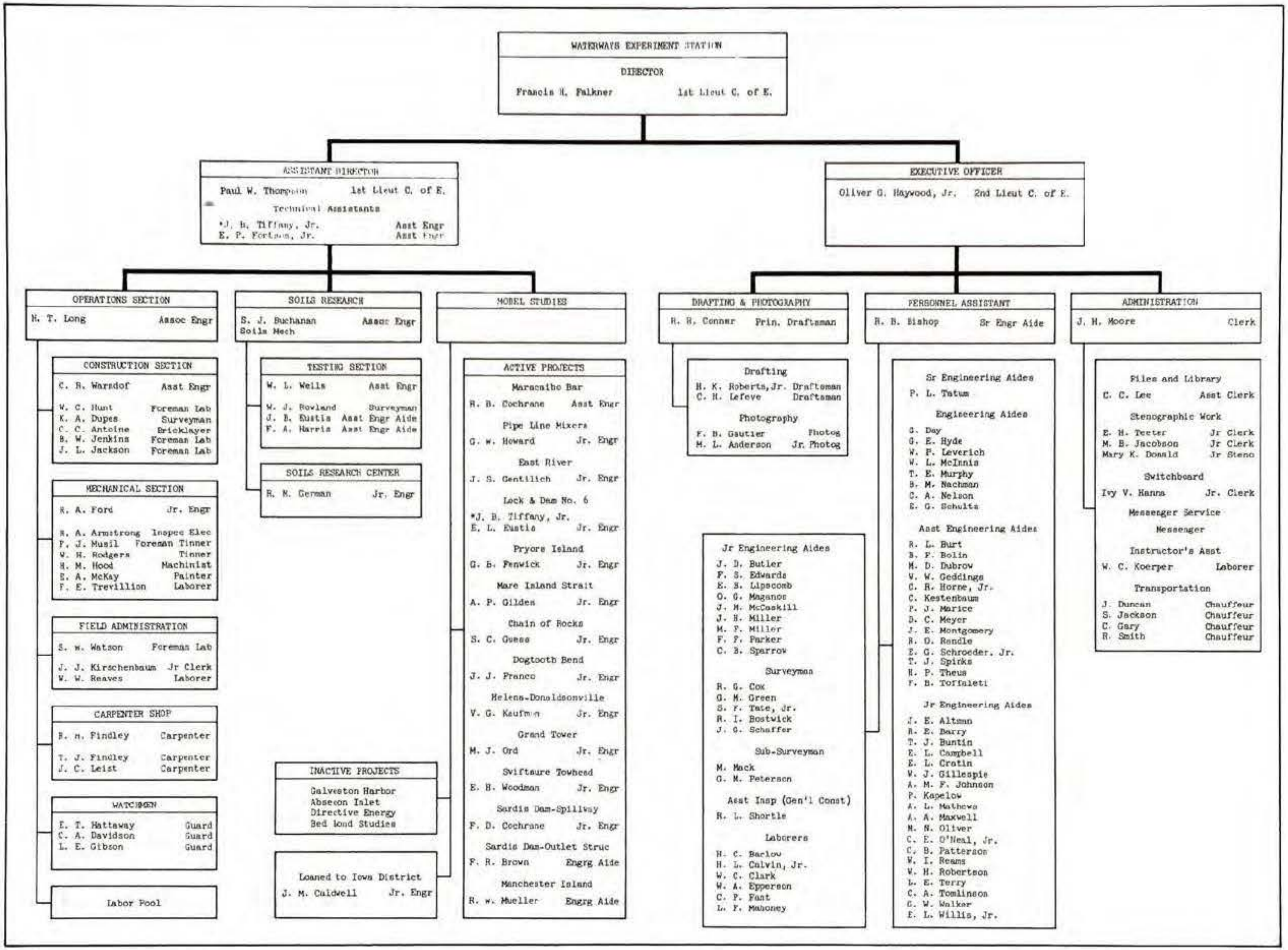
APPENDIX I

WES ORGANIZATION CHARTS
1937-1979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ASSISTANT DIRECTOR
Paul W. Thompson 1st Lieut C. of E.
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E. P. Fortson, Jr. Asst Engr
EXECUTIVE OFFICER
Oliver G. Haywood, Jr. 2nd Lieut C. of E.
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H. T. Long Assoc Engr
CONSTRUCTION SECTION
C. R. Warzdof Asst Engr
W. C. Hunt Foreman Lab
K. A. Dupes Surveyman
C. C. Antoine Bricklayer
B. W. Jenkins Foreman Lab
J. L. Jackson Foreman Lab
MECHANICAL SECTION
R. A. Ford Jr. Engr
R. A. Armstrong Inspec Elec
F. J. Musil Foreman Tinner
W. H. Rodgers Tinner
H. M. Hood Machinist
E. A. McKay Painter
F. E. Trevillion Laborer
FIELD ADMINISTRATION
S. W. Watson Foreman Lab
J. J. Kirschenbaum Jr Clerk
W. W. Reaves Laborer
CARPENTER SHOP
R. H. Findley Carpenter
T. J. Findley Carpenter
J. C. Leist Carpenter
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E. T. Hattaway Guard
C. A. Davidson Guard
L. E. Gibson Guard
Labor Pool
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Soils Mech
TESTING SECTION
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J. B. Eustis Asst Engr Aide
F. A. Harris Asst Engr Aide
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INACTIVE PROJECTS
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Directive Energy
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Loaned to Iowa District
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ACTIVE PROJECTS
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Pipe Line Mixers
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East River
J. S. Gentilich Jr. Engr
Lock & Dam No. 6
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E. L. Eustis Jr. Engr
Pryors Island
G. B. Fenwick Jr. Engr
Mare Island Strait
A. P. Gildea Jr. Engr
Chain of Rocks
S. C. Guess Jr. Engr
Dogtooth Bend
J. J. Franco Jr. Engr
Helena-Donaldsonville
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Grand Tower
M. J. Ord Jr. Engr
Swiftsure Towhead
E. B. Woodman Jr. Engr
Sardis Dam-Spillway
F. D. Cochrane Jr. Engr
Sardis Dam-Outlet Struc
F. R. Brown Engrg Aide
Manchester Island
R. W. Mueller Engrg Aide
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Drafting
H. K. Roberts, Jr. Draftsman
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Photography
F. B. Gautier Photog
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R. G. Cox
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Sub-Surveyman
M. Mack
G. M. Peterson
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W. C. Clark
W. A. Epperson
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Ivy V. Hanna Jr. Clerk
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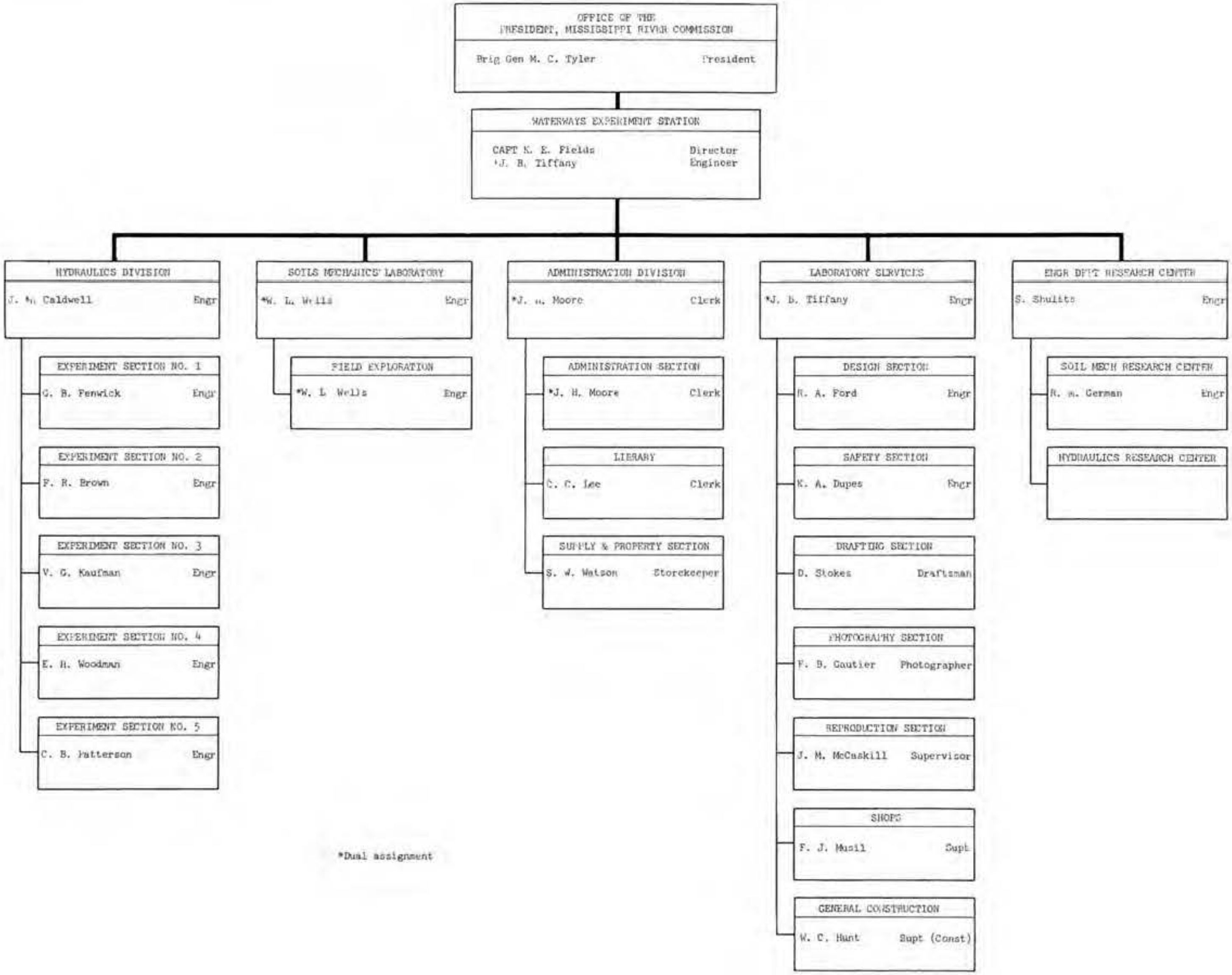
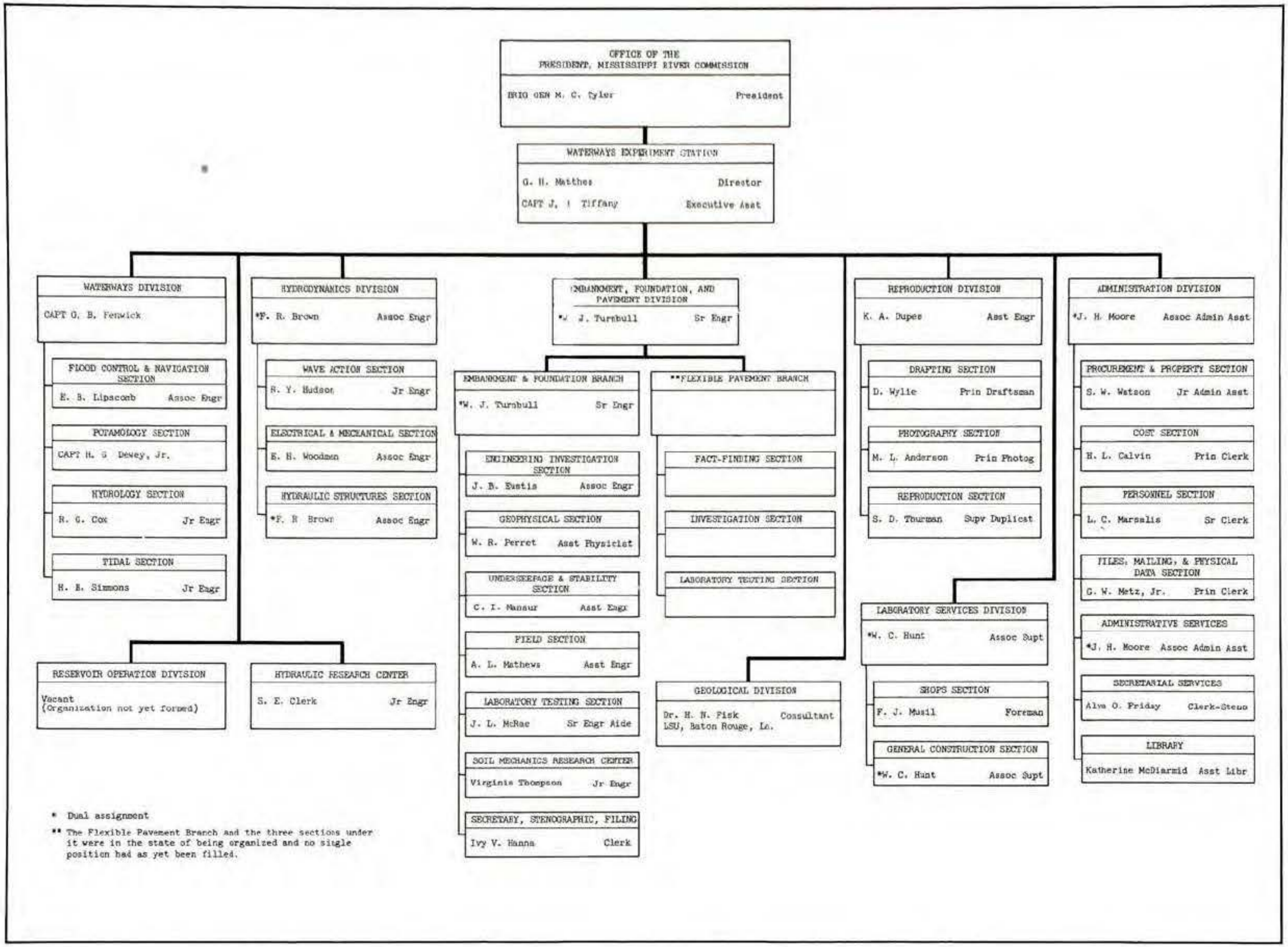
Messenger
Instructor's Asst
W. C. Koerper Laborer
Transportation
J. Duncan Chauffeur
S. Jackson Chauffeur
C. Gary Chauffeur
R. Smith Chauffeur

1 March 1937



*Dual assignment

1 January 1941



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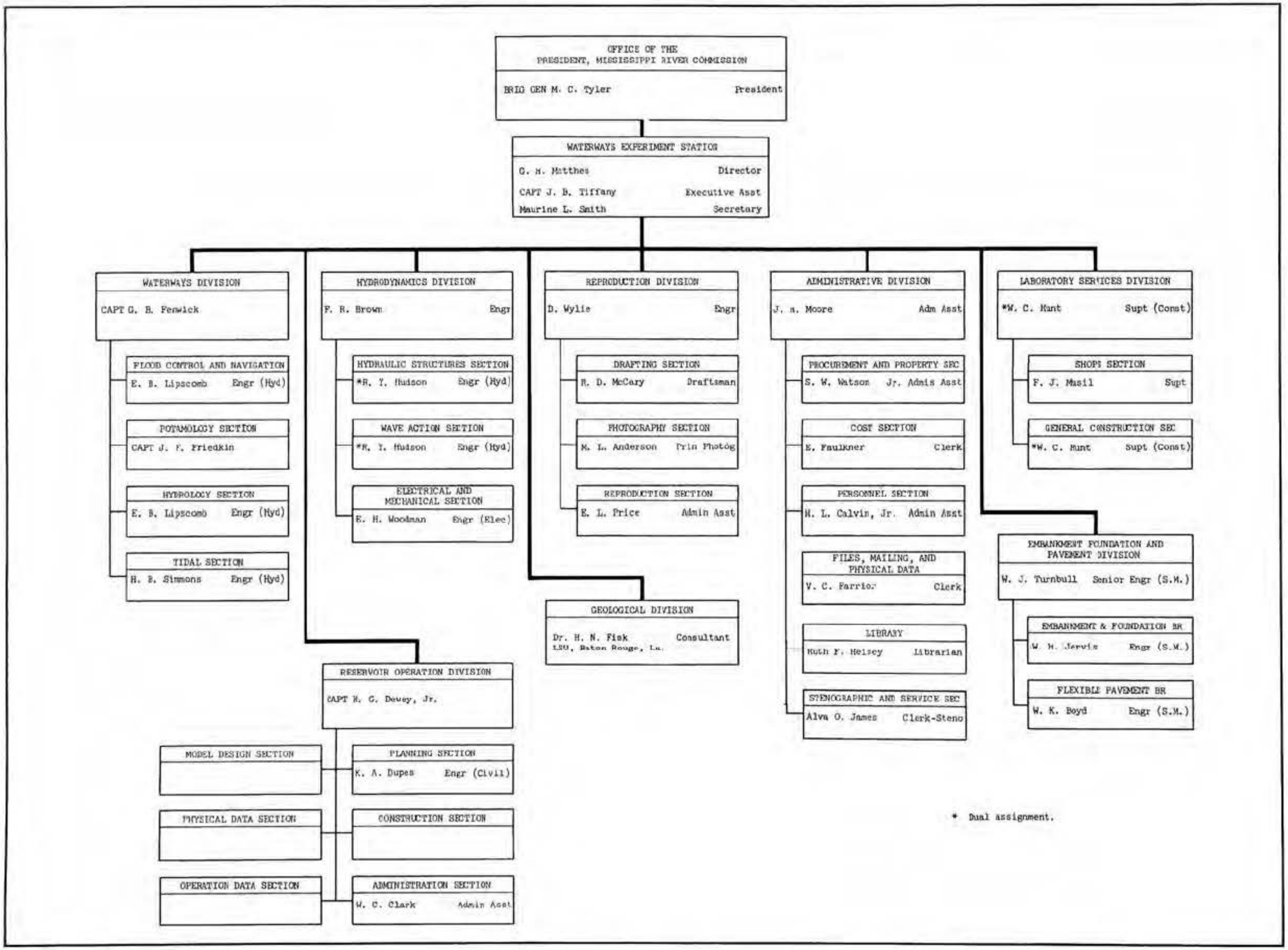
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LABORATORY SERVICES DIVISION
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W. H. Jervis Engr (S.M.)
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LSU, Baton Rouge, La.
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PHYSICAL DATA SECTION
OPERATION DATA SECTION
PLANNING SECTION
K. A. Dupes Engr (Civil)
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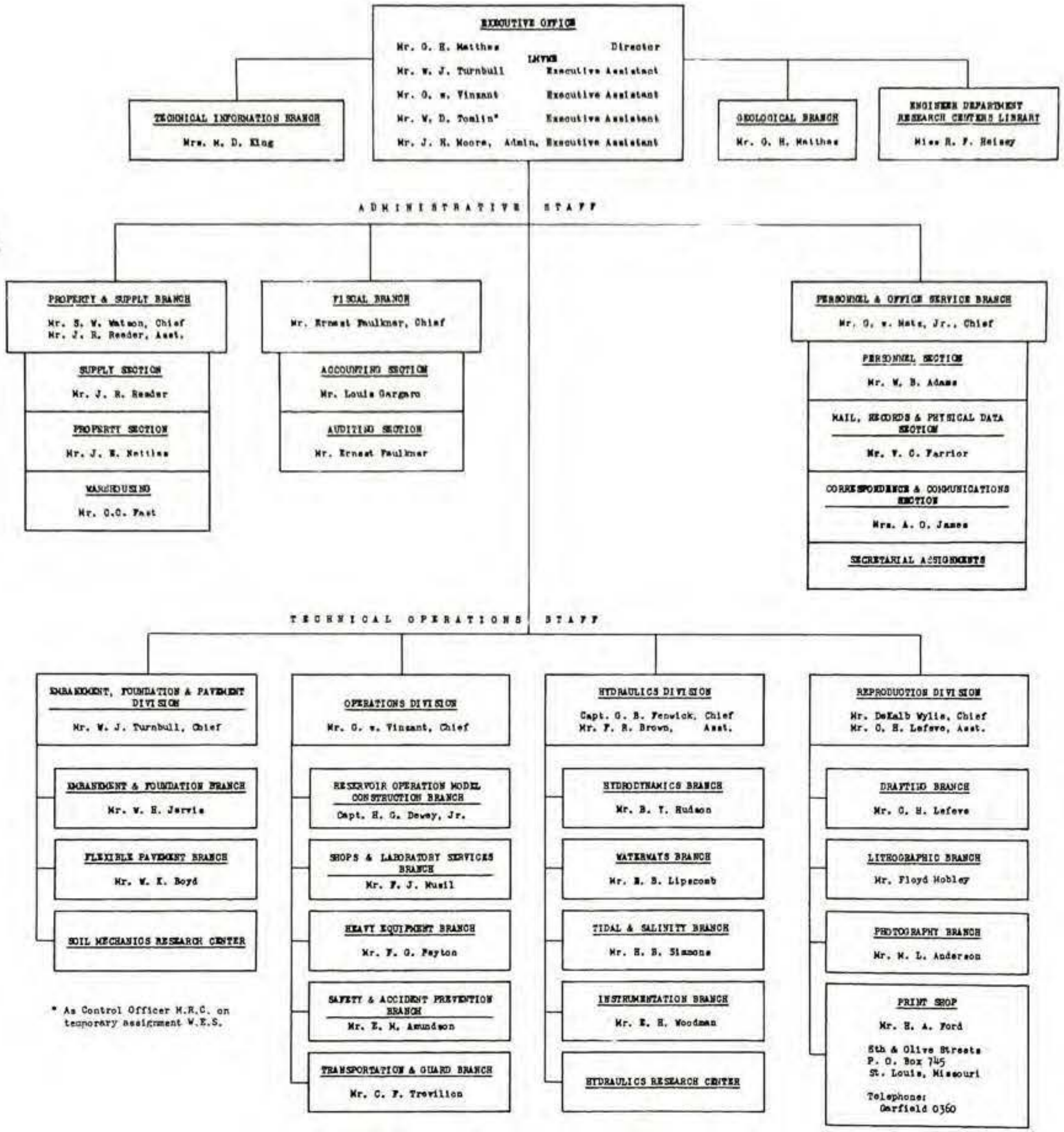
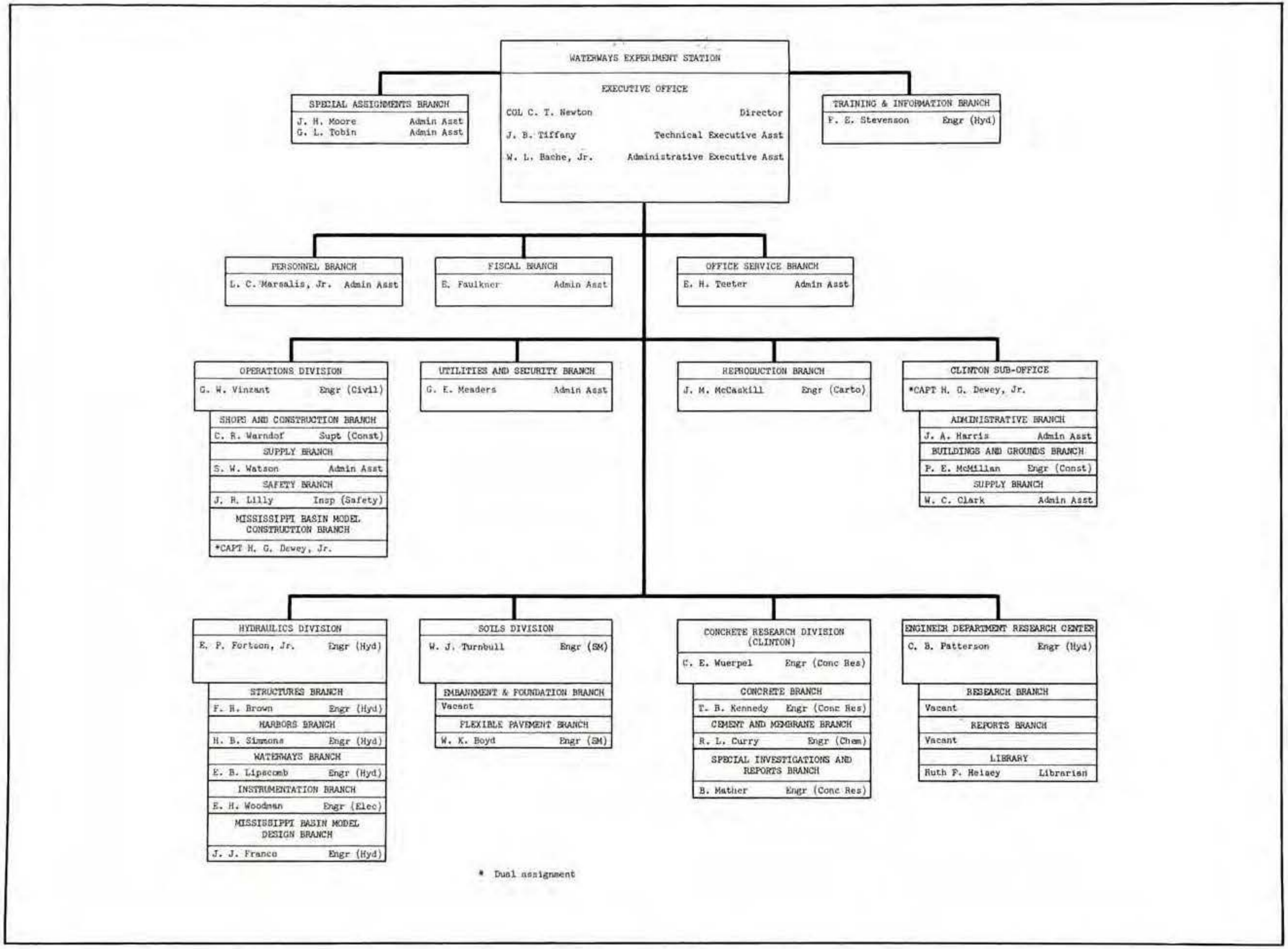
* Dual assignment.

1 July 1944



* As Control Officer M.R.C. on temporary assignment W.E.S.

13 September 1945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T. B. Kennedy Engr (Conc Res)
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R. L. Curry Engr (Chem)
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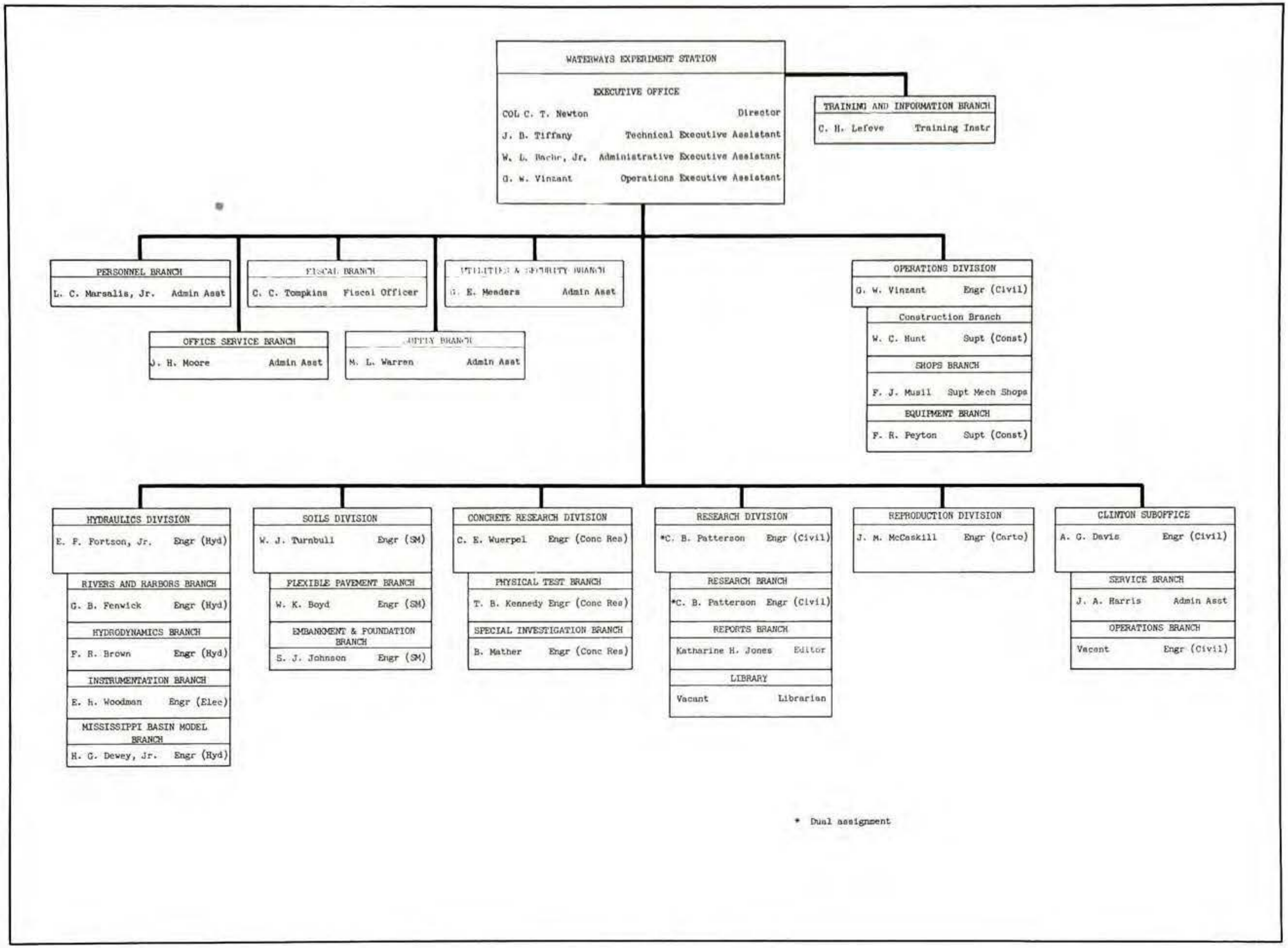
Ruth F. Heisey Librarian
* Dual assignment

1 July 1946



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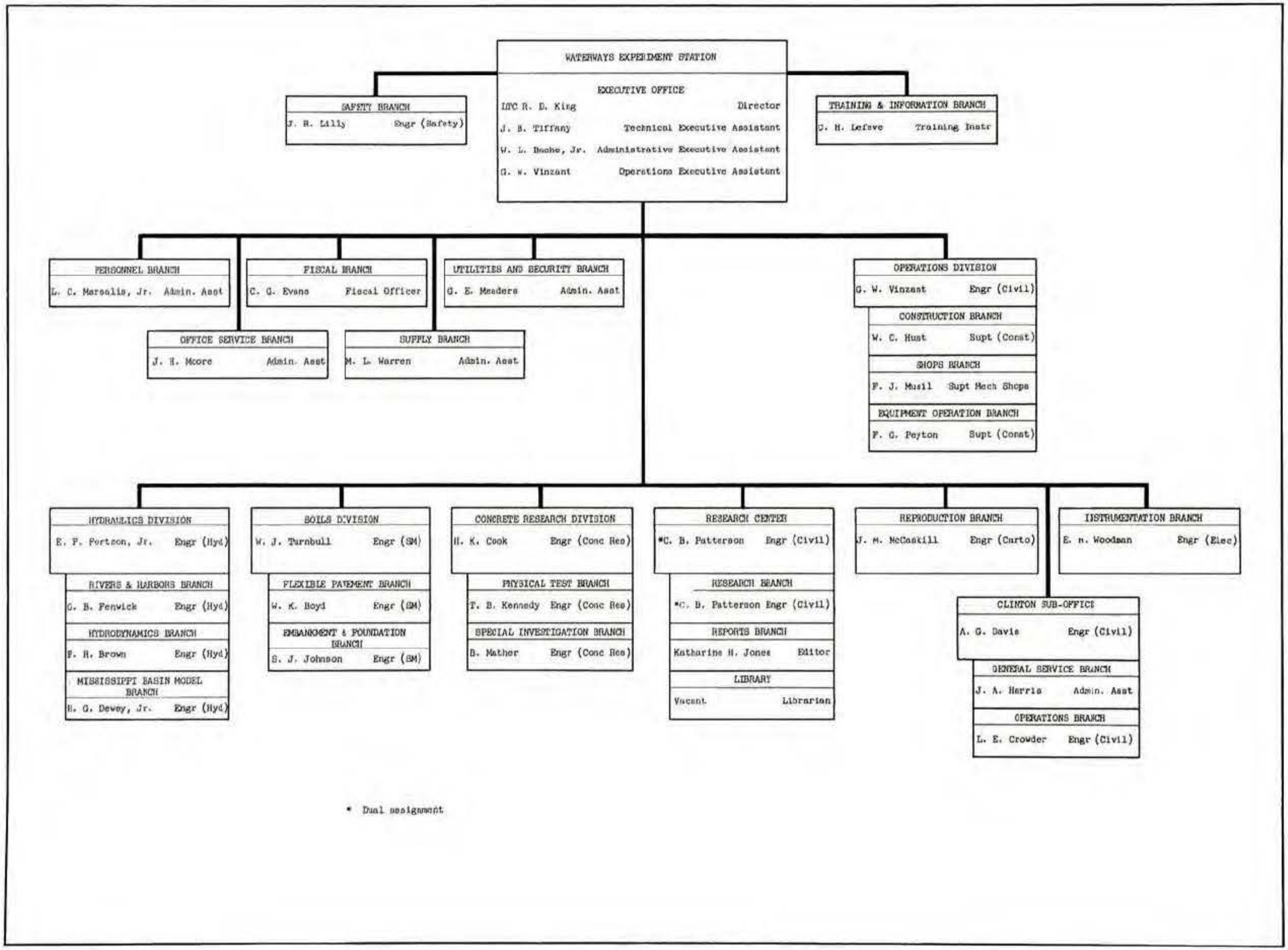
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W. L. Bache, Jr. Administrative Executive Assistant
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C. H. Lefeve Training Instr
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L. C. Marsalis, Jr. Admin. Asst
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C. G. Evans Fiscal Officer
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J. H. Moore Admin. Asst
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M. L. Warren Admin. Asst
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J. A. Harris Admin. Asst
OPERATIONS BRANCH
L. E. Crowder Engr (Civil)
* Dual assignment

1 July 1947

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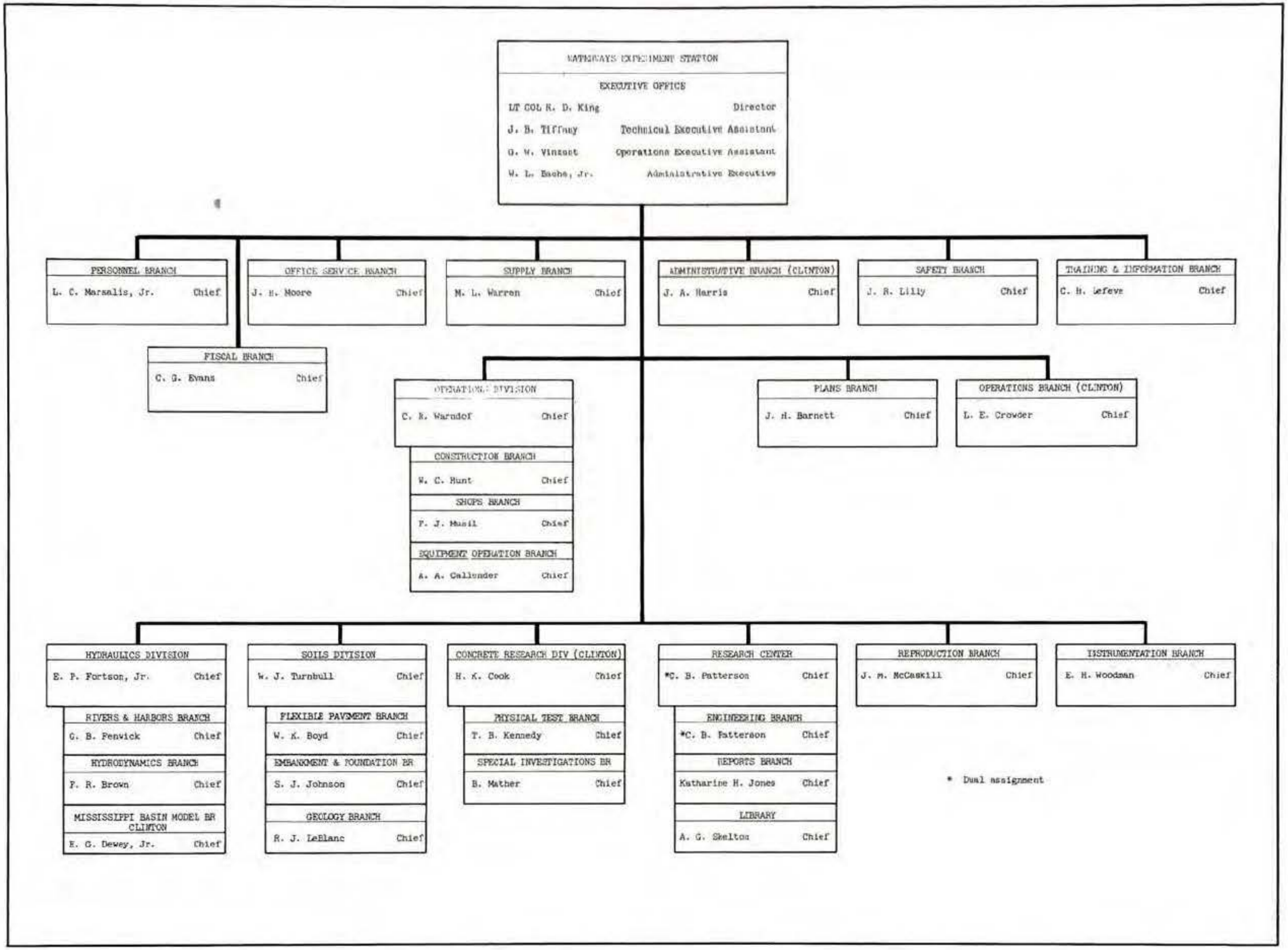

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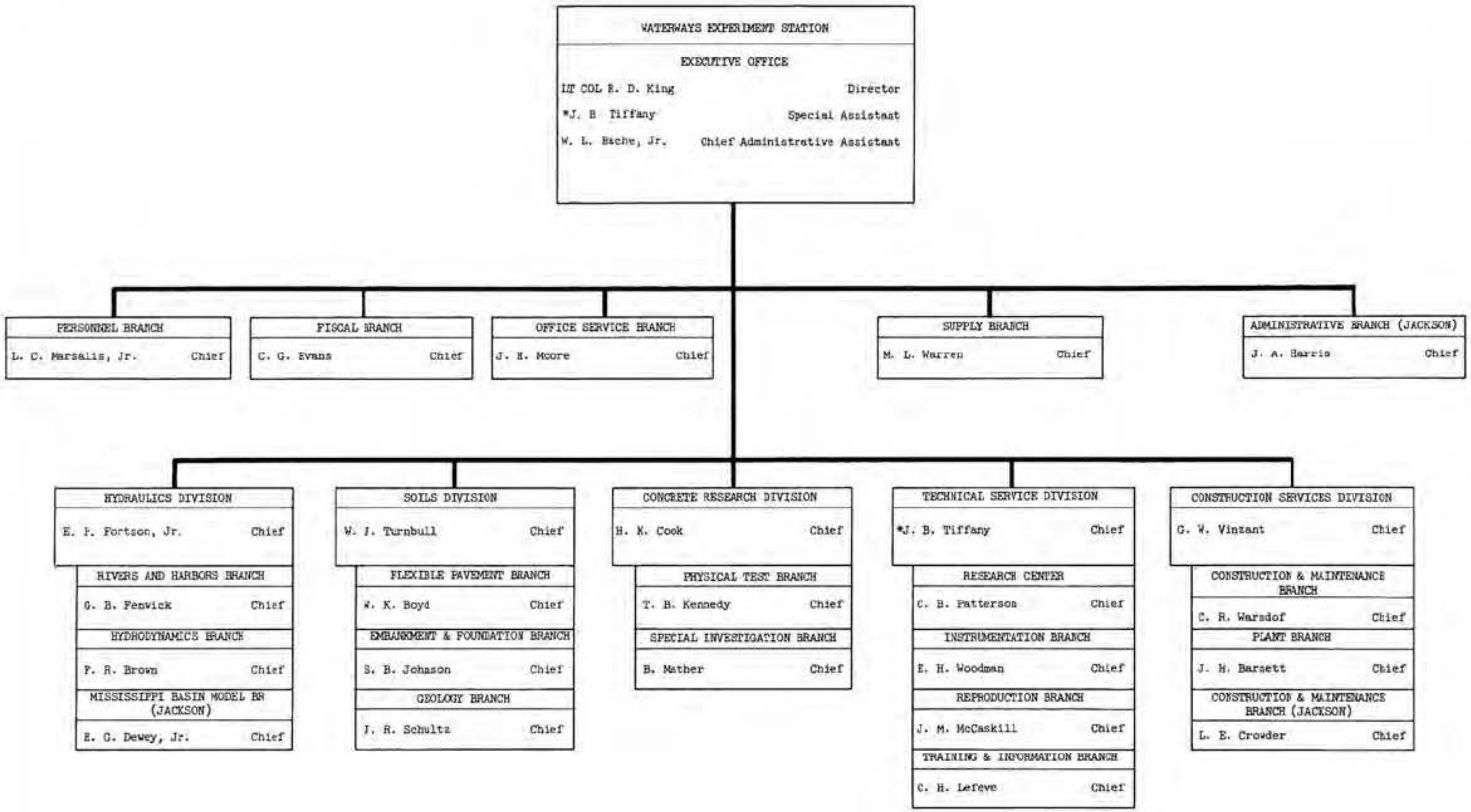

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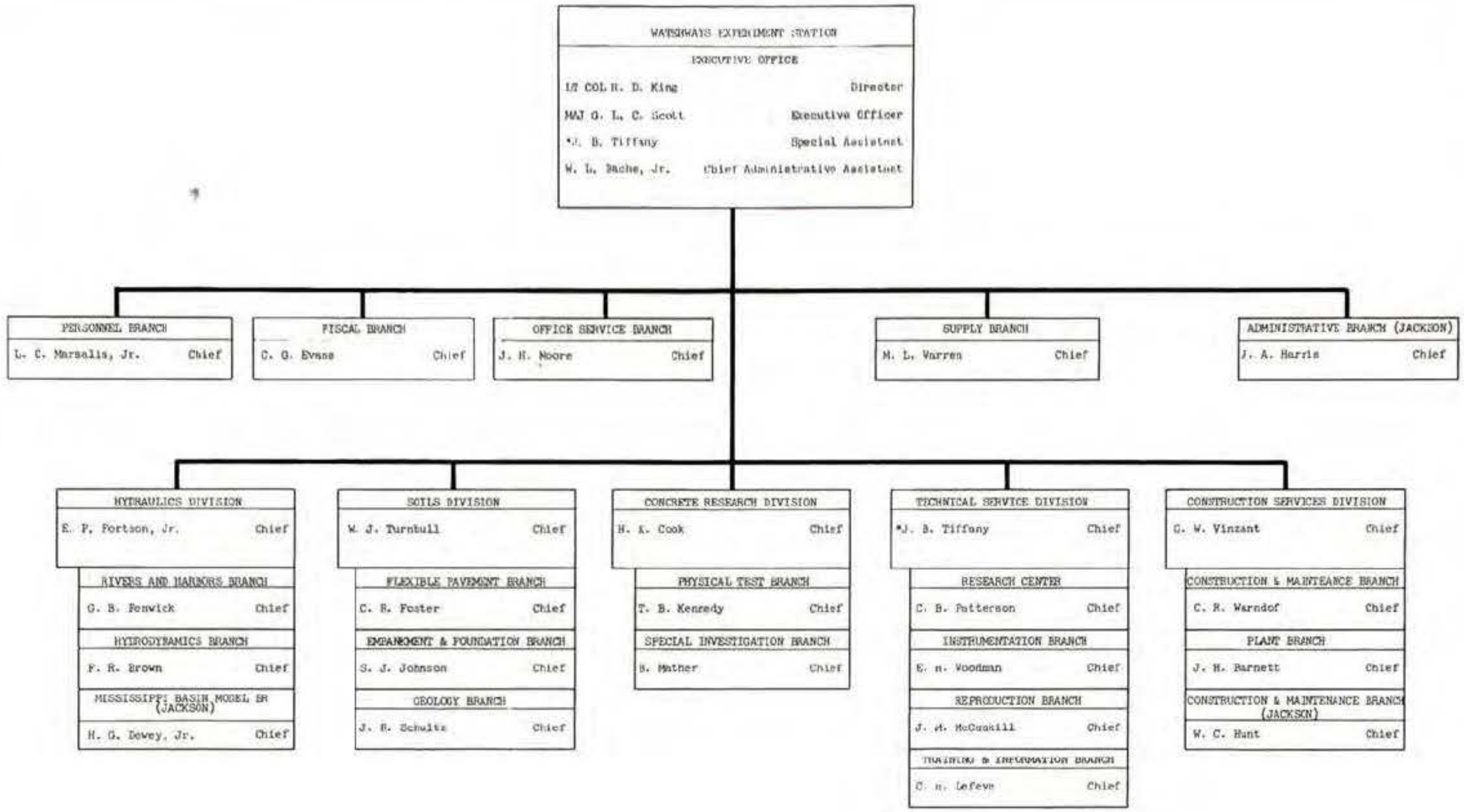

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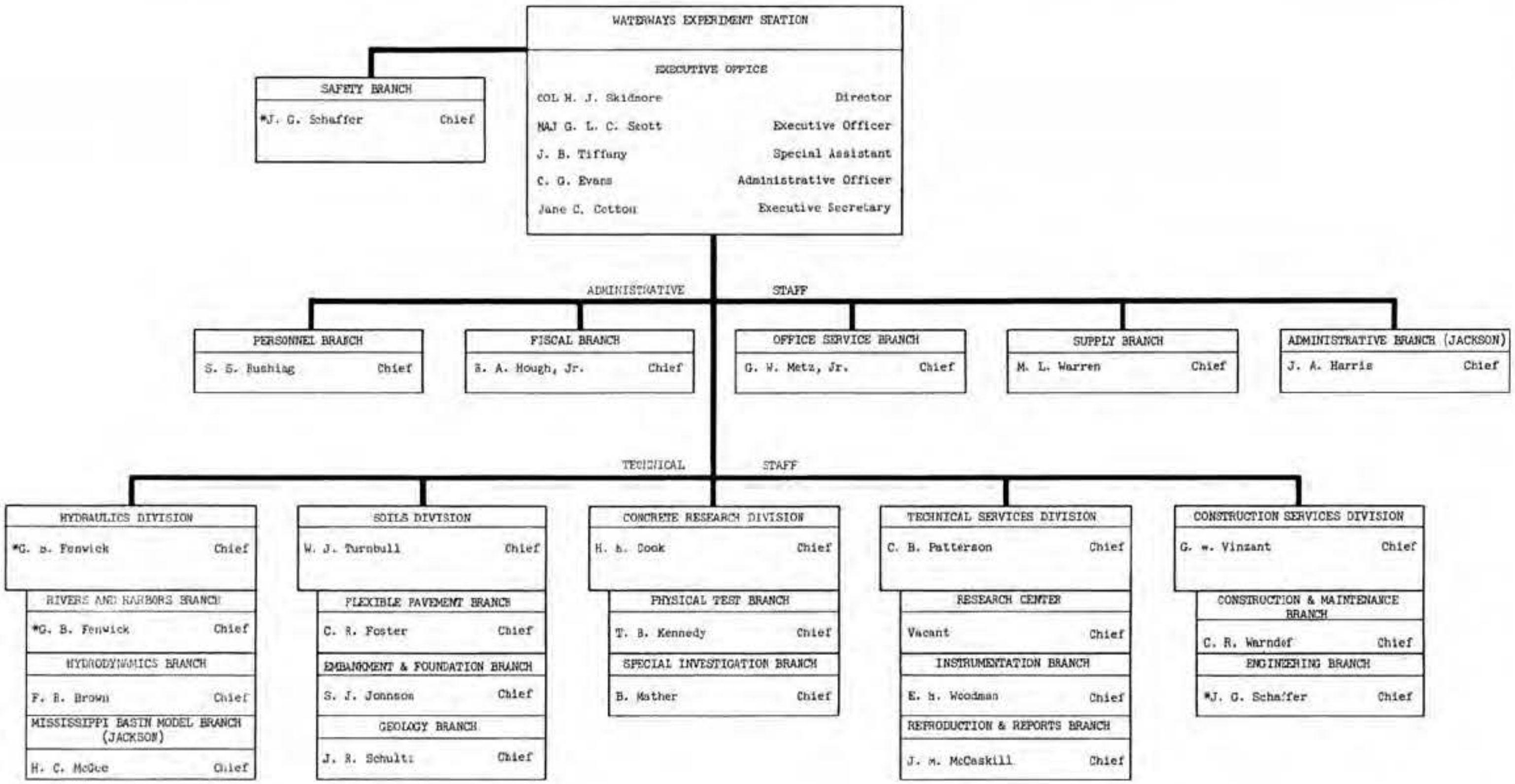

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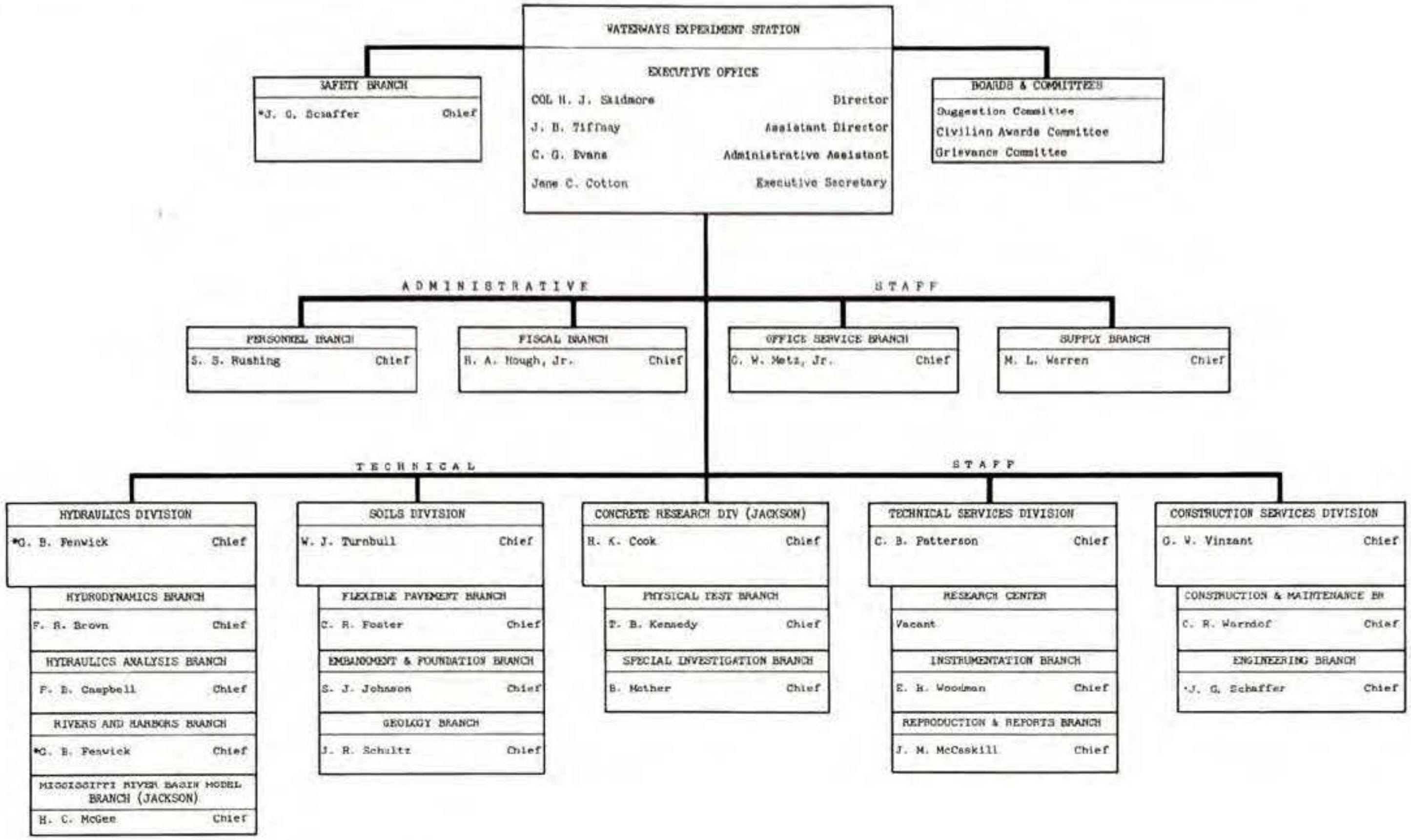
15 January 1951



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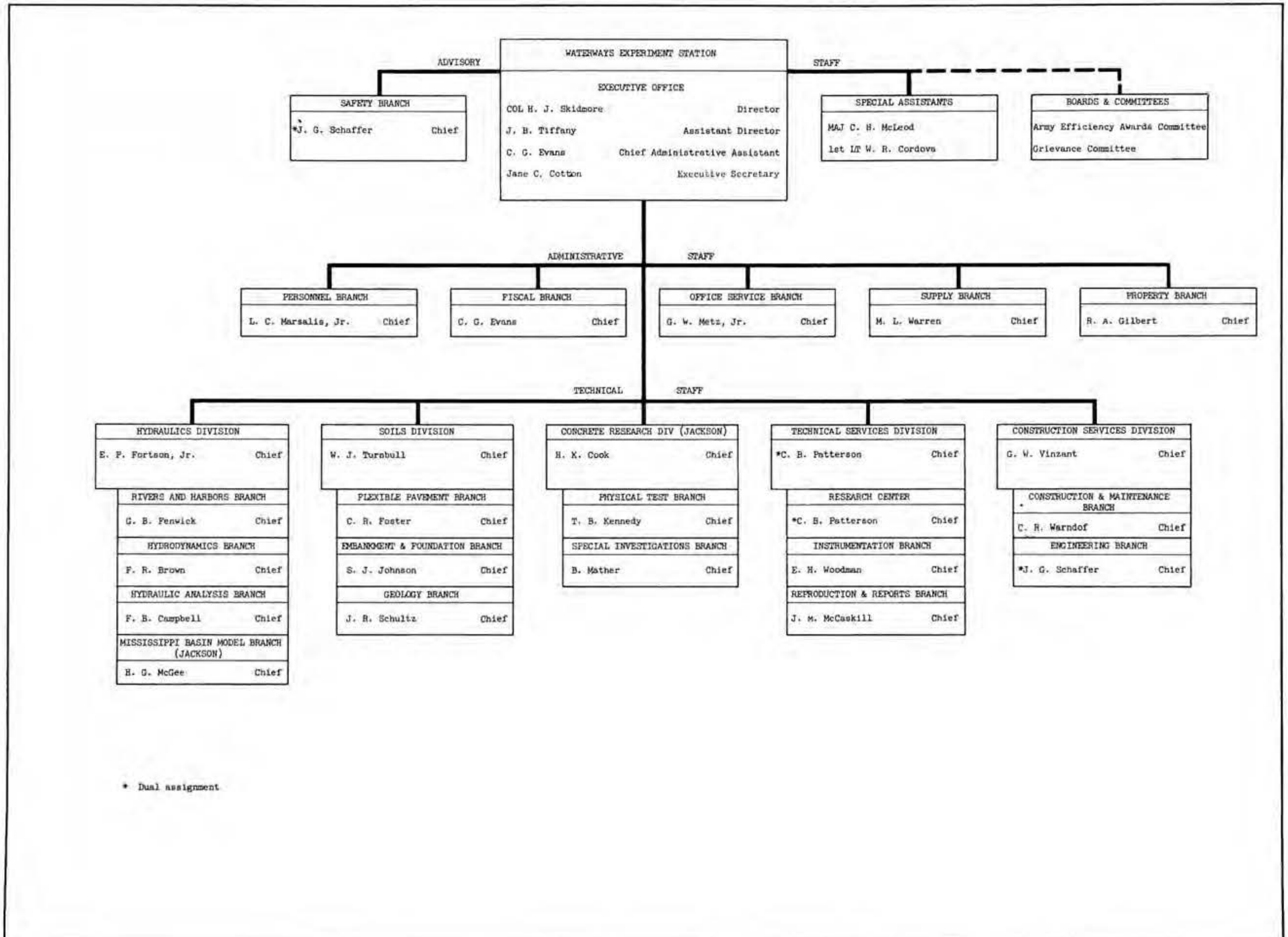
1 July 1951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J. B. Tiffany Assistant Director
C. G. Evans Chief Administrative Assistant
Jane C. Cotton Executive Secretary
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*J. G. Schaffer Chief
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1st LT W. R. Cordova
BOARDS & COMMITTEES
Army Efficiency Awards Committee
Grievance Committee
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M. L. Warren Chief
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R. A. Gilbert Chief
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C. R. Foster Chief
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S. J. Johnson Chief
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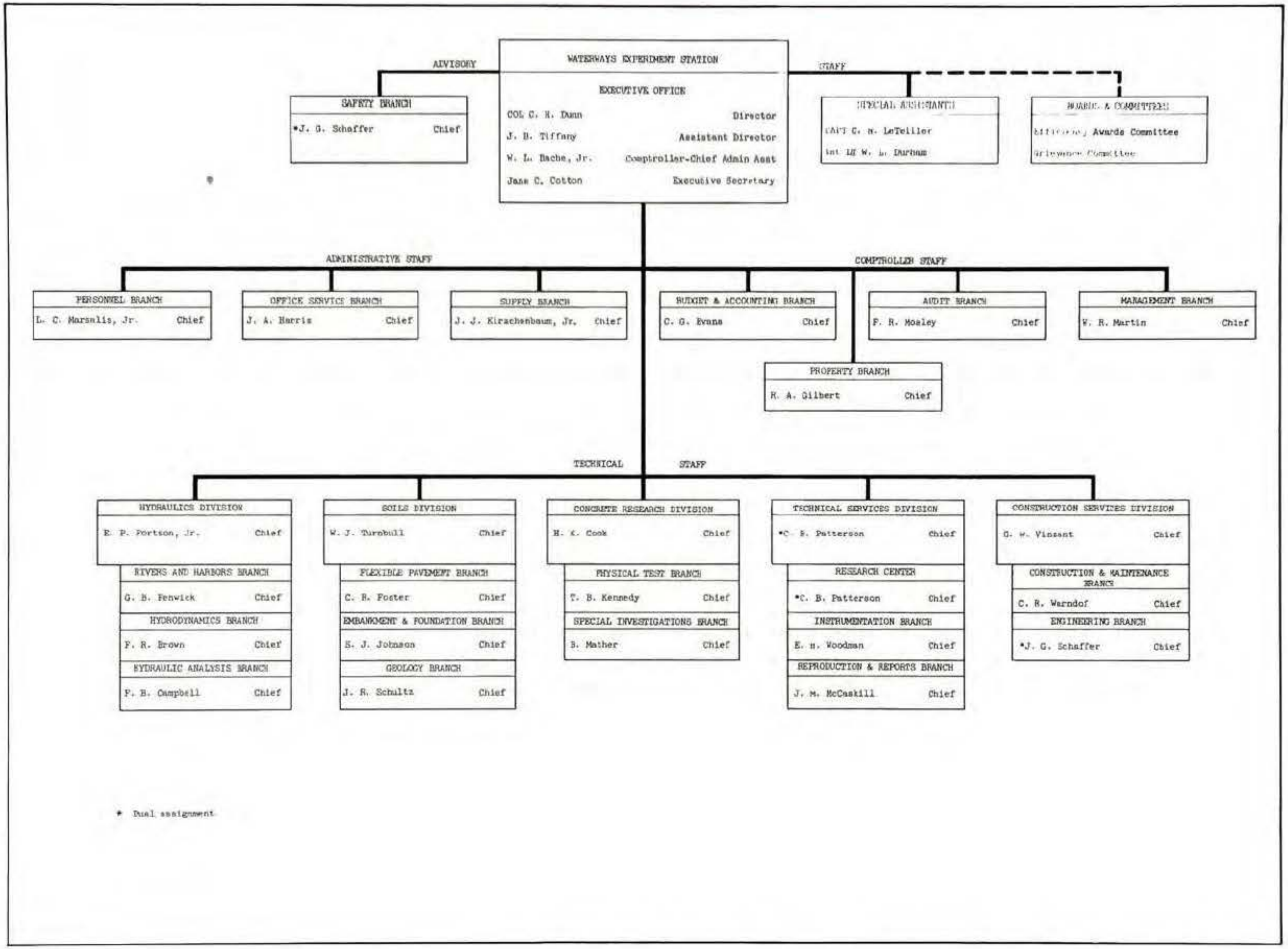
J. R. Schultz Chief
CONCRETE RESEARCH DIV (JACKSON)
H. K. Cook Chief
PHYSICAL TEST BRANCH
T. B. Kennedy Chief
SPECIAL INVESTIGATIONS BRANCH
B. Mather Chief
TECHNICAL SERVICES DIVISION
*C. B. Patterson Chief
RESEARCH CENTER
*C. B. Patterson Chief
INSTRUMENTATION BRANCH
E. H. Woodman Chief
REPRODUCTION & REPORTS BRANCH
J. M. McCaskill Chief
CONSTRUCTION SERVICES DIVISION
G. W. Vinzant Chief
CONSTRUCTION & MAINTENANCE BRANCH
C. R. Warndof Chief
ENGINEERING BRANCH
*J. G. Schaffer Chief
* Dual assignment

1 July 1952



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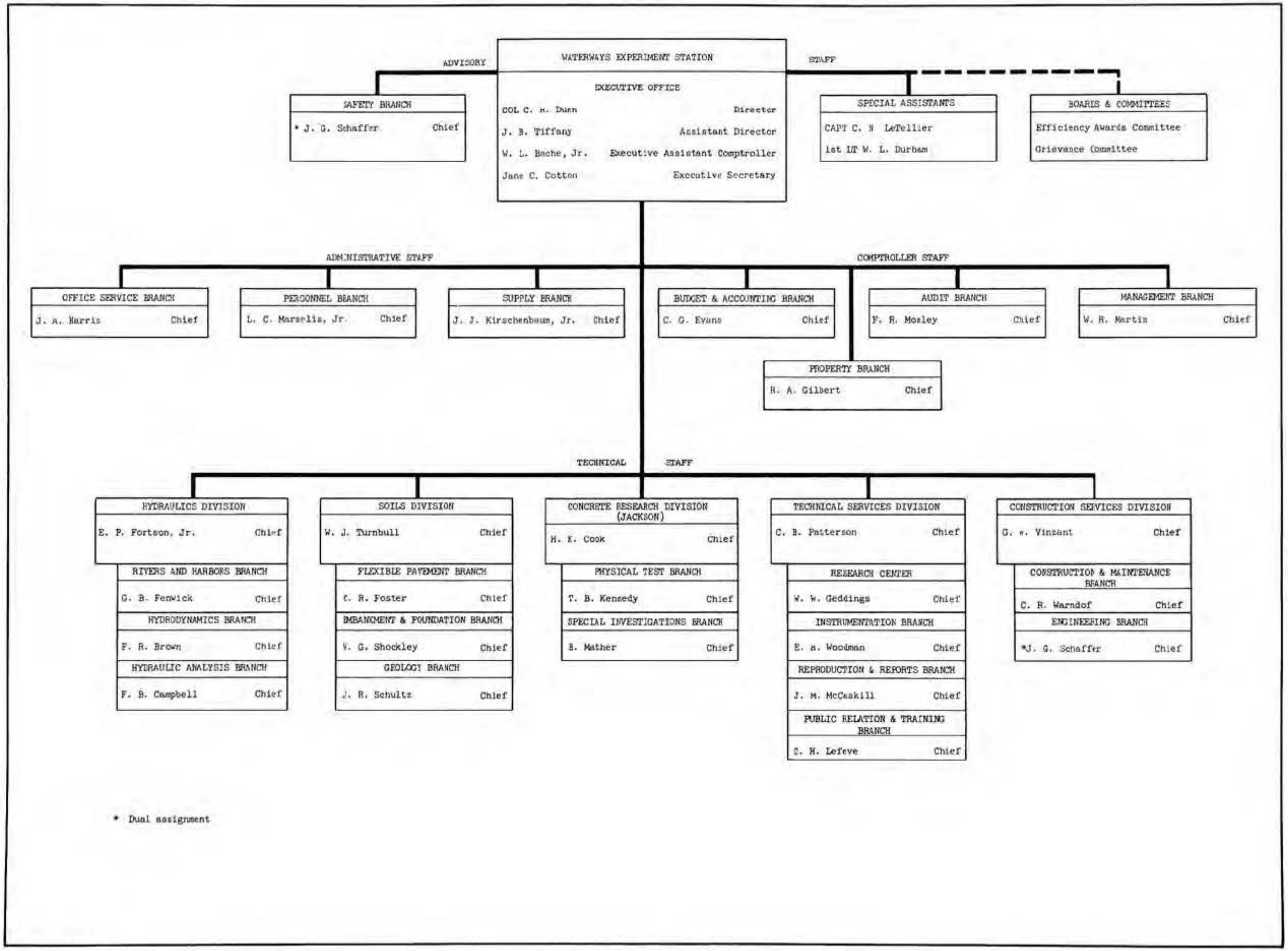
WATERWAYS EXPERIMENT STATION
EXECUTIVE OFFICE
COL C. H. Dunn Director
J. B. Tiffany Assistant Director
W. L. Bache, Jr. Executive Assistant Comptroller
Jane C. Cotton Executive Secretary
ADVISORY
SAFETY BRANCH
* J. G. Schaffer Chief
STAFF
SPECIAL ASSISTANTS
CAPT C. N LeTellier
1st LT W. L. Durham
BOARDS & COMMITTEES
Efficiency Awards Committee
Grievance Committee
ADMINISTRATIVE STAFF
OFFICE SERVICE BRANCH
J. A. Harris Chief
PERSONNEL BRANCH
L. C. Marselis, Jr. Chief
SUPPLY BRANCH
J. J. Kirschenbaum, Jr. Chief
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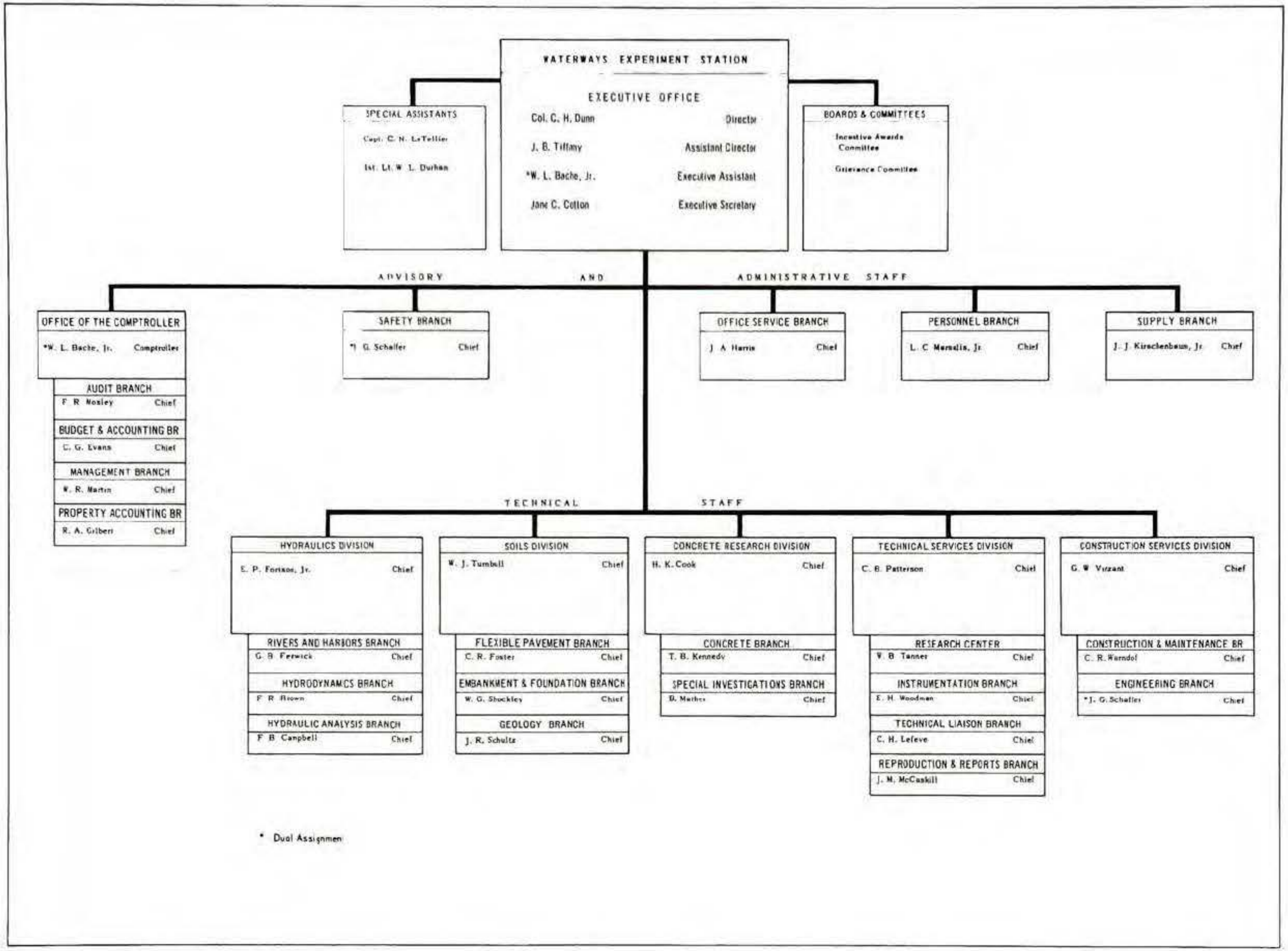
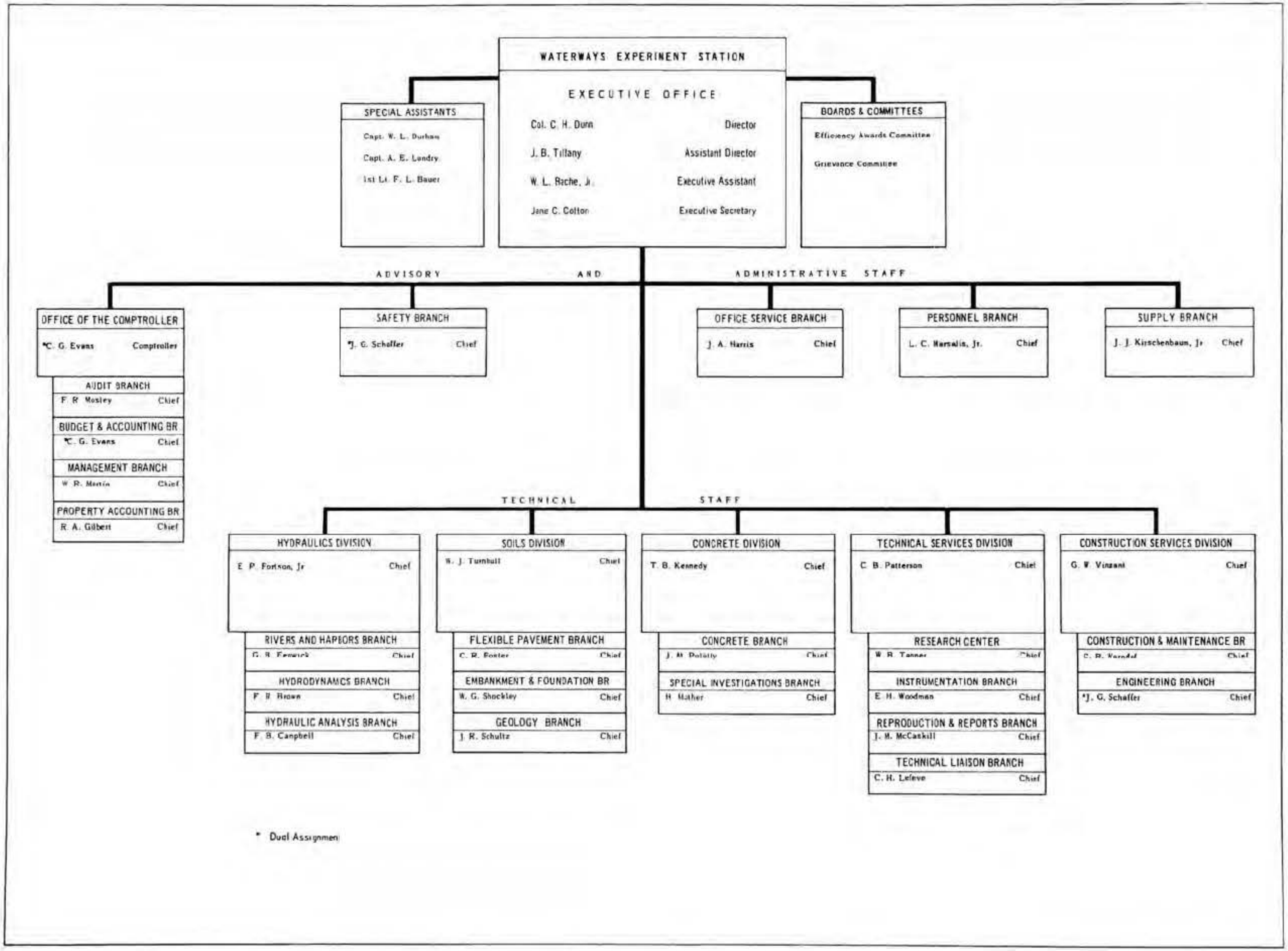
C. G. Evans Chief
AUDIT BRANCH
F. R. Mosley Chief
MANAGEMENT BRANCH
W. R. Martin Chief
PROPERTY BRANCH
R. A. Gilbert Chief
TECHNICAL STAFF
HYDRAULICS DIVISION
E. P. Fortson, Jr. Chief
RIVERS AND HARBORS BRANCH
G. B. Fenwick Chief
HYDRODYNAMICS BRANCH
F. R. Brown Chief
HYDRAULIC ANALYSIS BRANCH
F. B. Campbell Chief
SOILS DIVISION
W. J. Turnbull Chief
FLEXIBLE PAVEMENT BRANCH
C. R. Foster Chief
EMBANKMENT & FOUNDATION BRANCH
W. G. Shockley Chief
GEOLOGY BRANCH
J. R. Schultz Chief
CONCRETE RESEARCH DIVISION (JACKSON)
H. K. Cook Chief
PHYSICAL TEST BRANCH
T. B. Kennedy Chief
SPECIAL INVESTIGATIONS BRANCH
B. Mather Chief
TECHNICAL SERVICES DIVISION
C. B. Patterson Chief
RESEARCH CENTER
W. W. Geddings Chief
INSTRUMENTATION BRANCH
E. R. Woodman Chief
REPRODUCTION & REPORTS BRANCH
J. M. McCaskill Chief
PUBLIC RELATION & TRAINING BRANCH
C. H. Lefeve Chief
CONSTRUCTION SERVICES DIVISION
G. W. Vinzant Chief
CONSTRUCTION & MAINTENANCE BRANCH
C. R. Warndof Chief
ENGINEERING BRANCH
*J. G. Schaffer Chief
* Dual assignment

1 July 1953



1 January 1954



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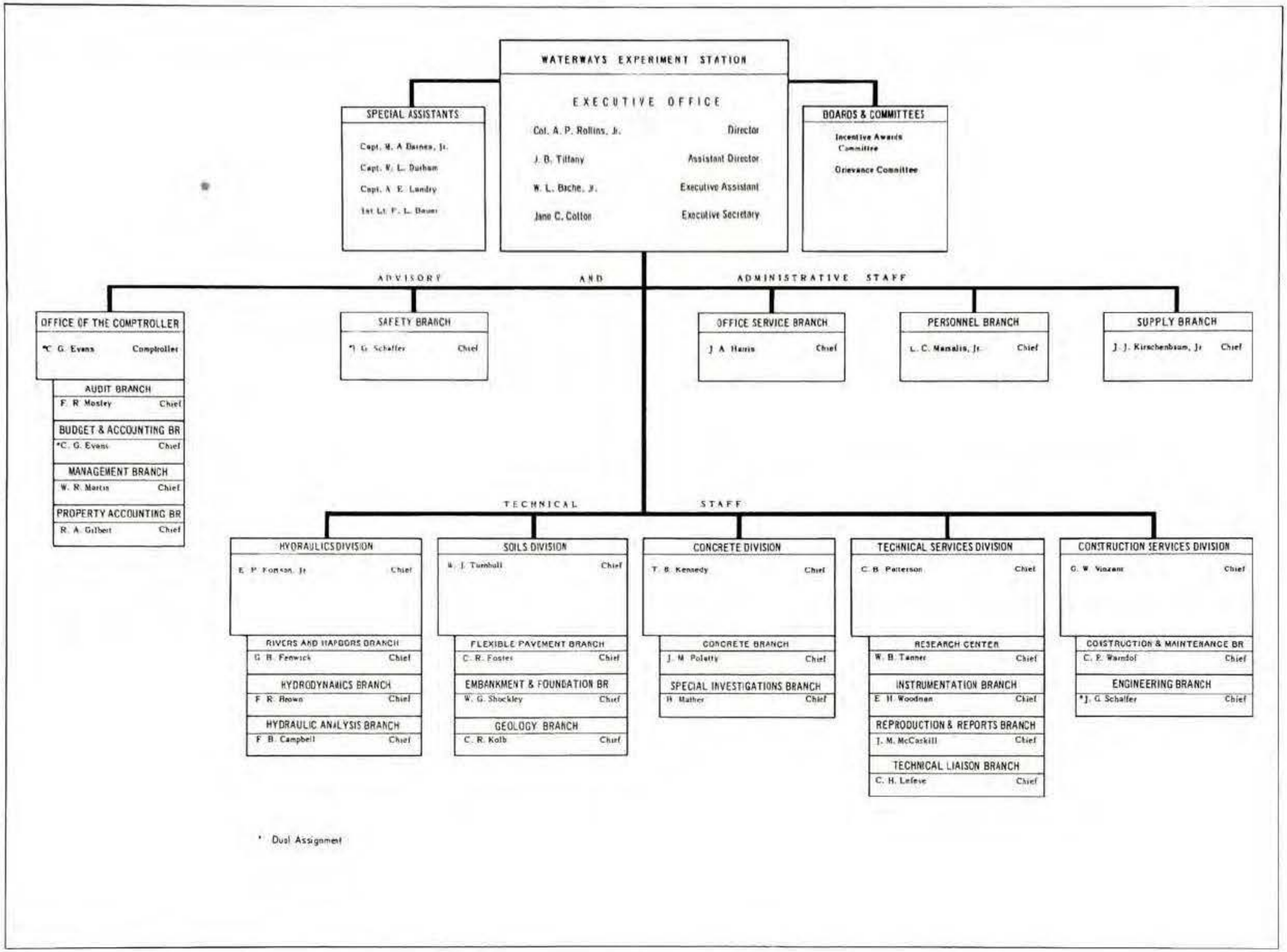
WATERWAYS EXPERIMENT STATION
EXECUTIVE OFFICE
Col. A. P. Rollins, Jr. Director
J. B. Tiffany Assistant Director
W. L. Bache, Jr. Executive Assistant
Jane C. Colton Executive Secretary
SPECIAL ASSISTANTS
Capt. W. A Barnes, Jr.
Capt. W. L. Durham
Capt. A. E. Landry
1st Lt. F. L. Bauer
BOARDS & COMMITTEES
Incentive Awards Committee
Grievance Committee
ADVISORY AND ADMINISTRATIVE STAFF
OFFICE OF THE COMPTROLLER
*C. G. Evans Comptroller
AUDIT BRANCH
F. R. Mosley Chief
BUDGET & ACCOUNTING BR
*C. G. Evans Chief
MANAGEMENT BRANCH
W. R. Martin Chief
PROPERTY ACCOUNTING BR
R. A. Gilbert Chief
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*J. G. Schaffer Chief
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J. A. Harris Chief
PERSONNEL BRANCH
L. C. Manalis, Jr. Chief
SUPPLY BRANCH
J. J. Kirschenbaum, Jr. Chief
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HYDRAULICS DIVISION
E. P. Fortson, Jr. Chief
RIVERS AND HARBORS BRANCH
G. B. Fenwick Chief
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F. R. Brown Chief
HYDRAULIC ANALYSIS BRANCH
F. B. Campbell Chief
SOILS DIVISION
W. J. Turnbull Chief
FLEXIBLE PAVEMENT BRANCH
C. R. Foster Chief
EMBANKMENT & FOUNDATION BR
W. G. Shockley Chief
GEOLOGY BRANCH
C. R. Kolb Chief
CONCRETE DIVISION
T. B. Kennedy Chief
CONCRETE BRANCH
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SPECIAL INVESTIGATIONS BRANCH
B. Mather Chief
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C. H. Lefeve Chief
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G. W. Vinzant Chief
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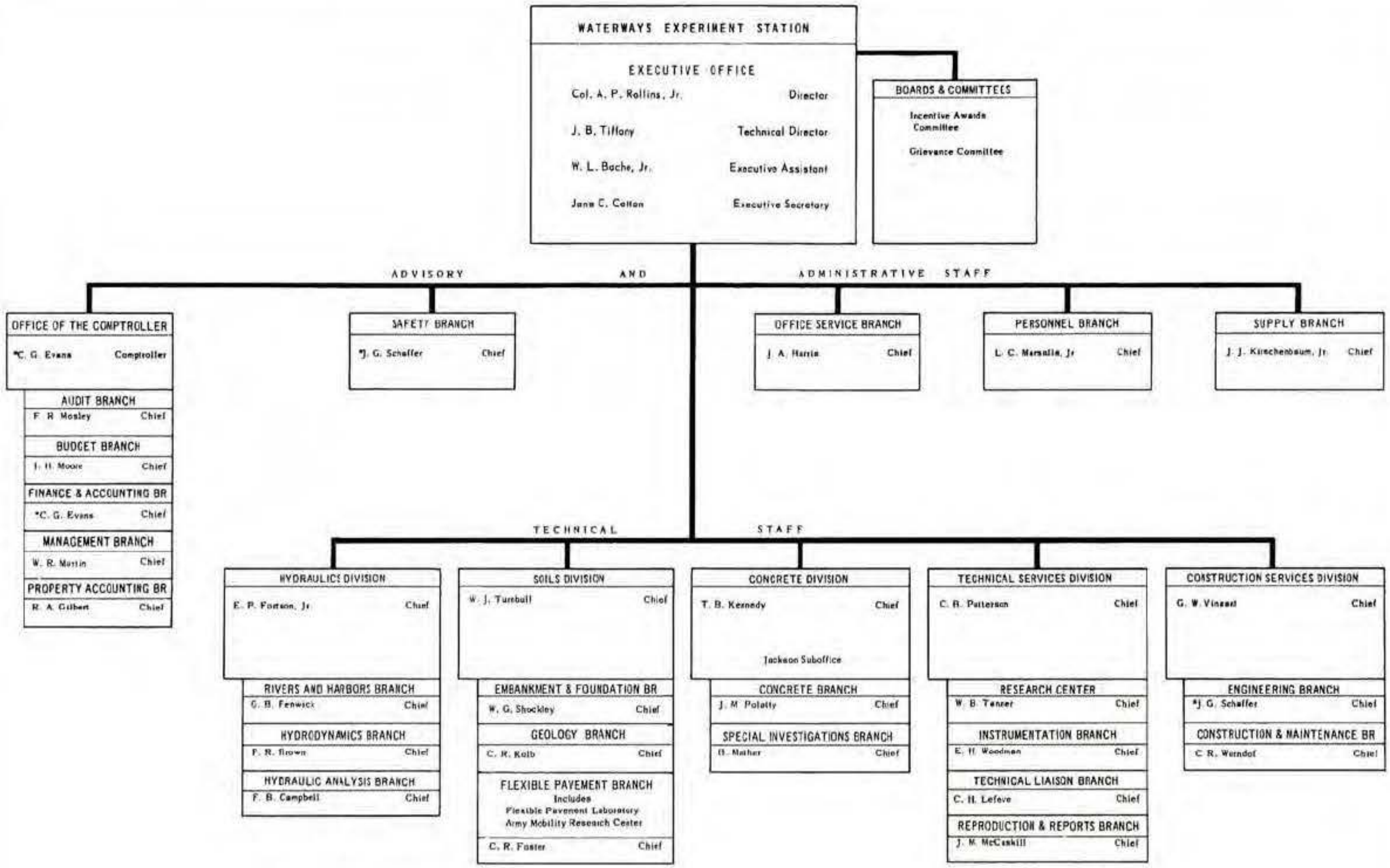
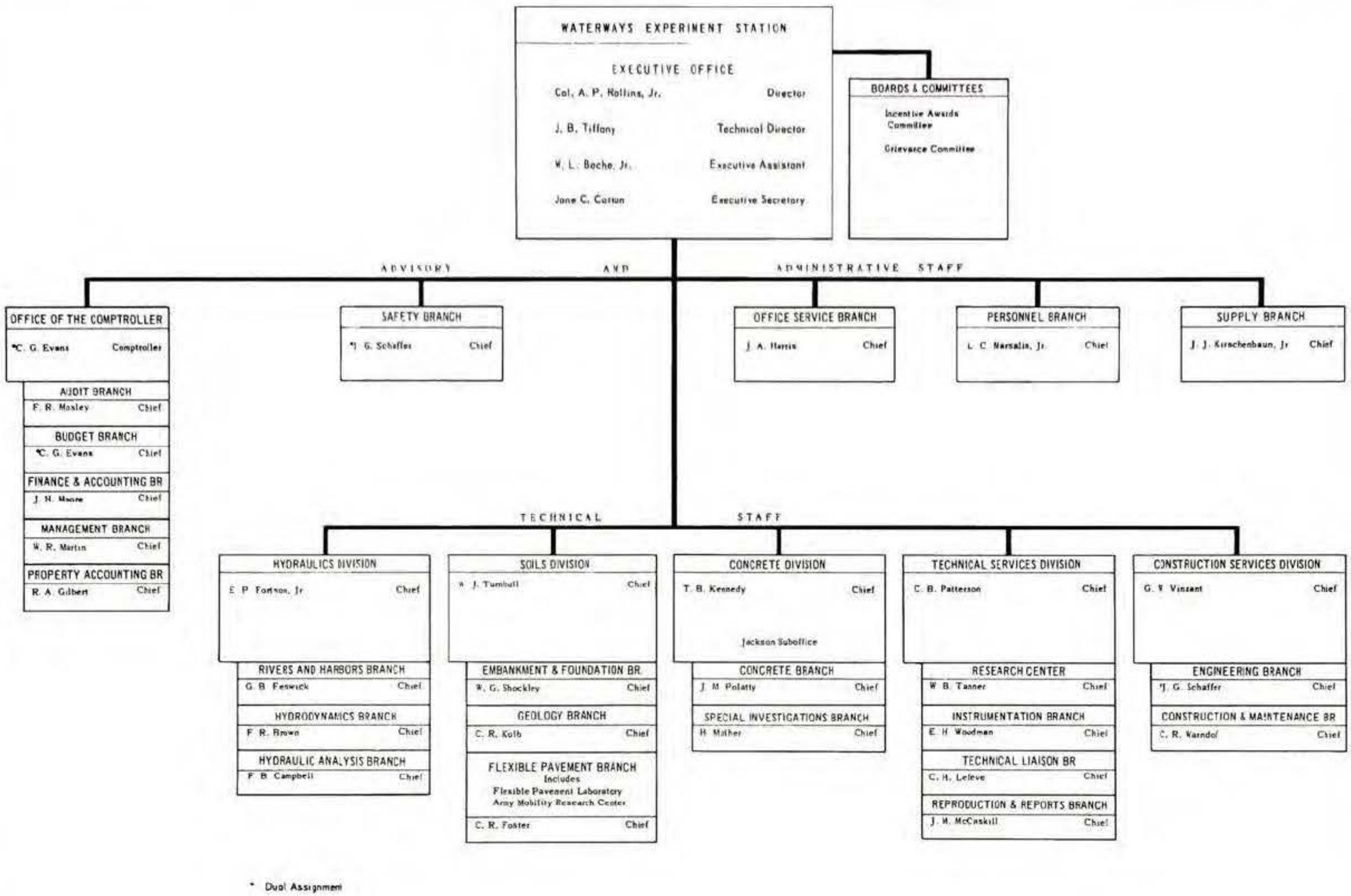
C. E. Warndof Chief
ENGINEERING BRANCH
*J. G. Schaffer Chief
* Dual Assignment

15 June 1955



* Dual Assignment

1 July 1956



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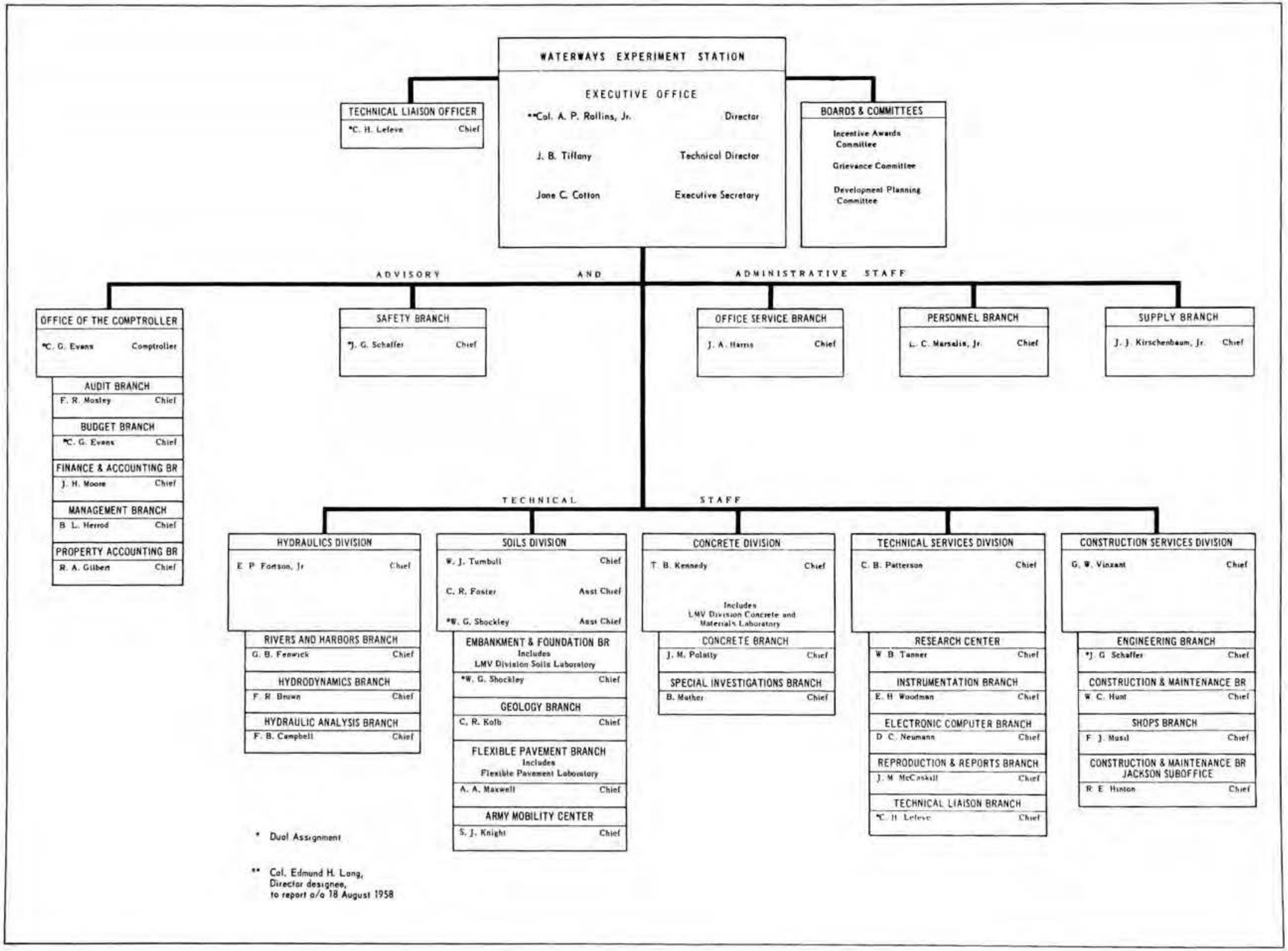
WATERWAYS EXPERIMENT STATION
EXECUTIVE OFFICE
**Col. A. P. Rollins, Jr. Director
J. B. Tiffany Technical Director
Jane C. Cotton Executive Secretary
TECHNICAL LIAISON OFFICER
*C. H. Lefeve Chief
BOARDS & COMMITTEES
Incentive Awards Committee
Grievance Committee
Development Planning Committee
ADVISORY AND ADMINISTRATIVE STAFF
OFFICE OF THE COMPTROLLER
*C. G. Evans Comptroller
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BUDGET BRANCH
*C. G. Evans Chief
FINANCE & ACCOUNTING BR
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HYDRAULICS DIVISION
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HYDRAULIC ANALYSIS BRANCH
F. B. Campbell Chief
SOILS DIVISION
W. J. Turnbull Chief
C. R. Foster Asst Chief
*W. G. Shockley Asst Chief
EMBANKMENT & FOUNDATION BR
Includes
LMV Division Soils Laboratory
*W. G. Shockley Chief
GEOLOGY BRANCH
C. R. Kolb Chief
FLEXIBLE PAVEMENT BRANCH
Includes
Flexible Pavement Laboratory
A. A. Maxwell Chief
ARMY MOBILITY CENTER
S. J. Knight Chief
CONCRETE DIVISION
T. B. Kennedy Chief
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LMV Division Concrete and Materials Laboratory
CONCRETE BRANCH
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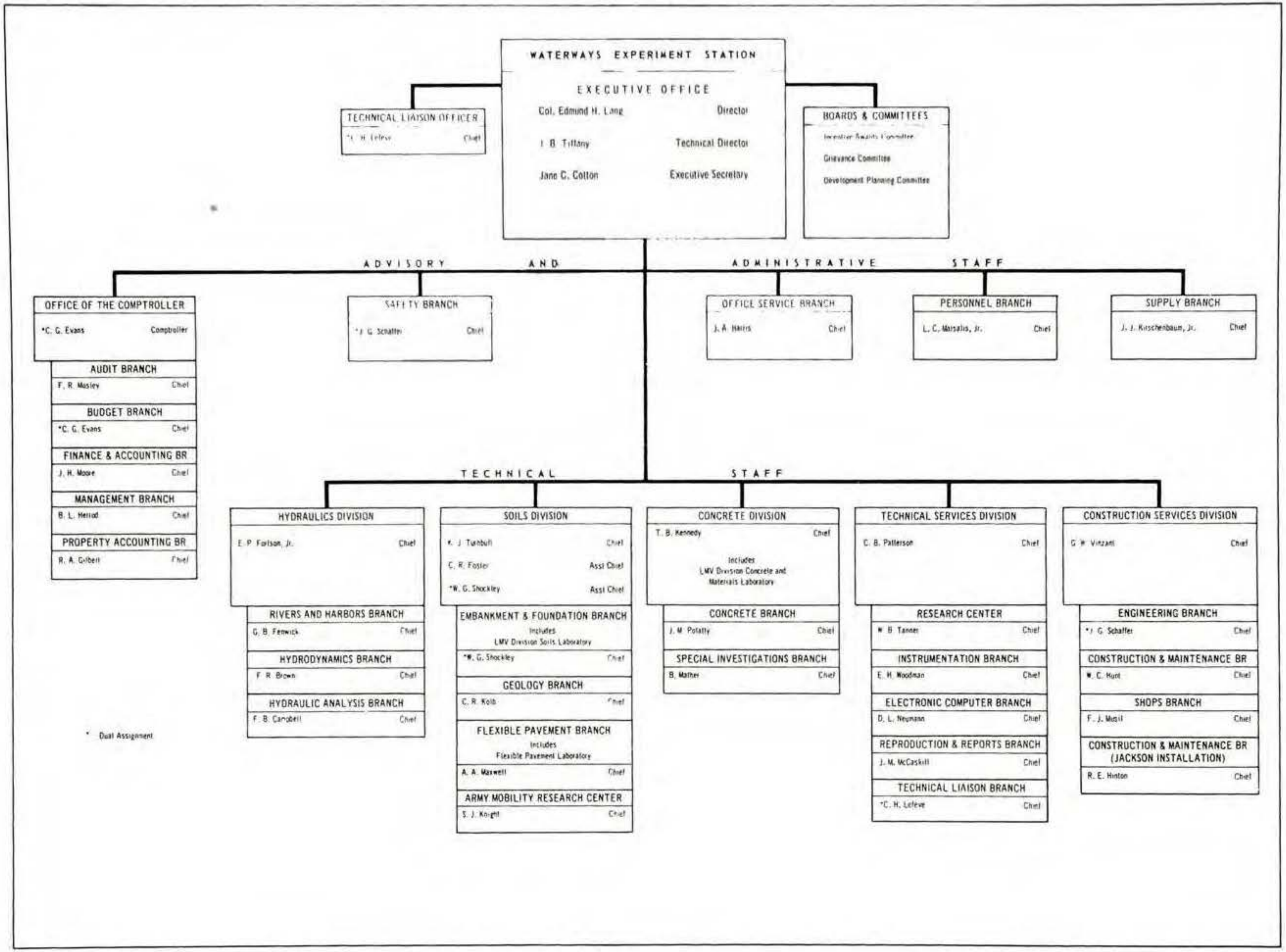
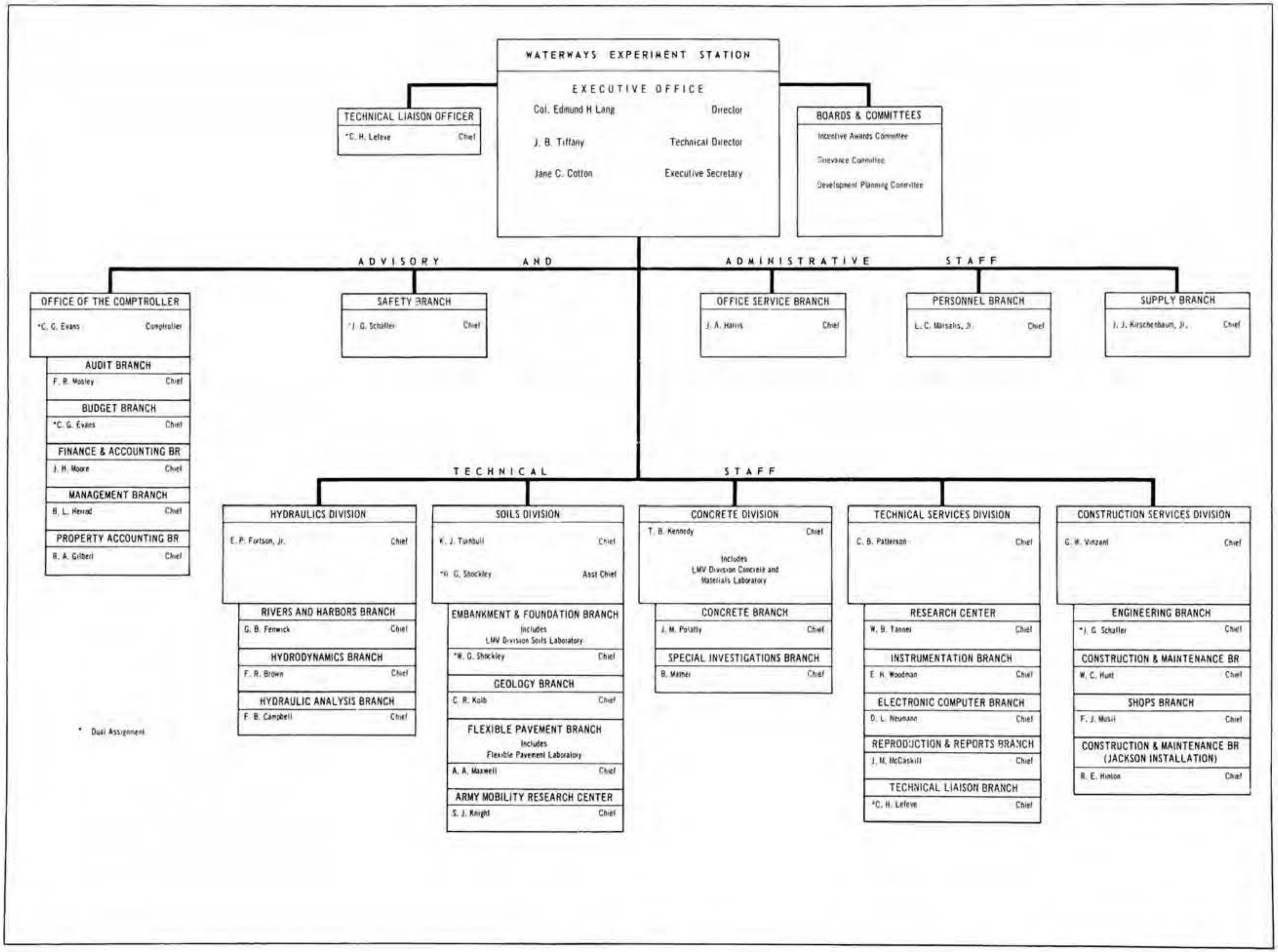
G. W. Vinzant Chief
ENGINEERING BRANCH
*J. G. Schaffer Chief
CONSTRUCTION & MAINTENANCE BR
W. C. Hunt Chief
SHOPS BRANCH
F. J. Musil Chief
CONSTRUCTION & MAINTENANCE BR
JACKSON SUBOFFICE
R. E. Hinton Chief
* Dual Assignment
** Col. Edmund H. Long, Director designee, to report o/a 18 August 1958

1 July 1958



1 January 1959


WATERWAYS EXPERIMENT STATION
EXECUTIVE OFFICE
Col. Edmund H Lang Director
J. B. Tiffany Technical Director
Jane C. Cotton Executive Secretary
TECHNICAL LIAISON OFFICER
*C. H. Lefeve Chief
BOARDS & COMMITTEES
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OFFICE OF THE COMPTROLLER
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F. B. Campbell Chief
SOILS DIVISION
K. J. Turnbull Chief
*W. G. Shockley Asst Chief
EMBANKMENT & FOUNDATION BRANCH
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*W. G. Shockley Chief
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C. R. Kolb Chief
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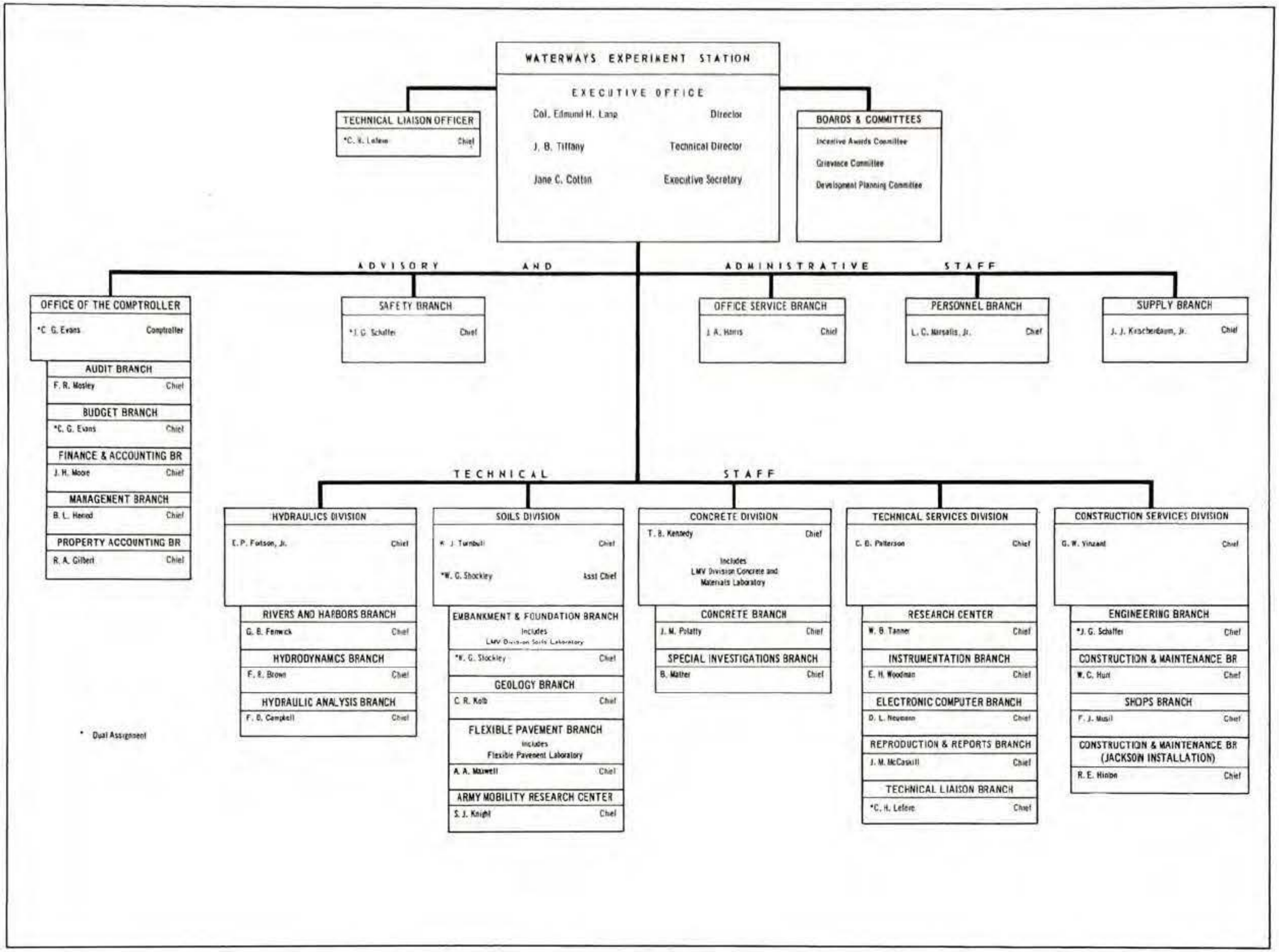
*J. G. Schaffer Chief
CONSTRUCTION & MAINTENANCE BR
W. C. Hunt Chief
SHOPS BRANCH
F. J. Musil Chief
CONSTRUCTION & MAINTENANCE BR
(JACKSON INSTALLATION)
R. E. Hinton Chief
* Dual Assignment

15 May 1959


WATERWAYS EXPERIMENT STATION
EXECUTIVE OFFICE
Col. Edmund H. Lang Director
J. B. Tiffany Technical Director
Jane C. Cotton Executive Secretary
TECHNICAL LIAISON OFFICER
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CONSTRUCTION SERVICES DIVISION
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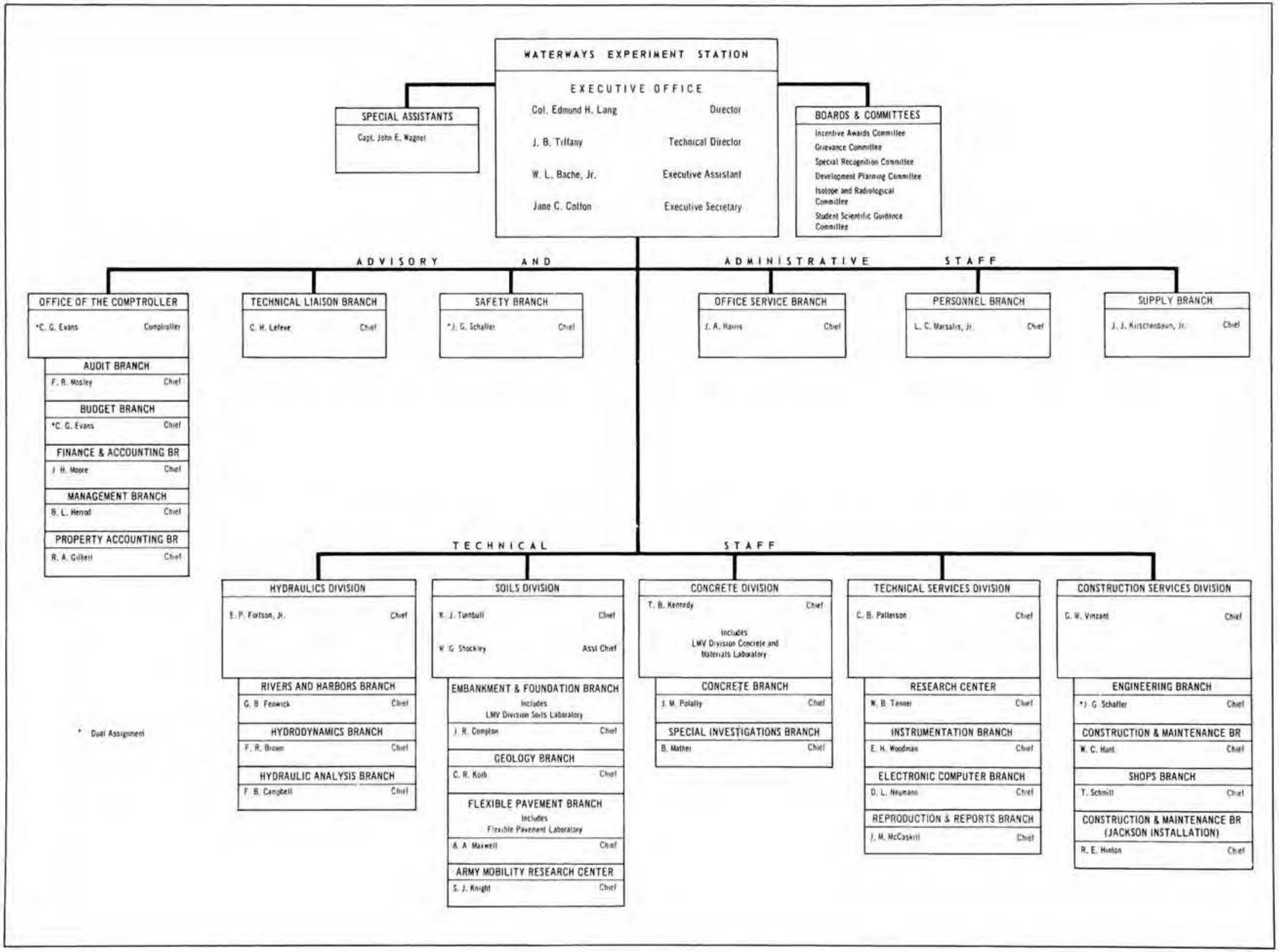
CONSTRUCTION & MAINTENANCE BR
W. C. Hunt Chief
SHOPS BRANCH
F. J. Musil Chief
CONSTRUCTION & MAINTENANCE BR
(JACKSON INSTALLATION)
R. E. Hinbe Chief
* Dual Assignment

1 July 1959



WATERWAYS EXPERIMENT STATION
EXECUTIVE OFFICE
Col. Edmund H. Lang Director
J. B. Tiffany Technical Director
W. L. Bache, Jr. Executive Assistant
Jane C. Cotton Executive Secretary
SPECIAL ASSISTANTS
Capt. John E. Wagner
BOARDS & COMMITTEES
Incentive Awards Committee
Grievance Committee
Special Recognition Committee
Development Planning Committee
Isotope and Radiological Committee
Student Scientific Guidance Committee
ADVISORY AND ADMINISTRATIVE STAFF
OFFICE OF THE COMPTROLLER
*C. G. Evans Comptroller
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HYDRAULICS DIVISION
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W. G. Shockley Asst Chief
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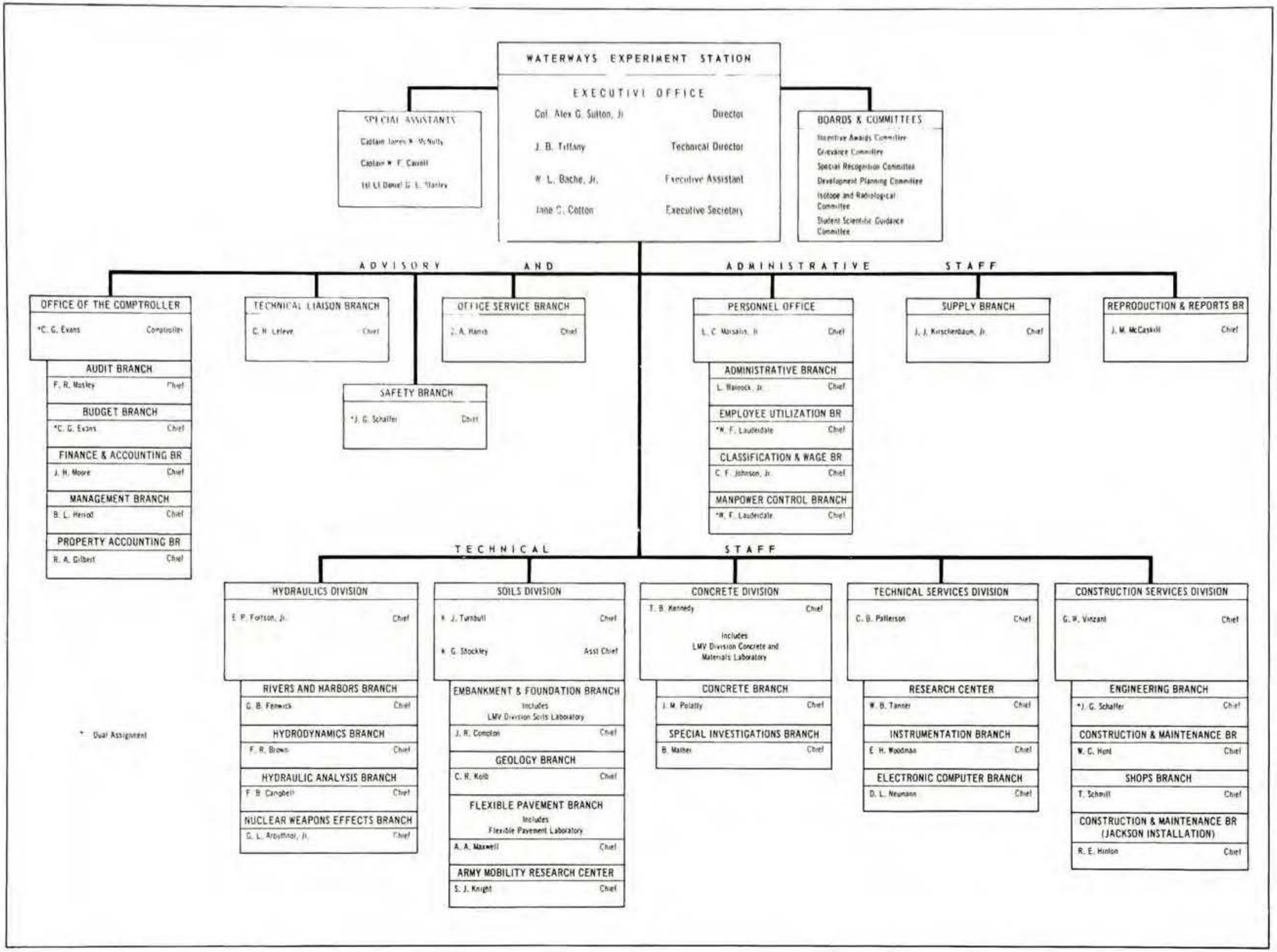
G. W. Vinzant Chief
ENGINEERING BRANCH
*J. G. Schaller Chief
CONSTRUCTION & MAINTENANCE BR
W. C. Hunt Chief
SHOPS BRANCH
T. Schmitt Chief
CONSTRUCTION & MAINTENANCE BR (JACKSON INSTALLATION)
R. E. Hinton Chief
* Dual Assignment

1 May 1961


WATERWAYS EXPERIMENT STATION
EXECUTIVE OFFICE
Col. Alex G. Sutton, Jr. Director
J. B. Tiffany Technical Director
W. L. Bache, Jr. Executive Assistant
Jane C. Cotton Executive Secretary
SPECIAL ASSISTANTS
Captain James W. McNulty
Captain W. F. Carroll
1st Lt Daniel G. L. Stanley
BOARDS & COMMITTEES
Incentive Awards Committee
Grievance Committee
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J. A. Hanks Chief
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L. C. Marsalis, Jr. Chief
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L. Walcock, Jr. Chief
EMPLOYEE UTILIZATION BR
*W. F. Lauderdale Chief
CLASSIFICATION & WAGE BR
C. F. Johnson, Jr. Chief
MANPOWER CONTROL BRANCH
*W. F. Lauderdale Chief
SUPPLY BRANCH
J. J. Kirschenbaum, Jr. Chief
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J. M. McCaskill Chief
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HYDRAULICS DIVISION
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F. B. Campbell Chief
NUCLEAR WEAPONS EFFECTS BRANCH
G. L. Arbuthnot, Jr. Chief
SOILS DIVISION
W. J. Turnbull Chief
W. G. Shockley Asst Chief
EMBANKMENT & FOUNDATION BRANCH
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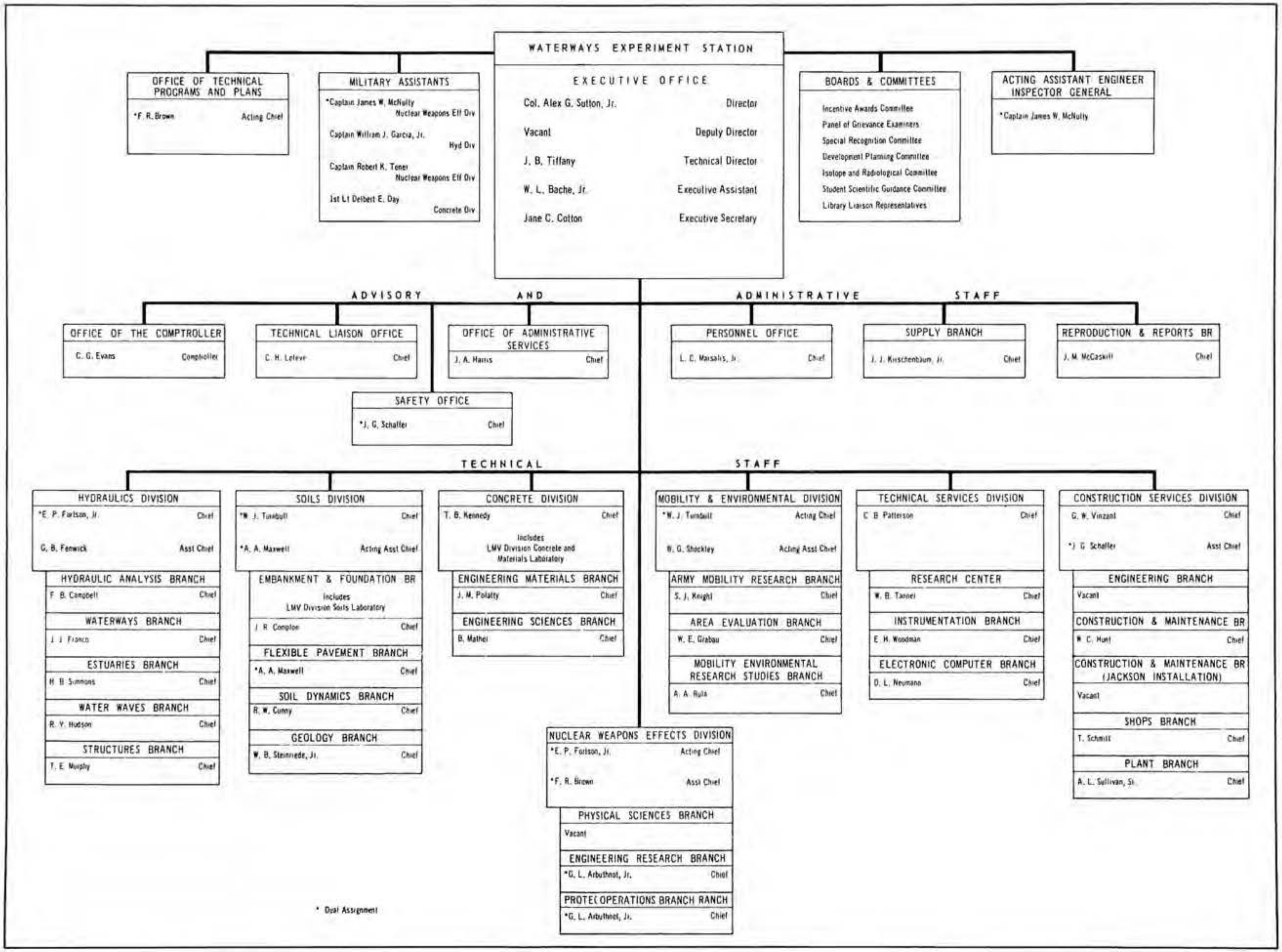
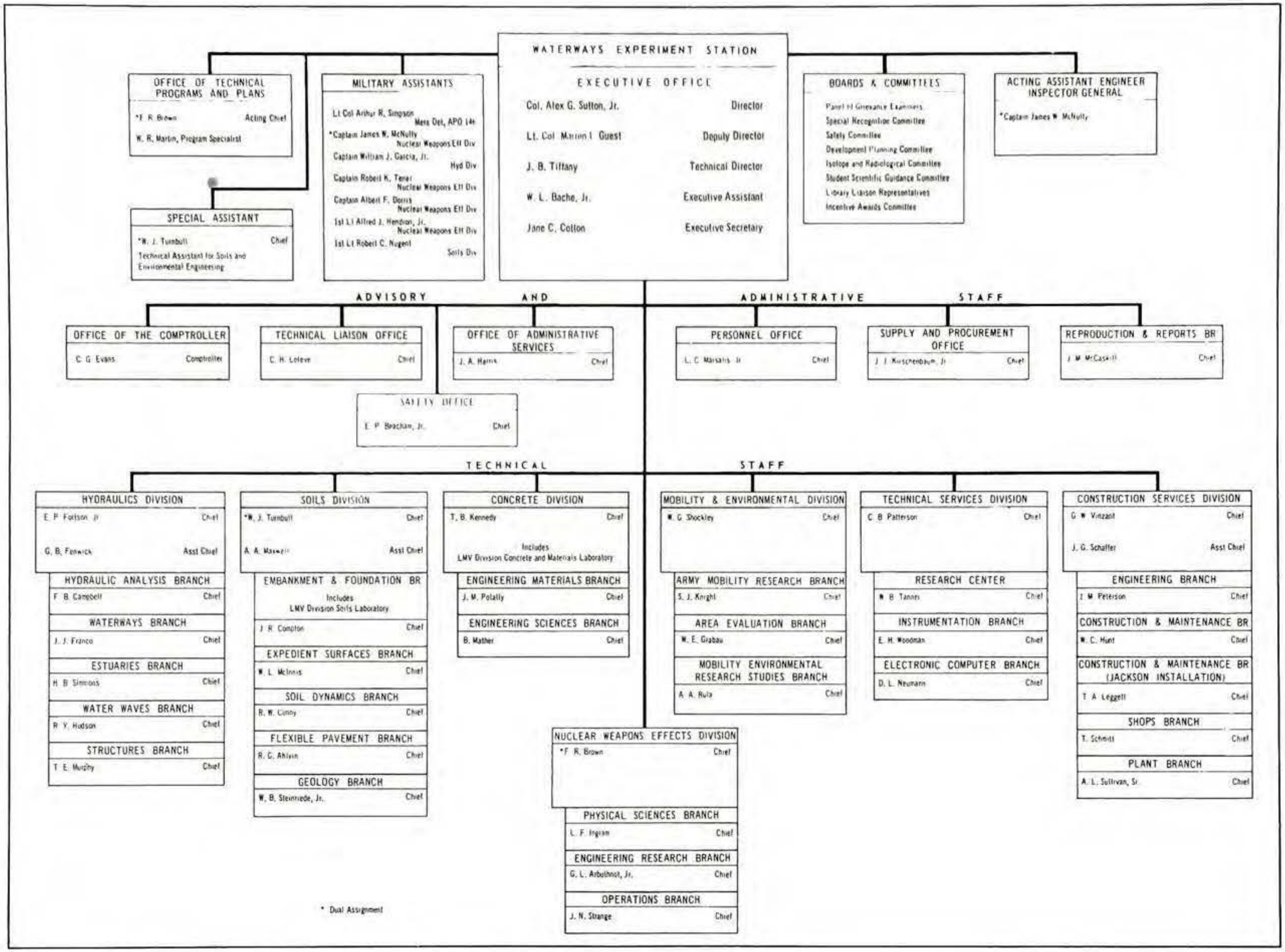
CONSTRUCTION & MAINTENANCE BR
W. C. Hunt Chief
SHOPS BRANCH
T. Schmitt Chief
CONSTRUCTION & MAINTENANCE BR (JACKSON INSTALLATION)
R. E. Hinton Chief
* Dual Assignment

1 July 1962



1 August 1963



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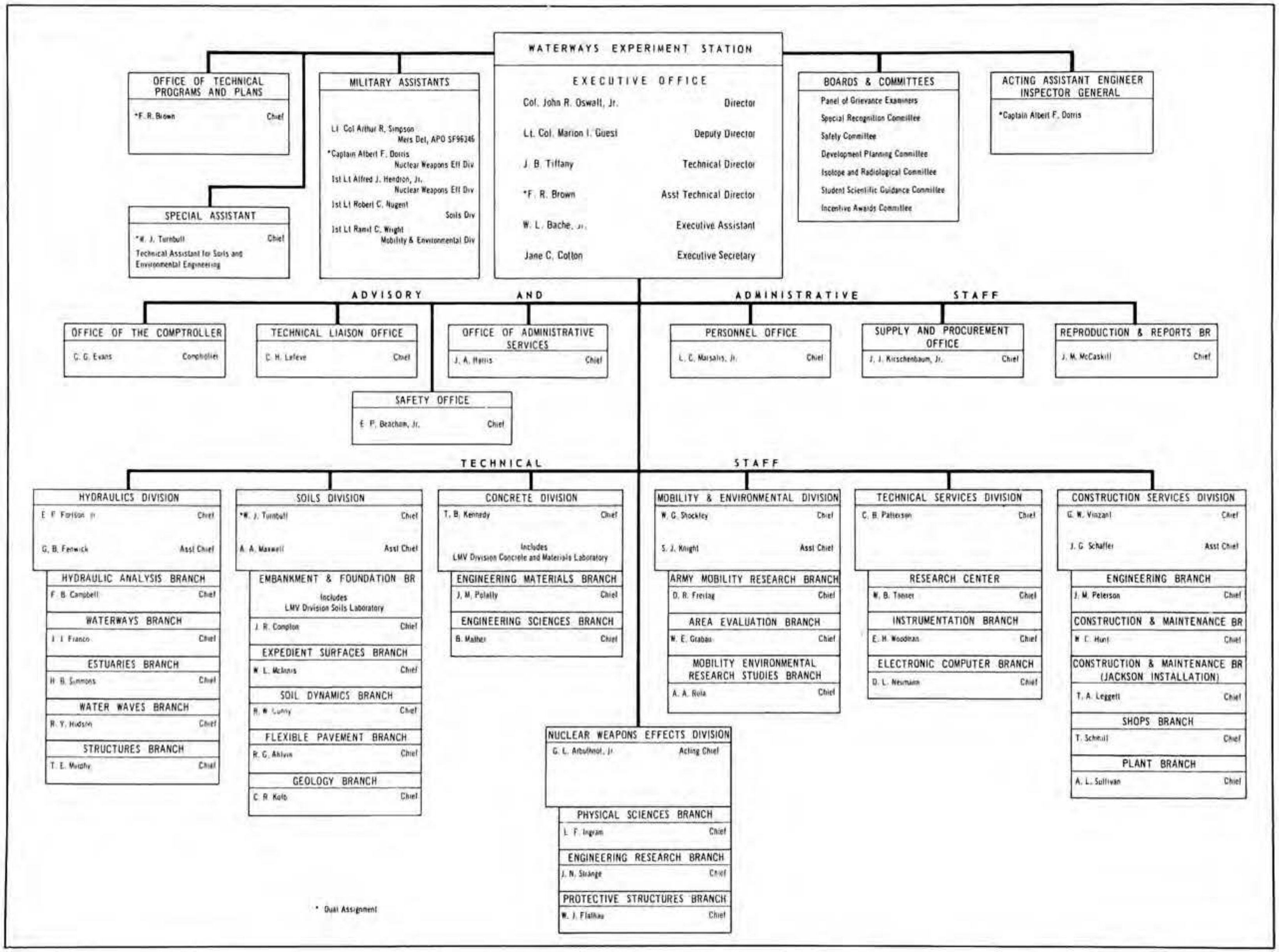
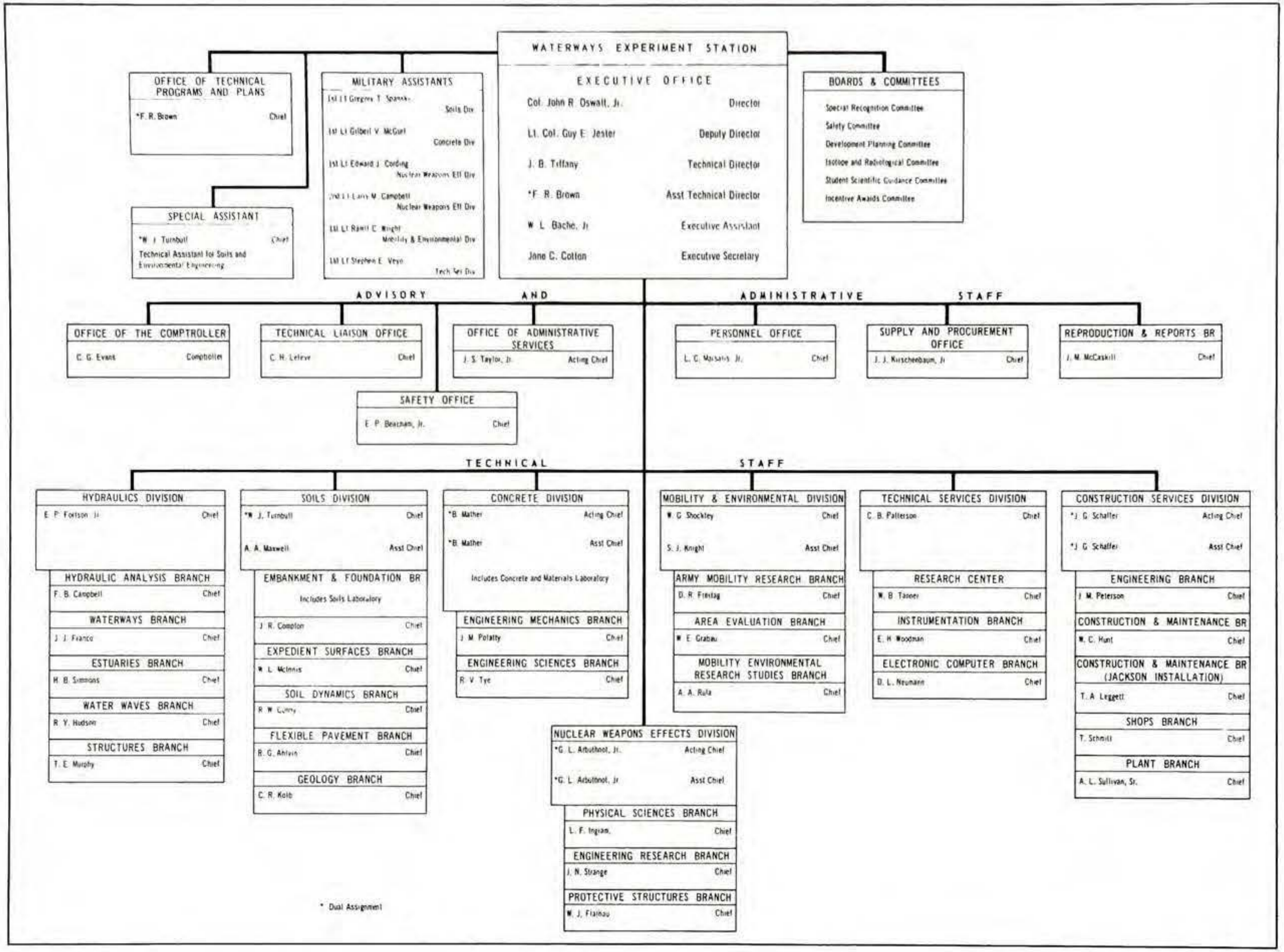
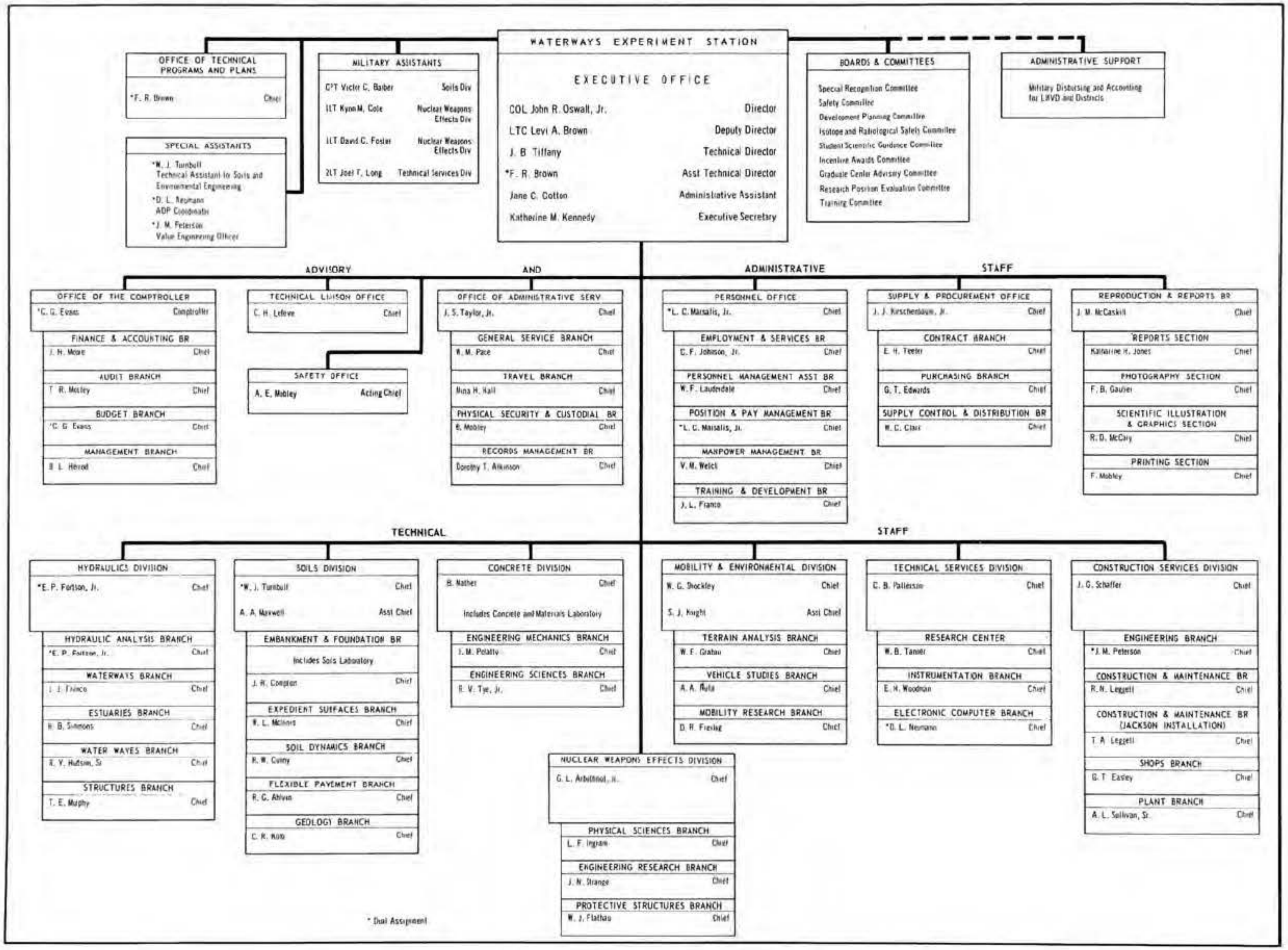


1 February 1965



1 February 1966



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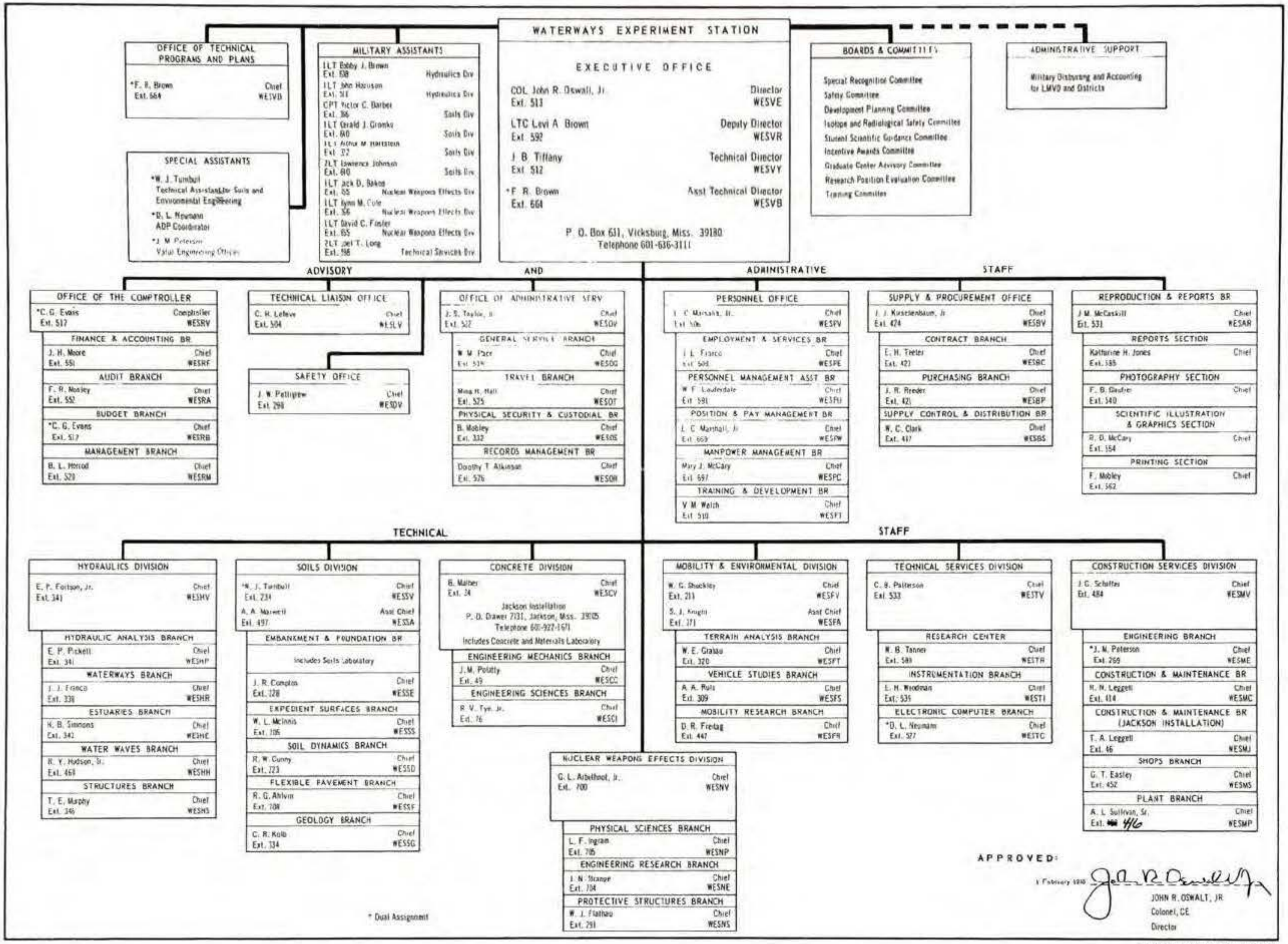

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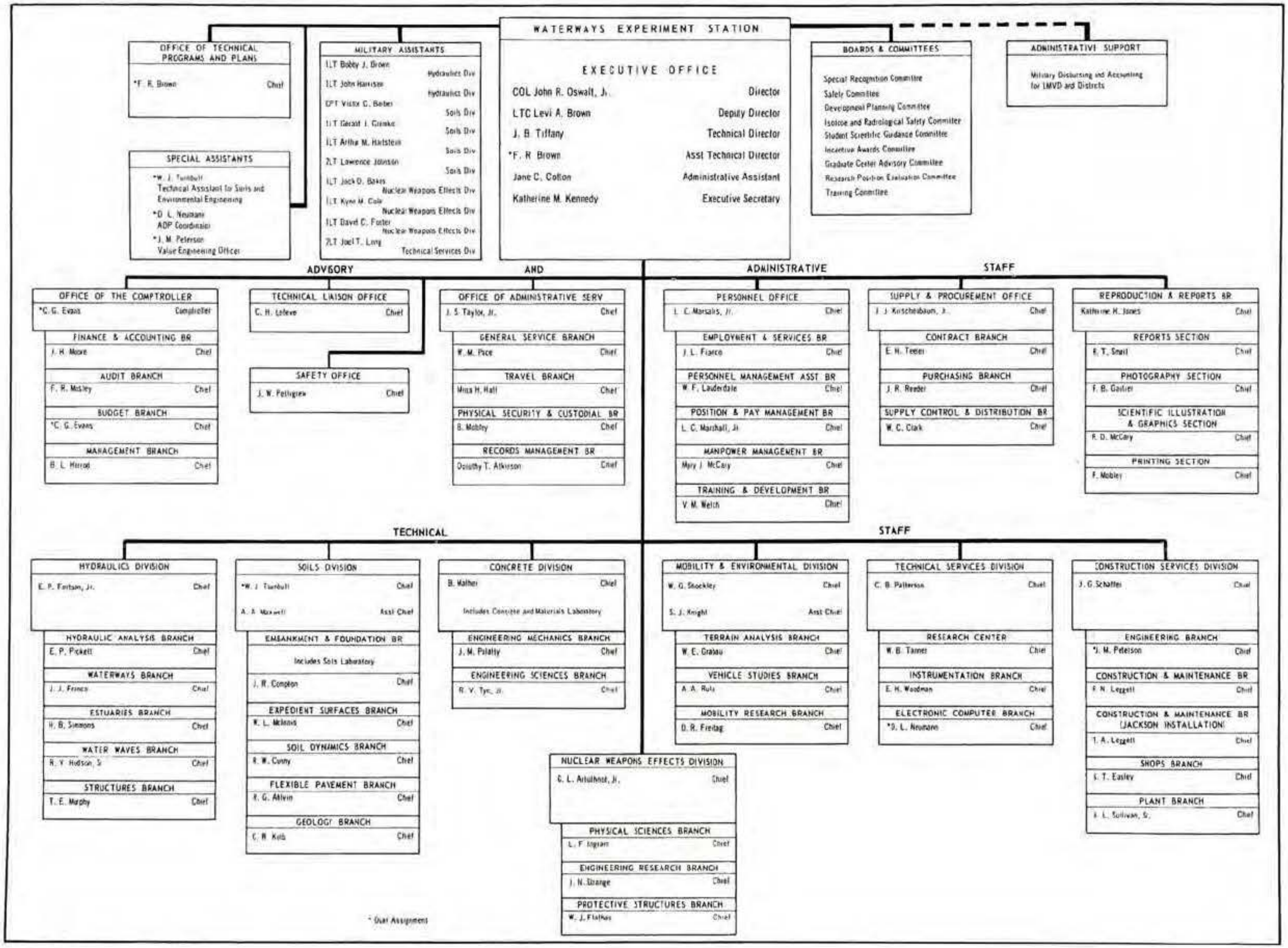
WATERWAYS EXPERIMENT STATION
EXECUTIVE OFFICE
COL John R. Oswalt, Jr. Director
LTC Levi A. Brown Deputy Director
J. B. Tiffany Technical Director
*F. R. Brown Asst Technical Director
Jane C. Colton Administrative Assistant
Katherine M. Kennedy Executive Secretary
OFFICE OF TECHNICAL PROGRAMS AND PLANS
*F. R. Brown Chief
SPECIAL ASSISTANTS
*W. J. Turnbull Technical Assistant for Soils and Environmental Engineering
*D. L. Neumann ADP Coordinator
*J. M. Peterson Value Engineering Officer
MILITARY ASSISTANTS
1LT Bobby J. Brown Hydraulics Div
1LT John Harrison Hydraulics Div
CPT Victor C. Barber Soils Div
1LT Gerald J. Cronke Soils Div
1LT Arthur M. Hartstein Soils Div
2LT Lawrence Johnson Soils Div
1LT Jack D. Bakes Nuclear Weapons Effects Div
1LT Kyne M. Cole Nuclear Weapons Effects Div
1LT David C. Foster Nuclear Weapons Effects Div
2LT Joel T. Long Technical Services Div
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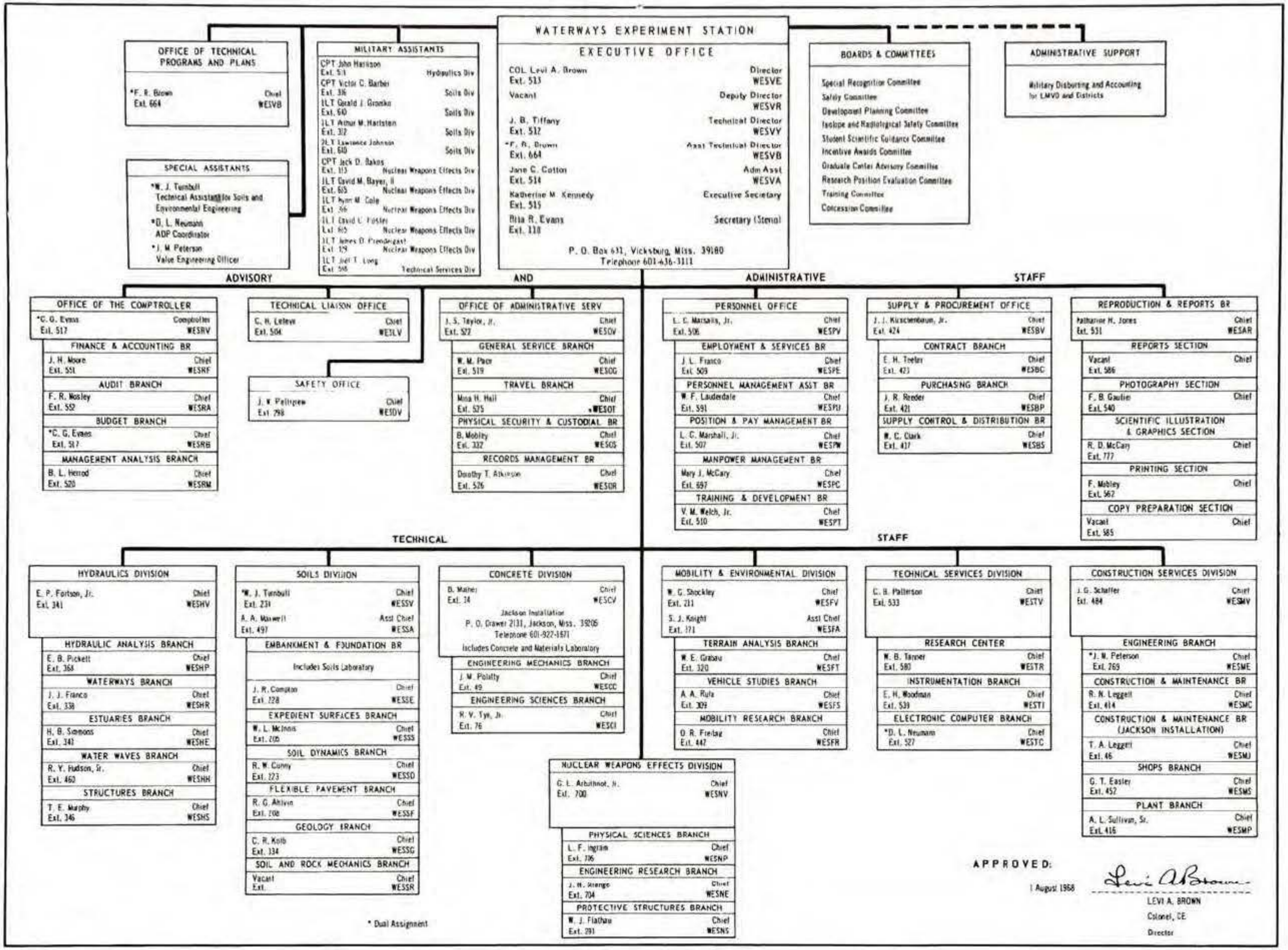
1 May 1968



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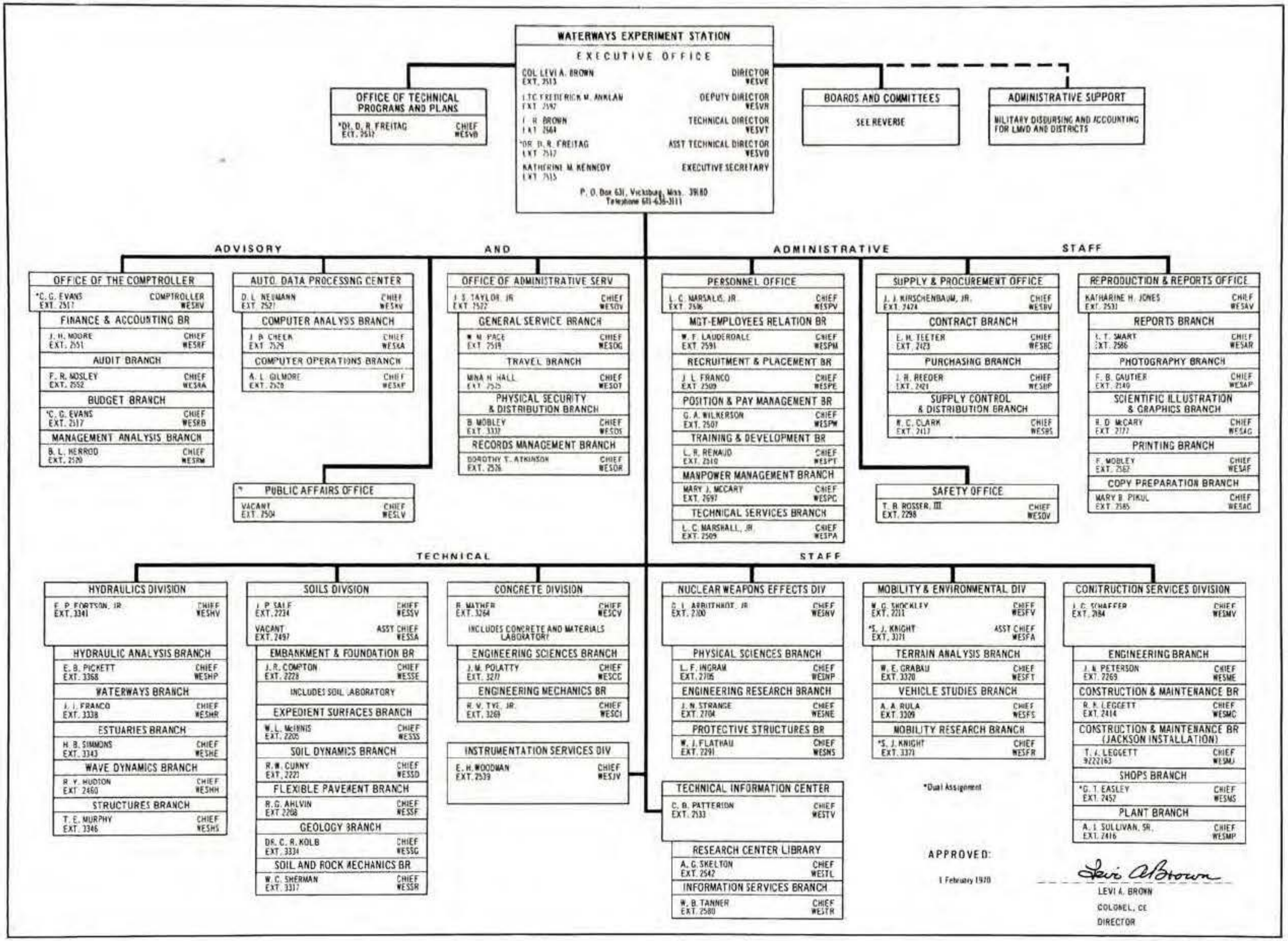

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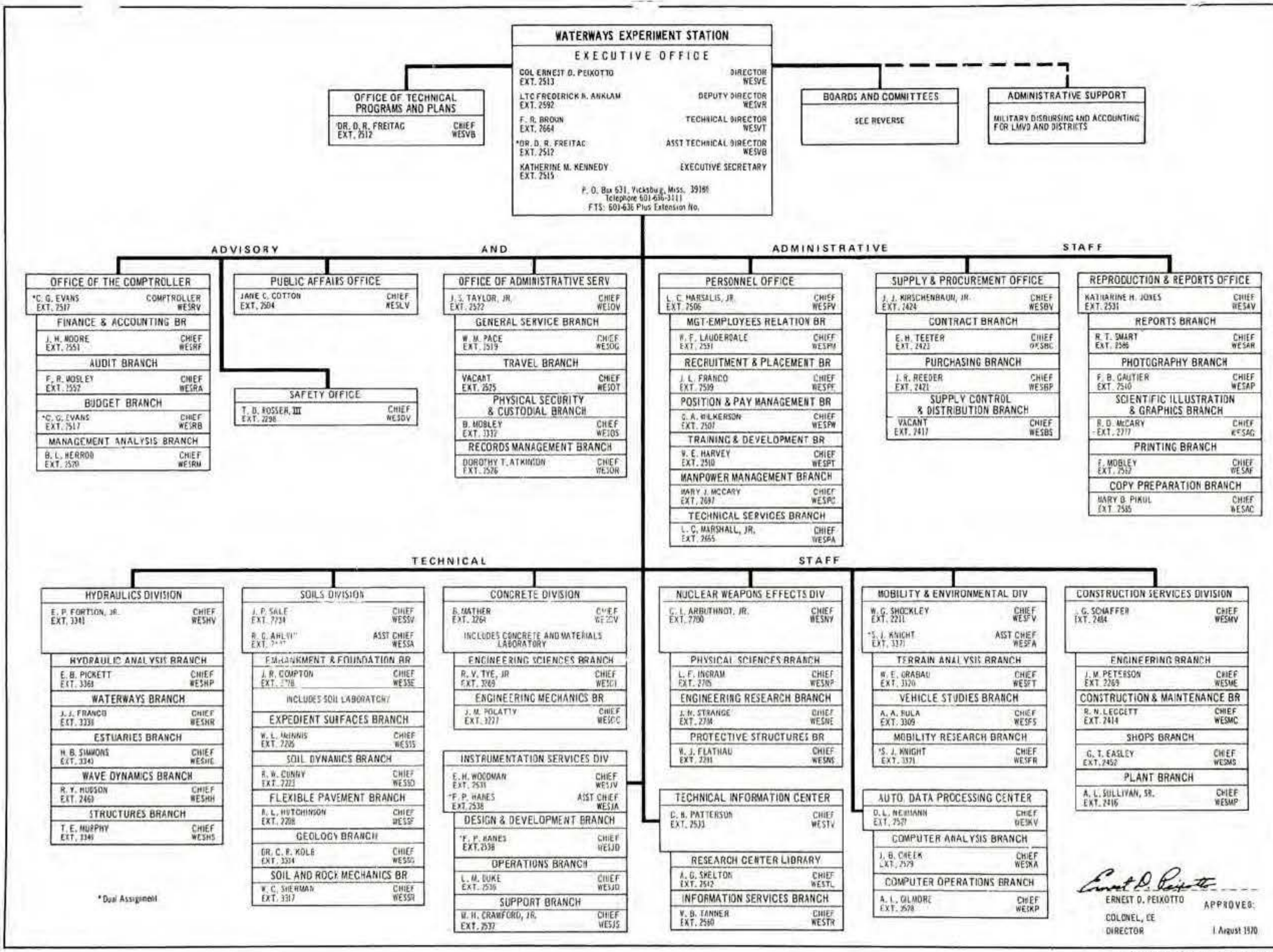

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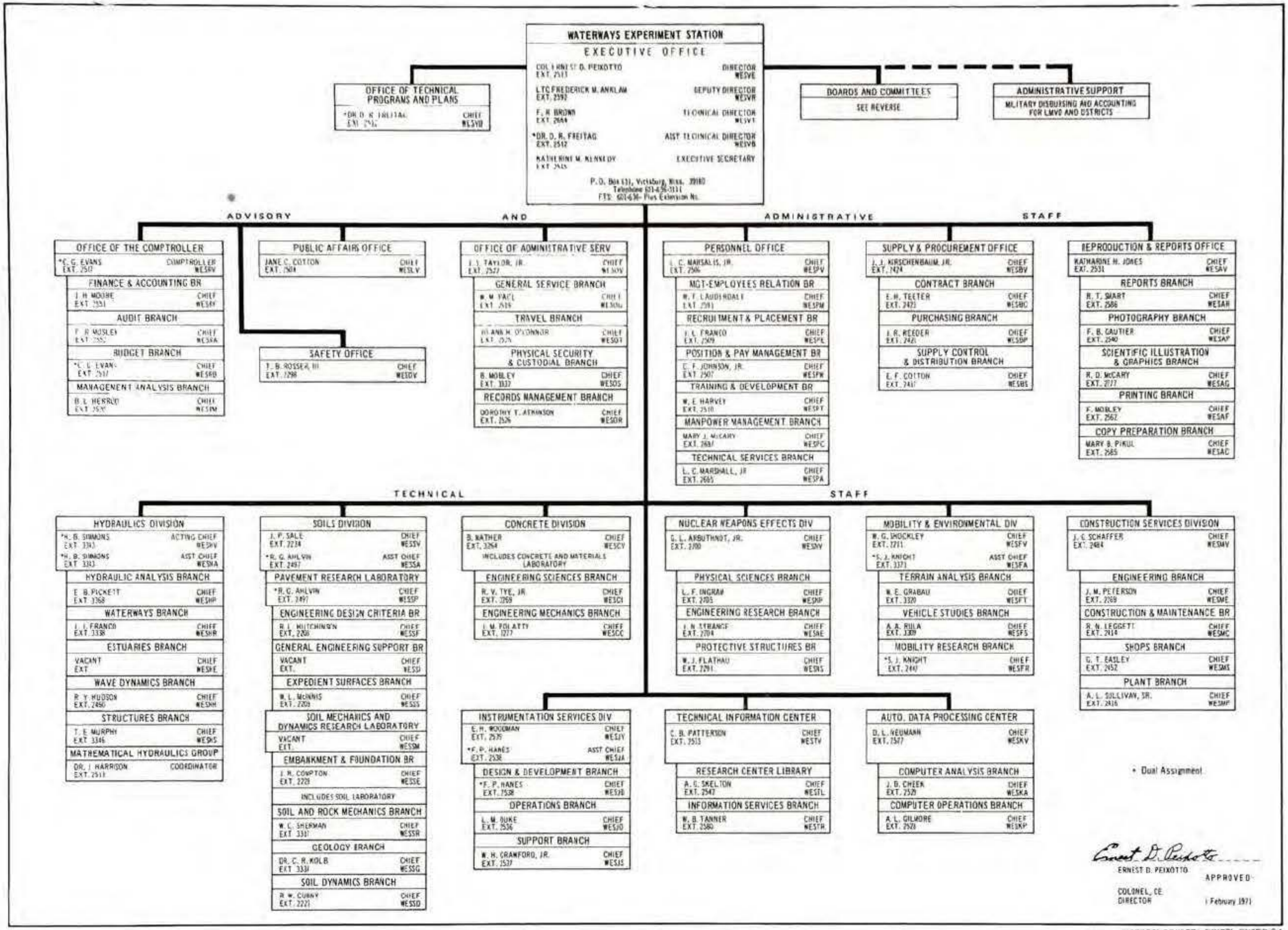

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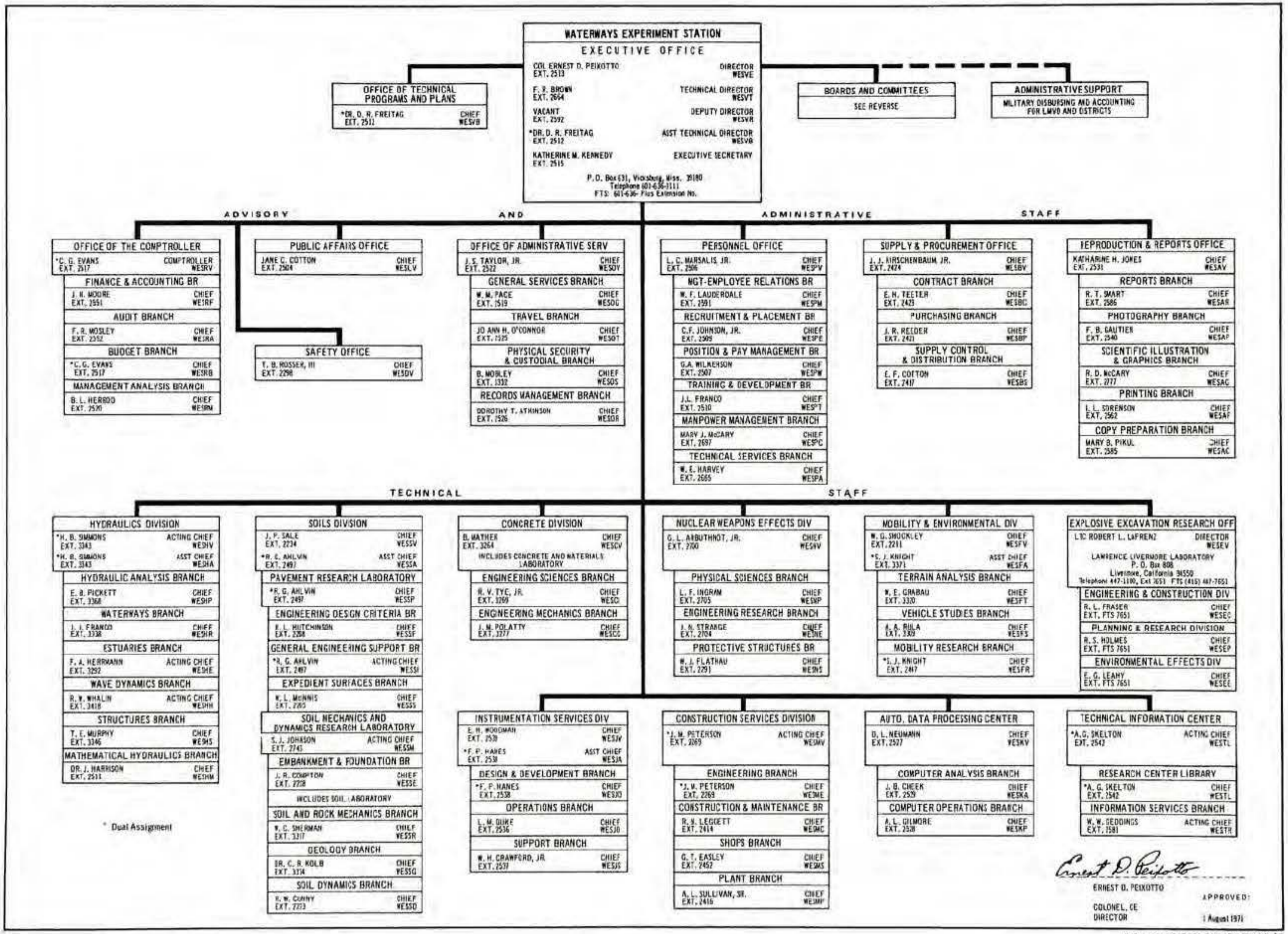

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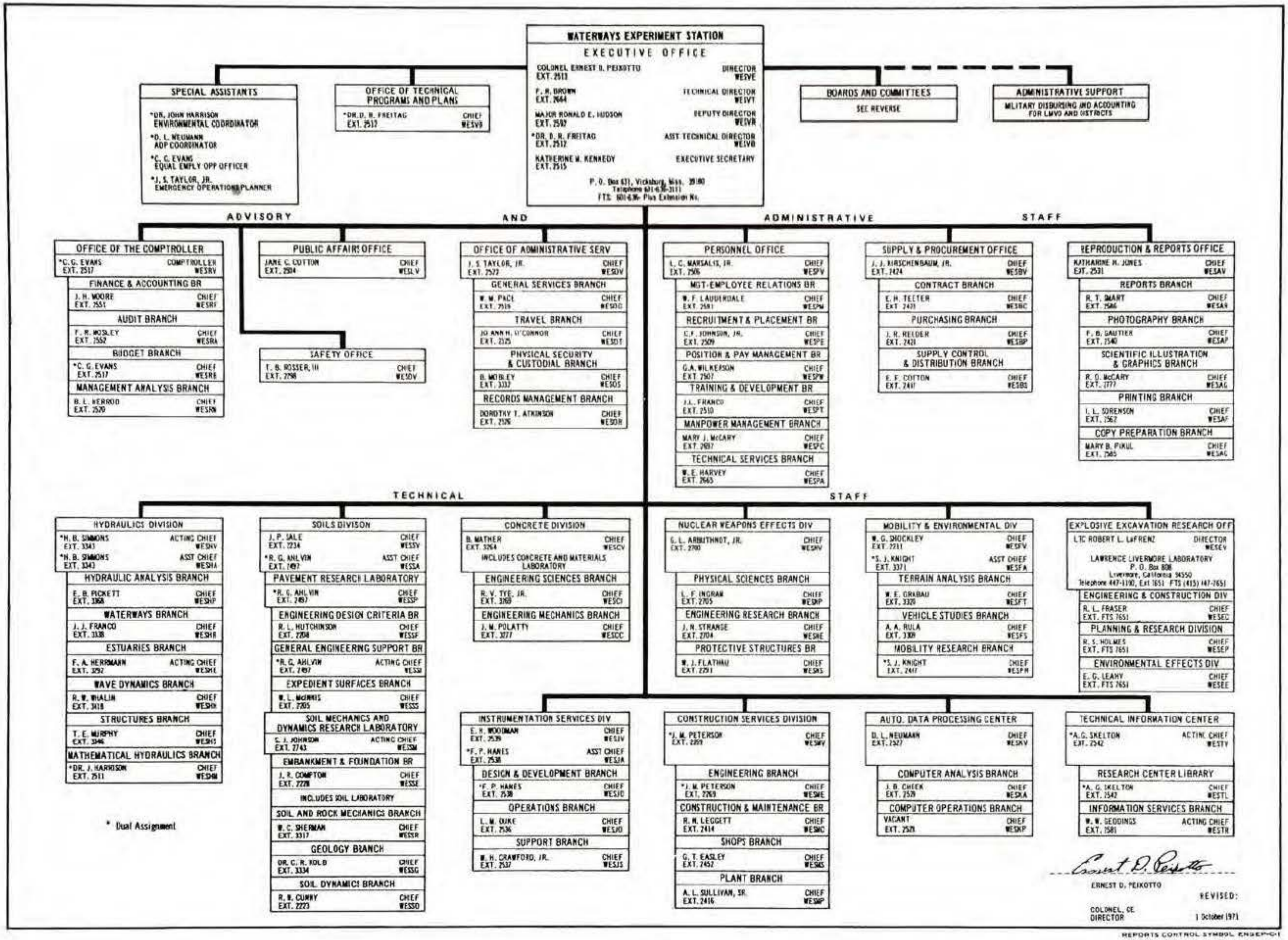
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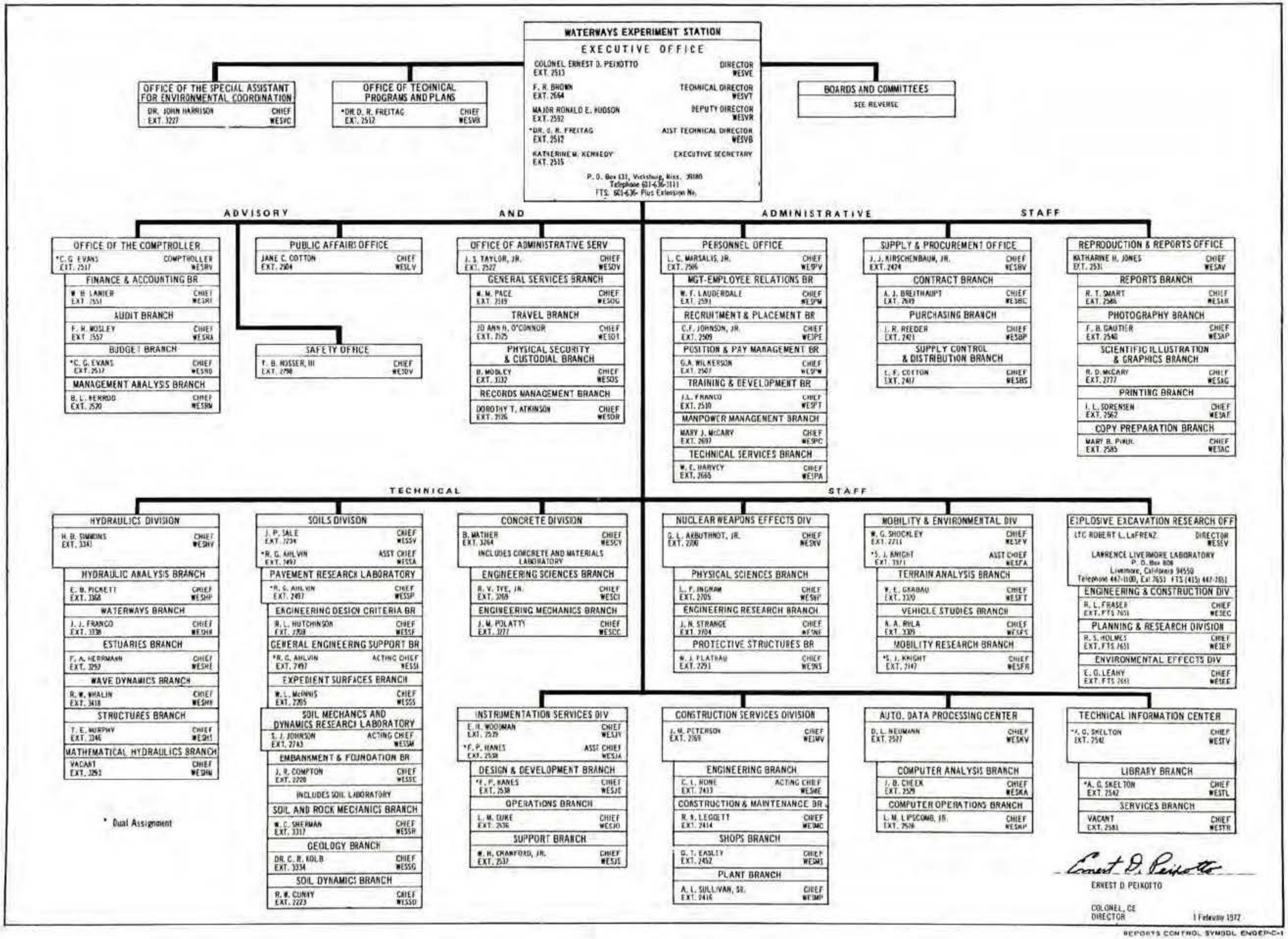

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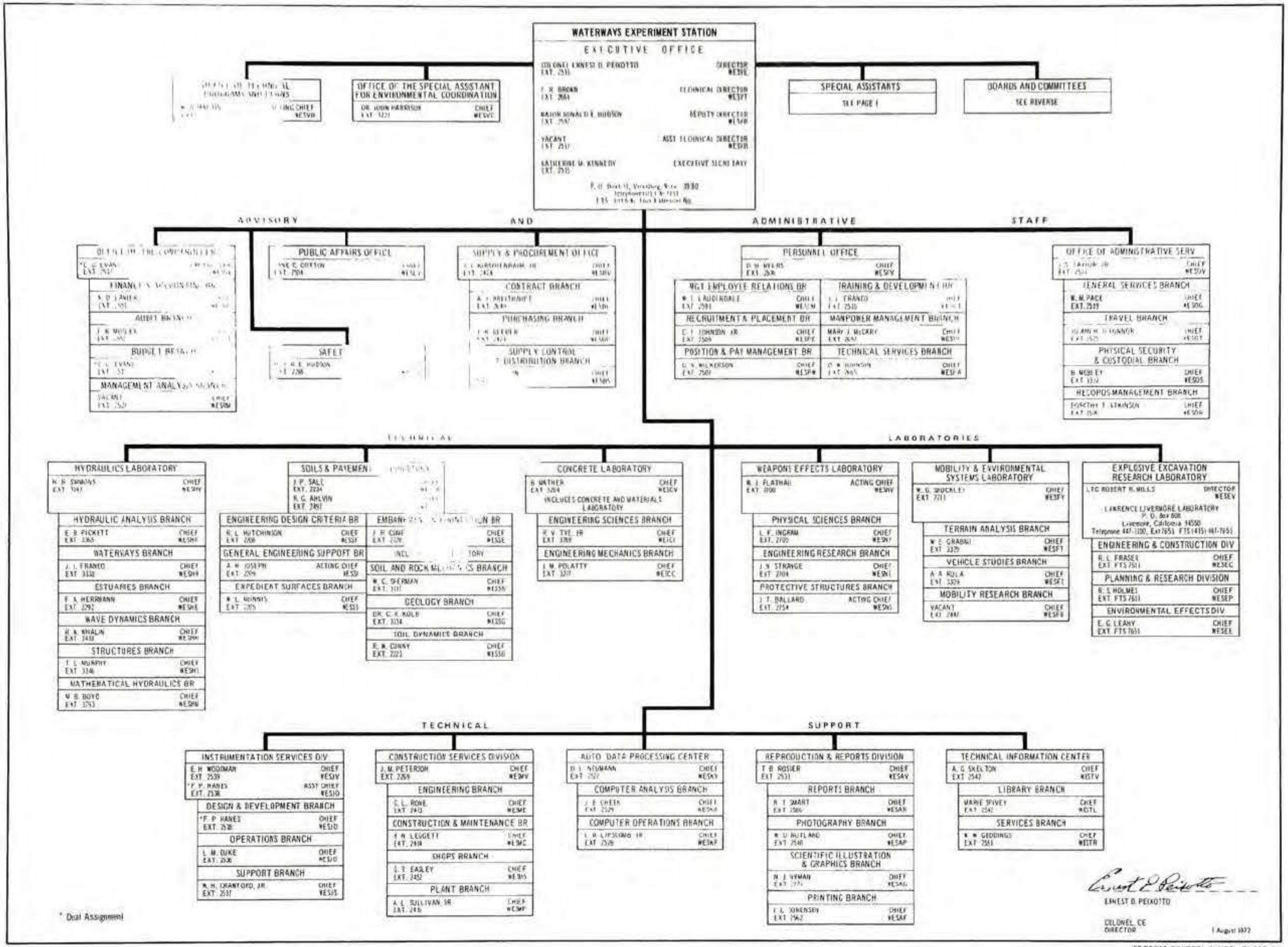

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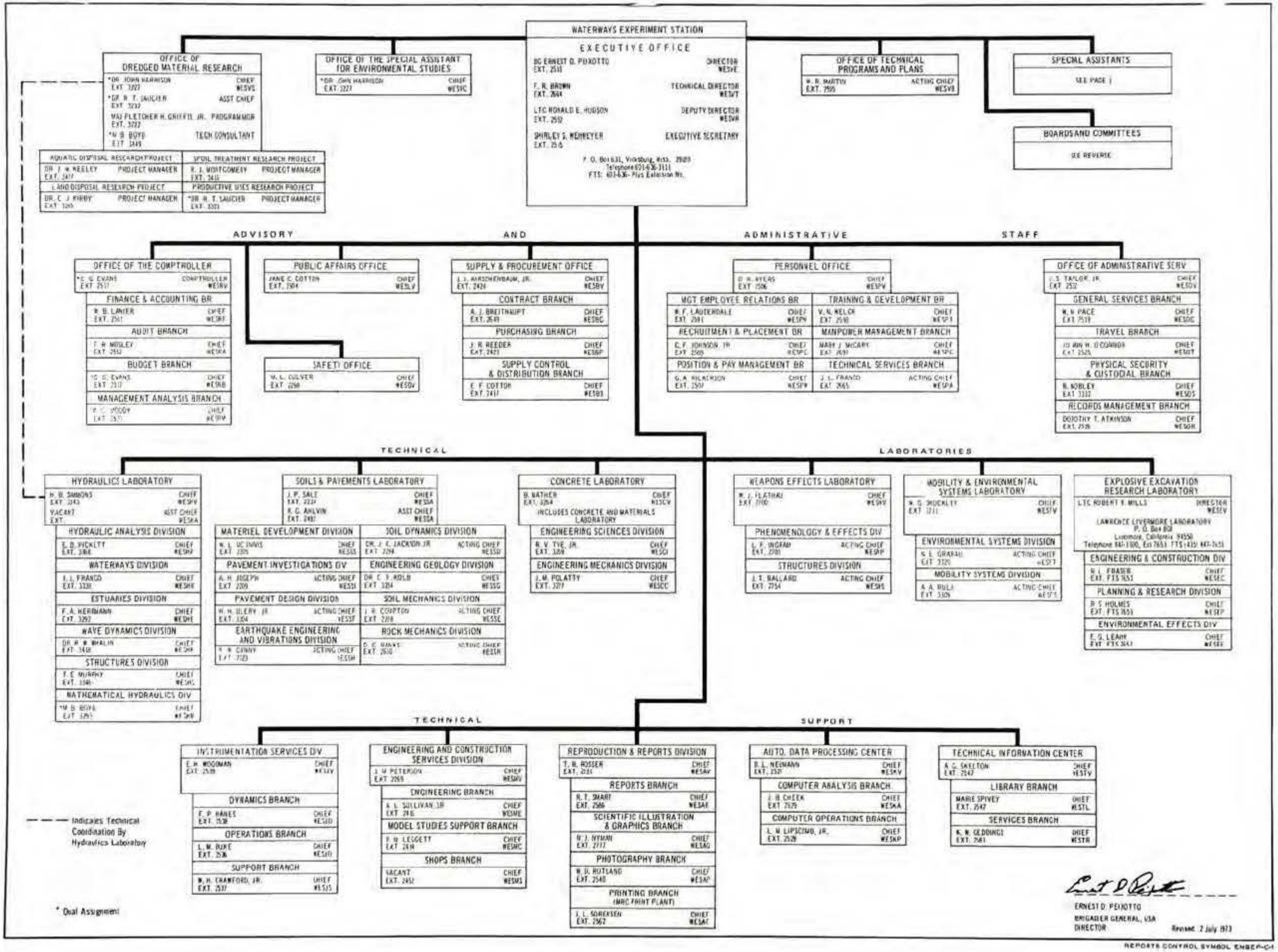

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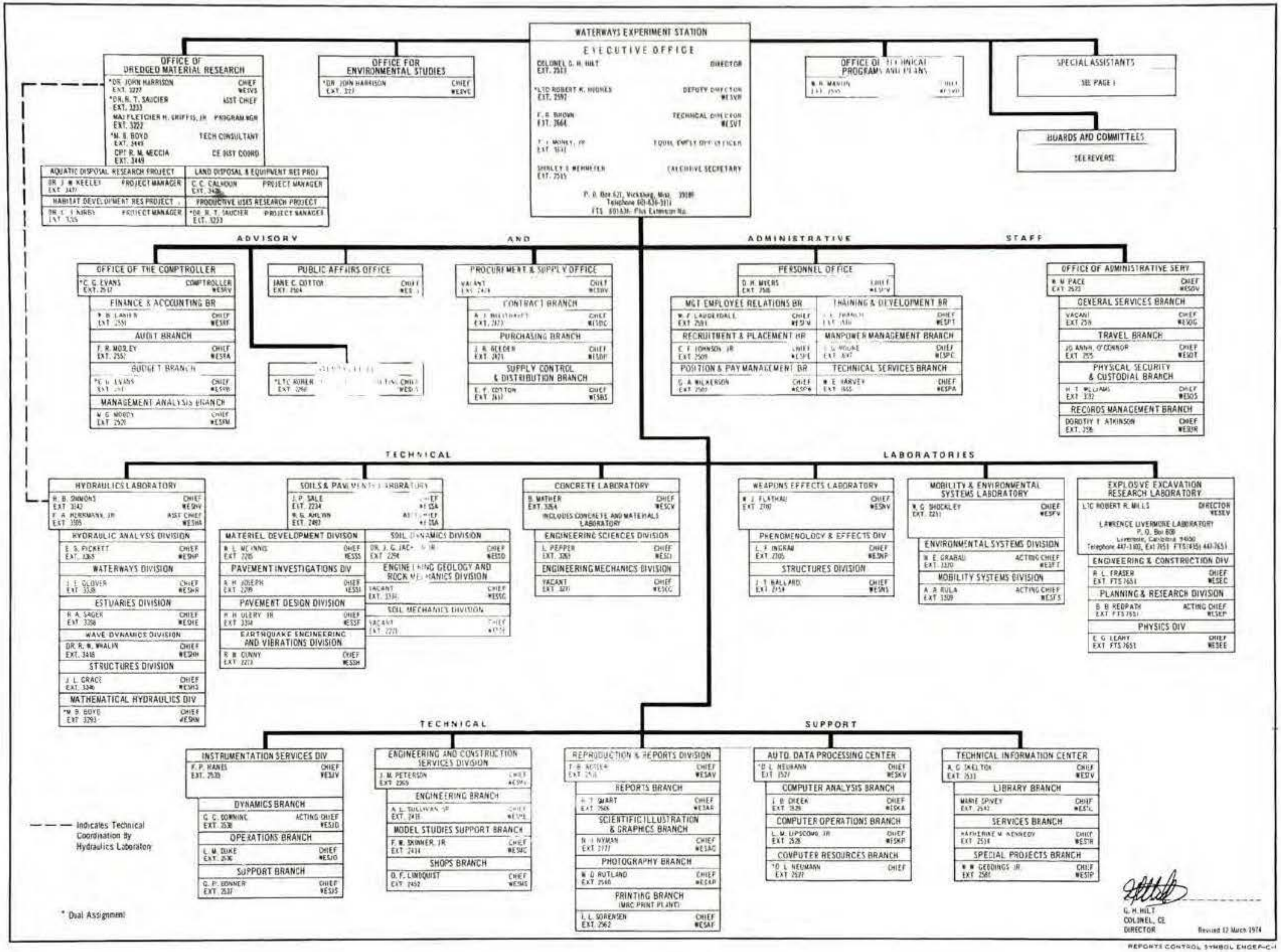

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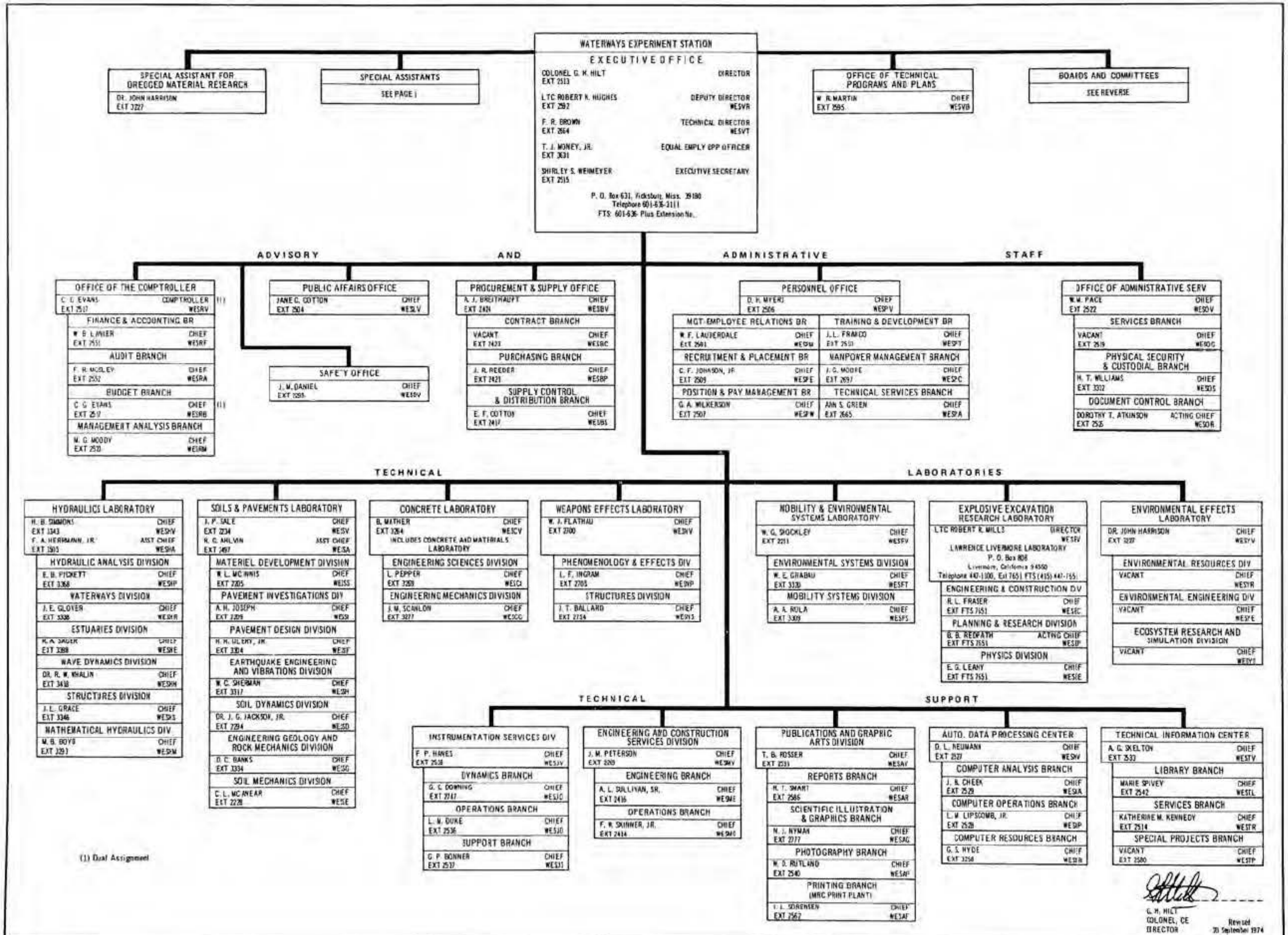

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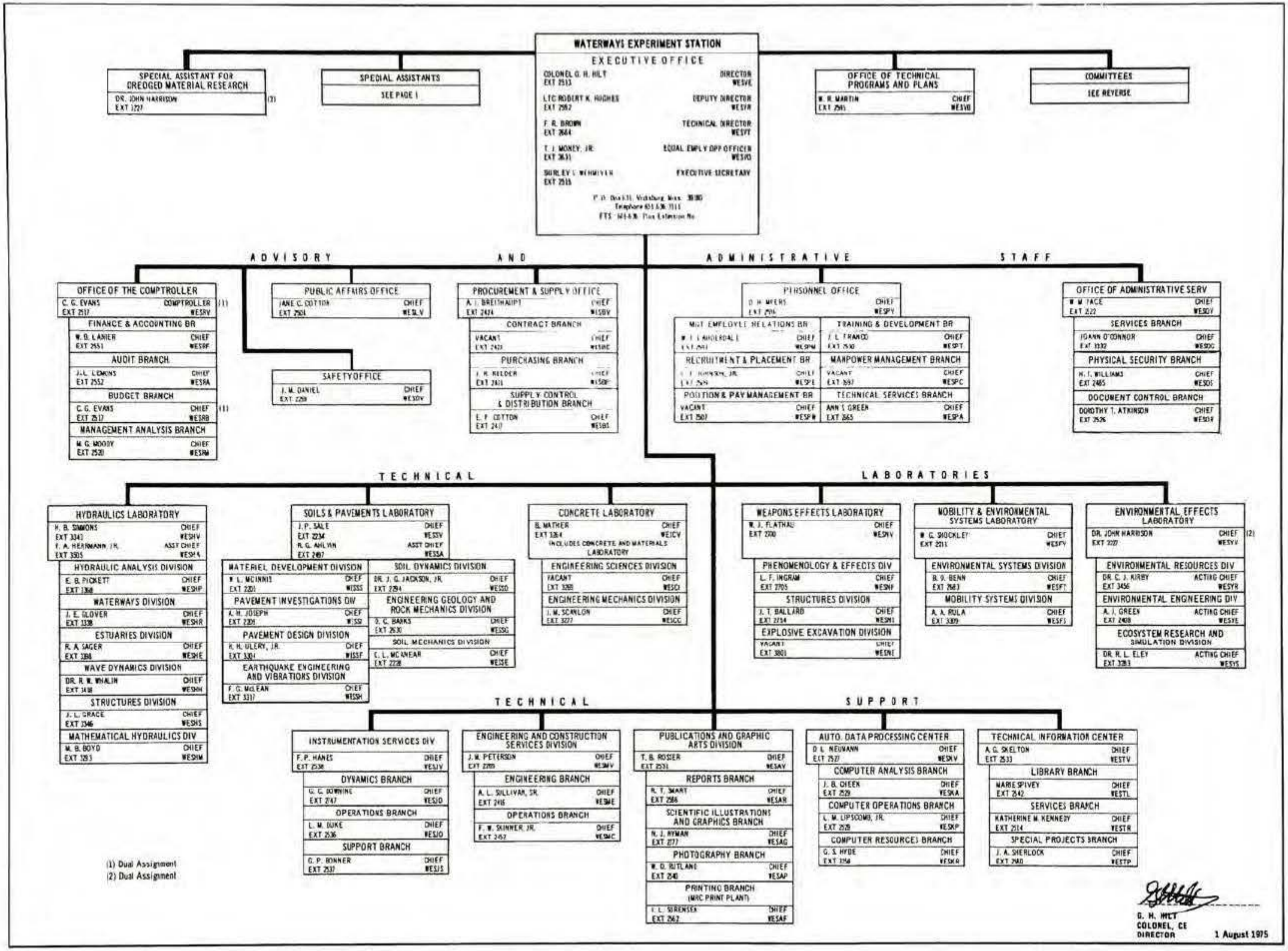
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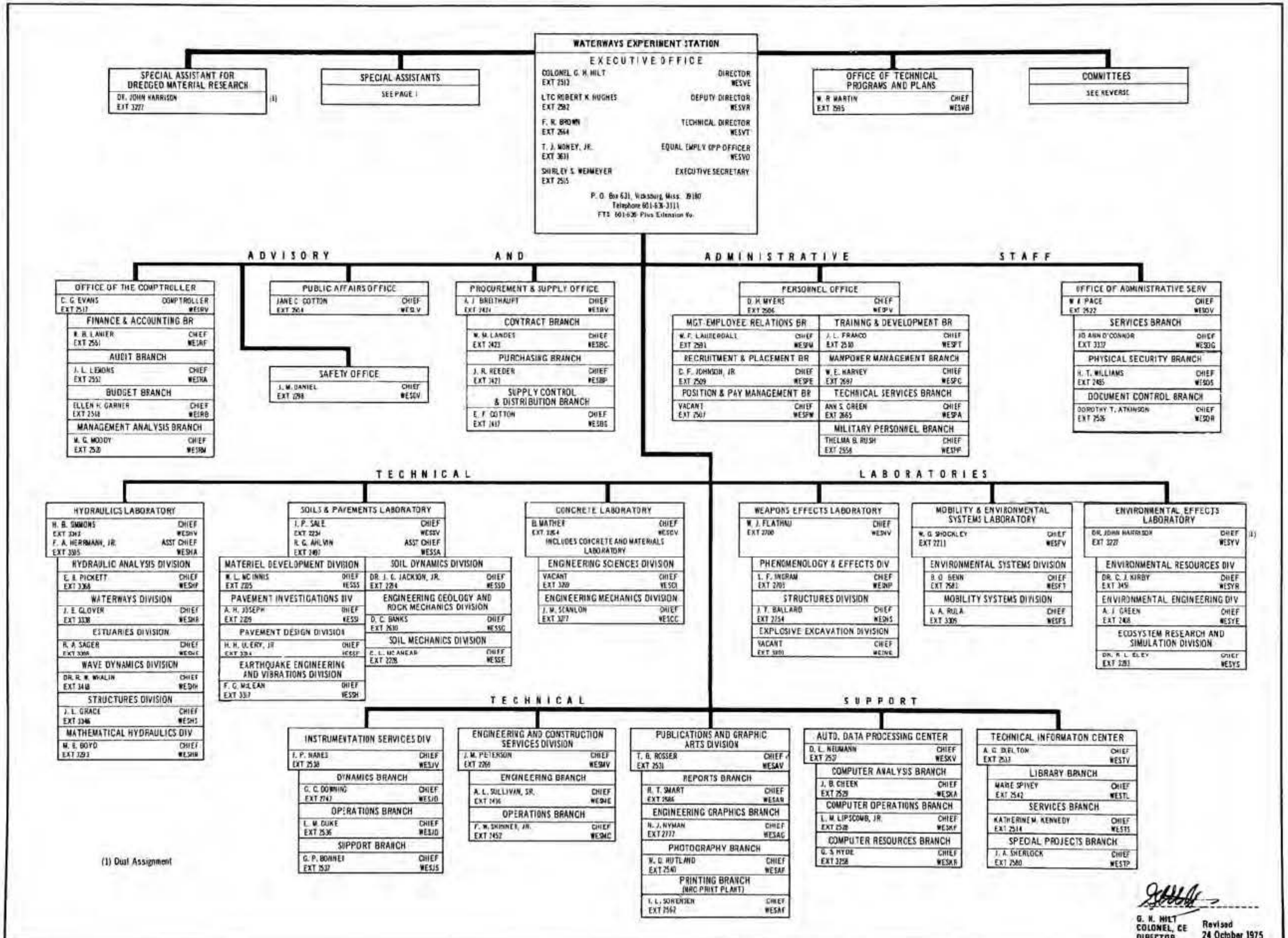
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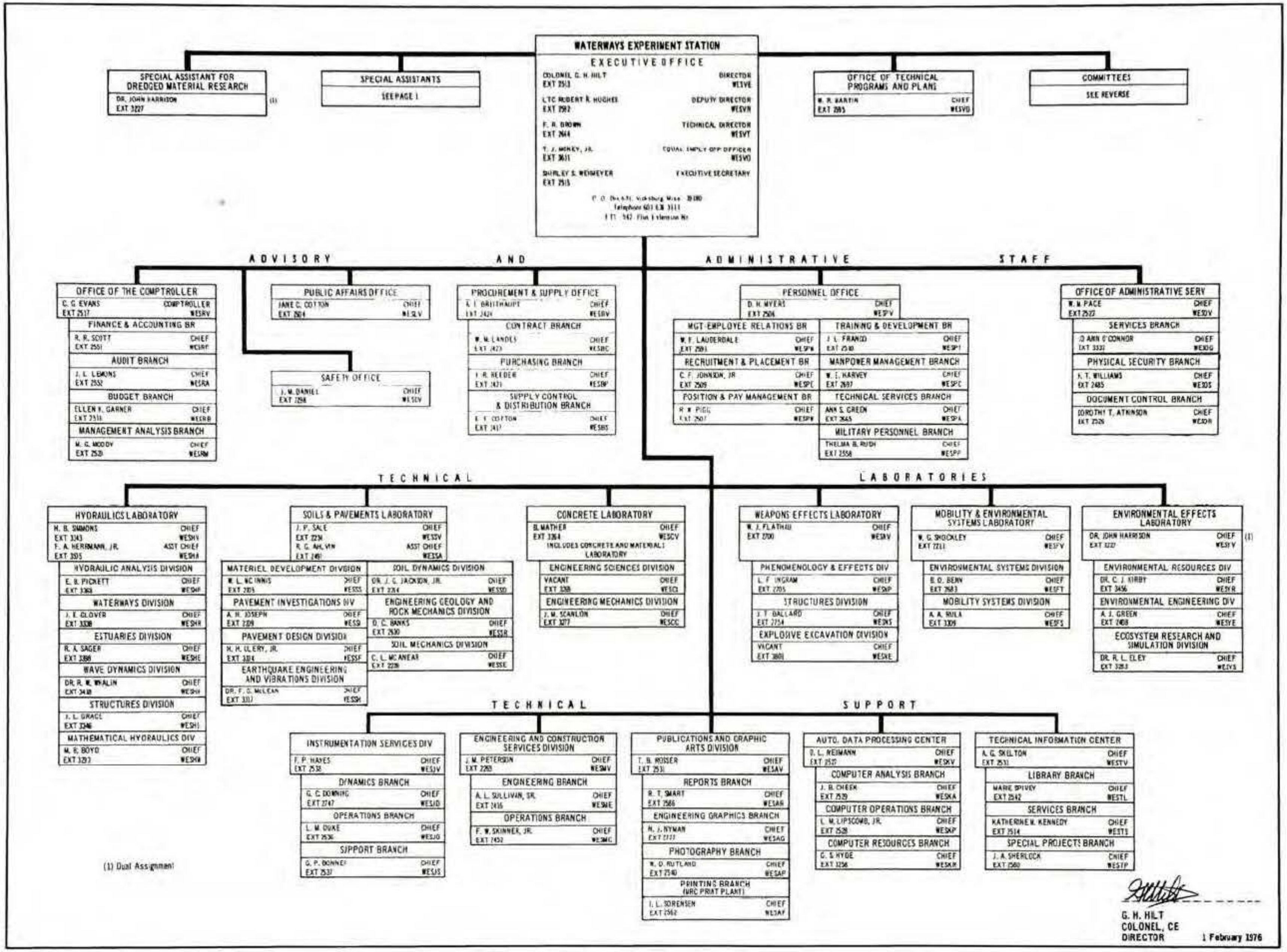
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(1) Dual Assignment
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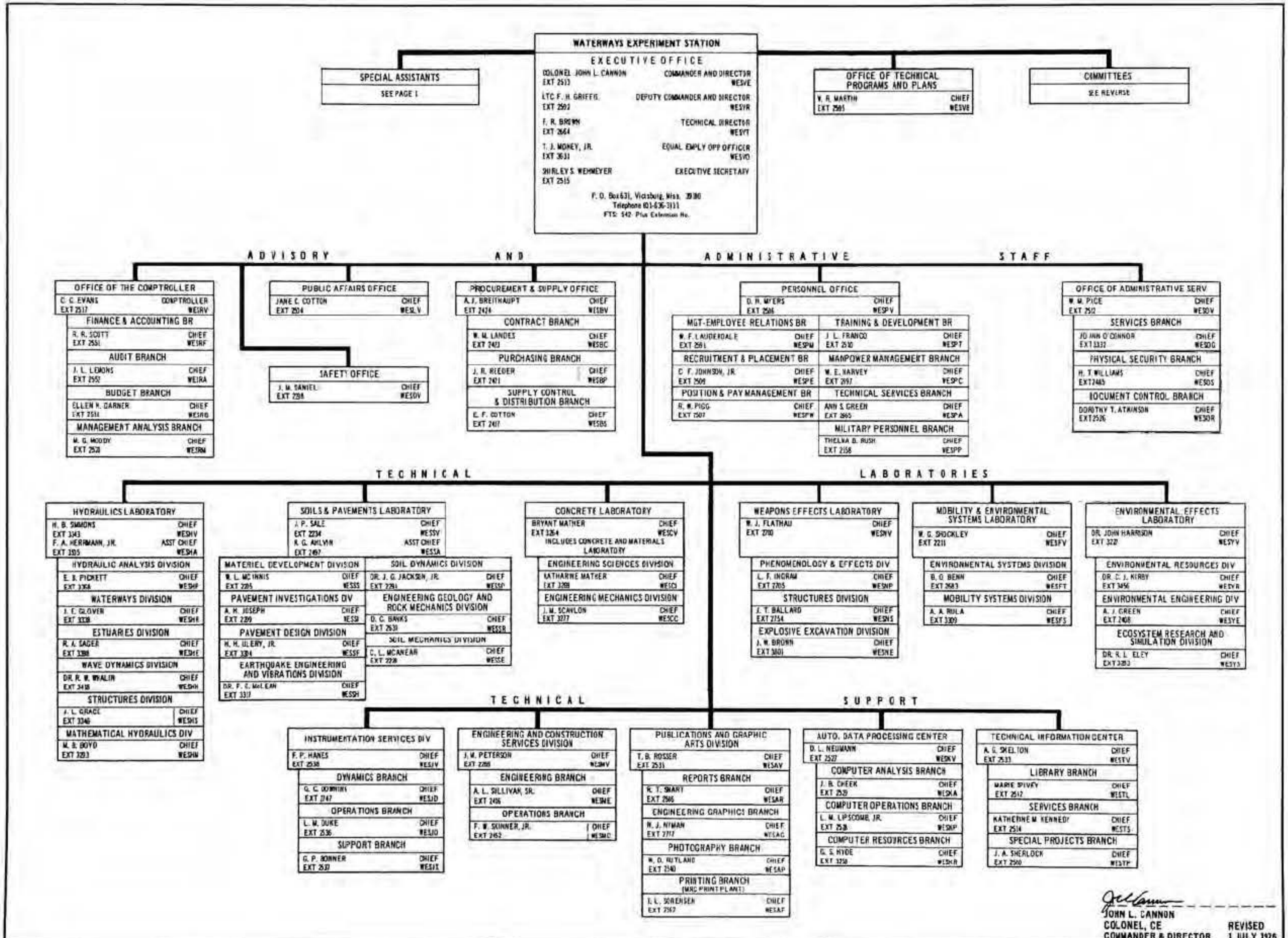
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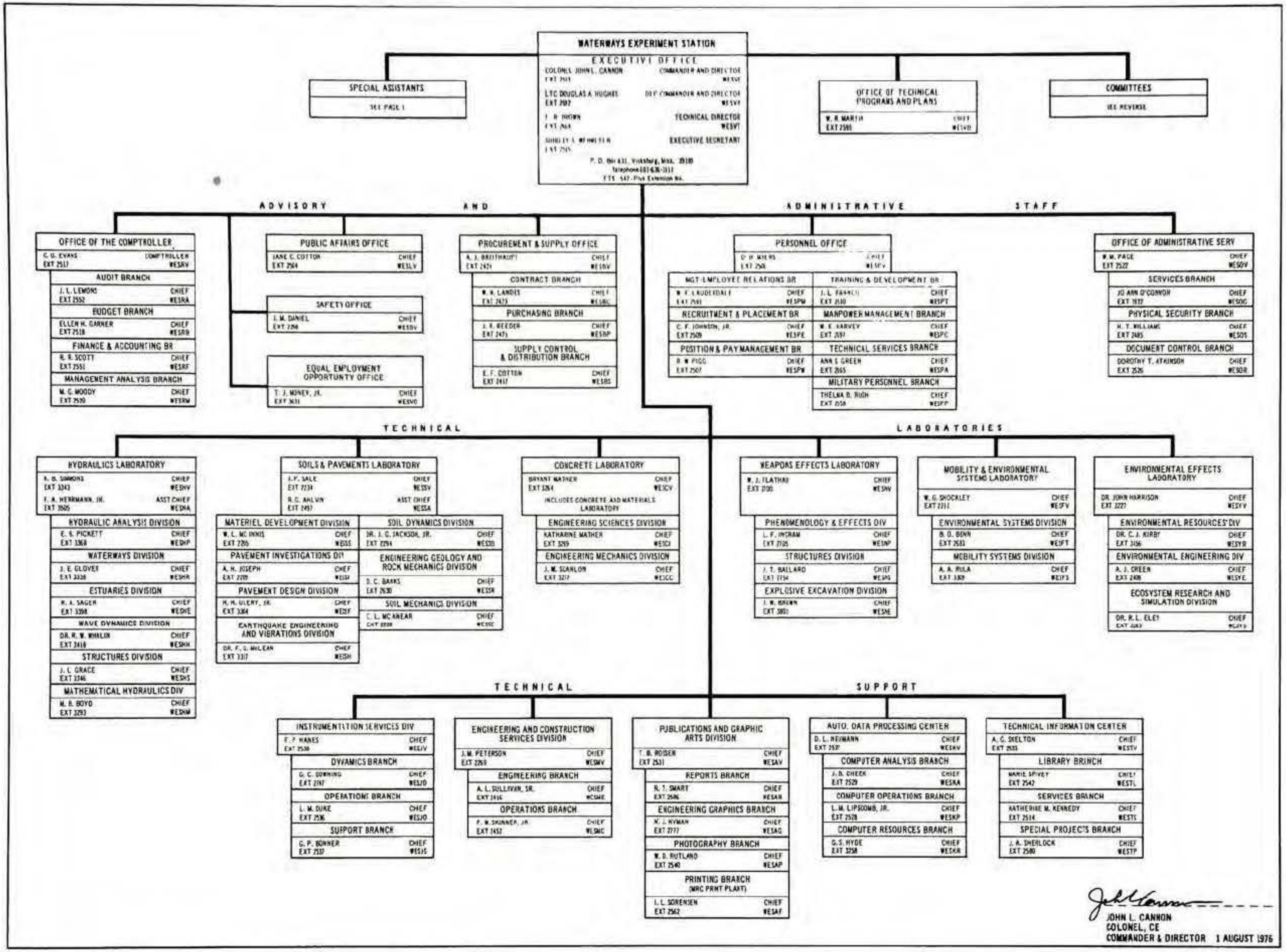
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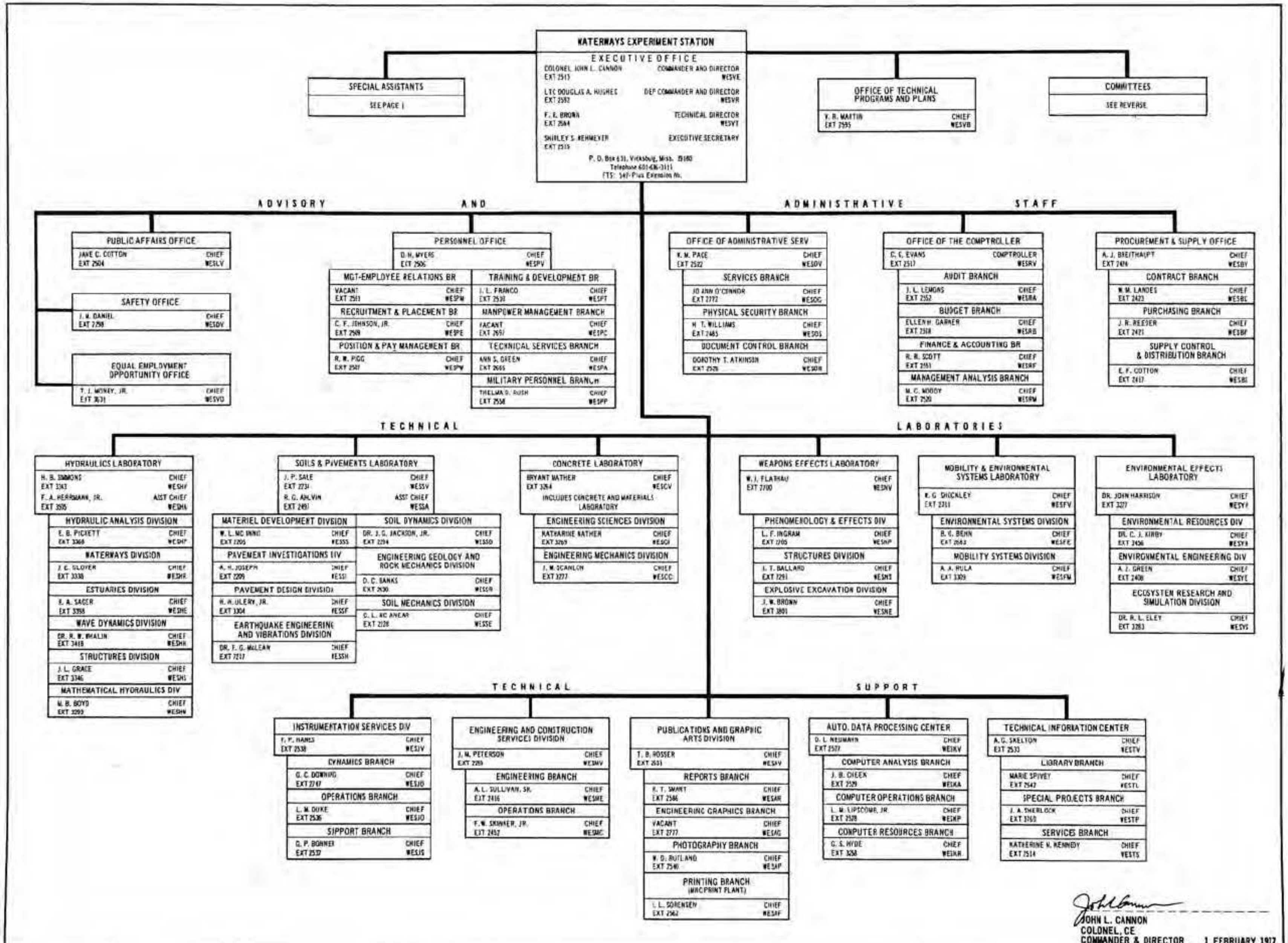

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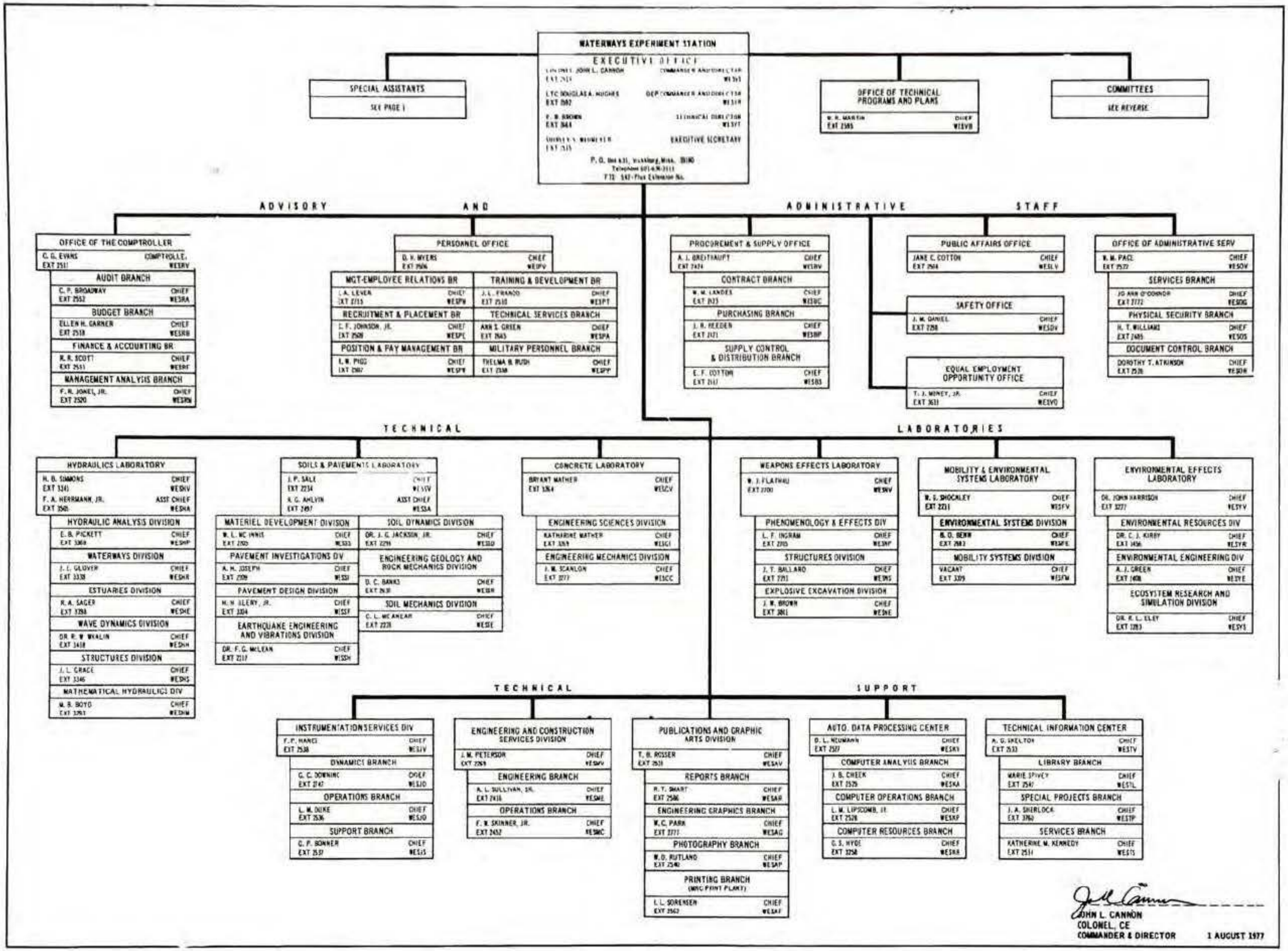

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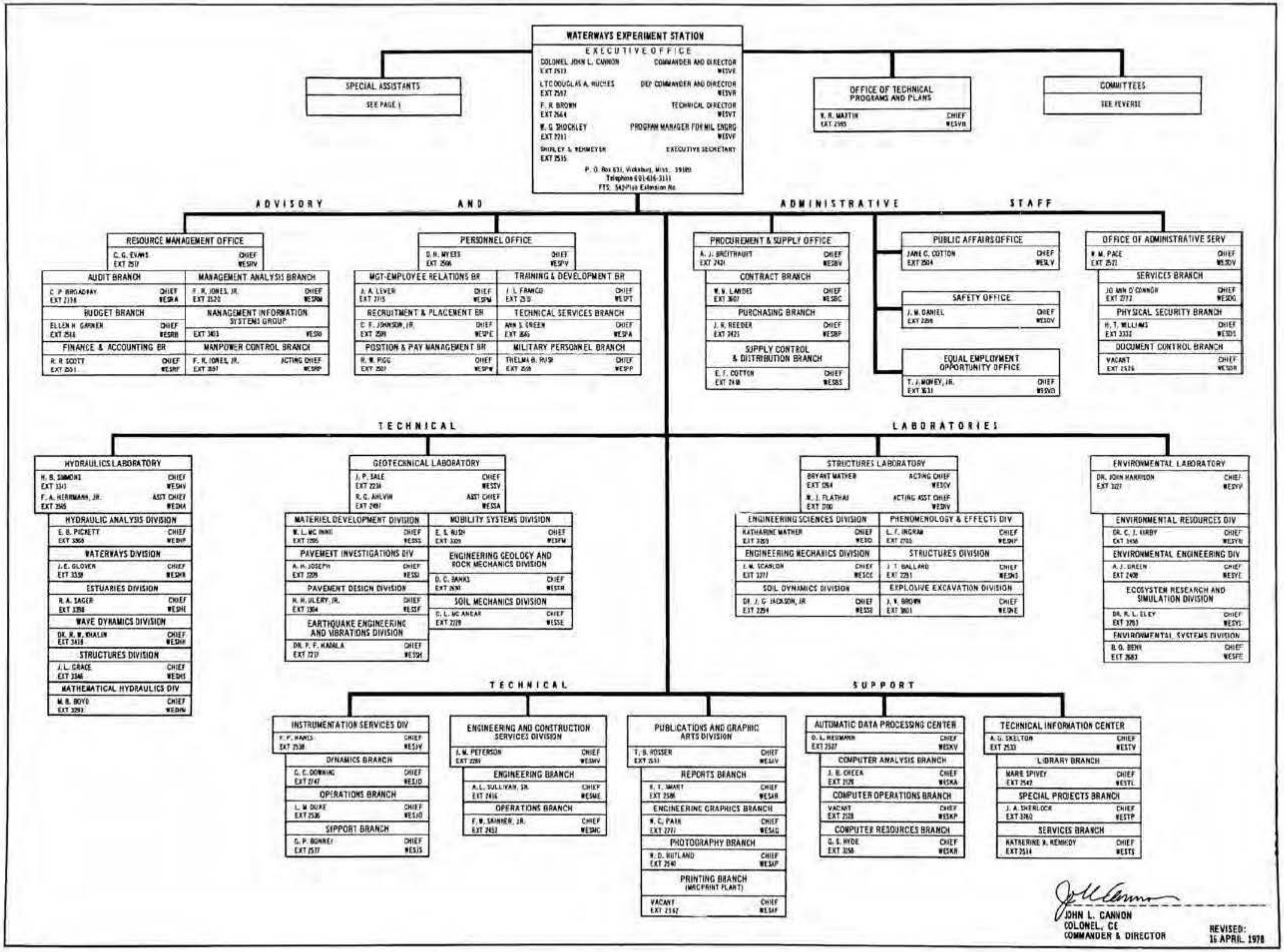

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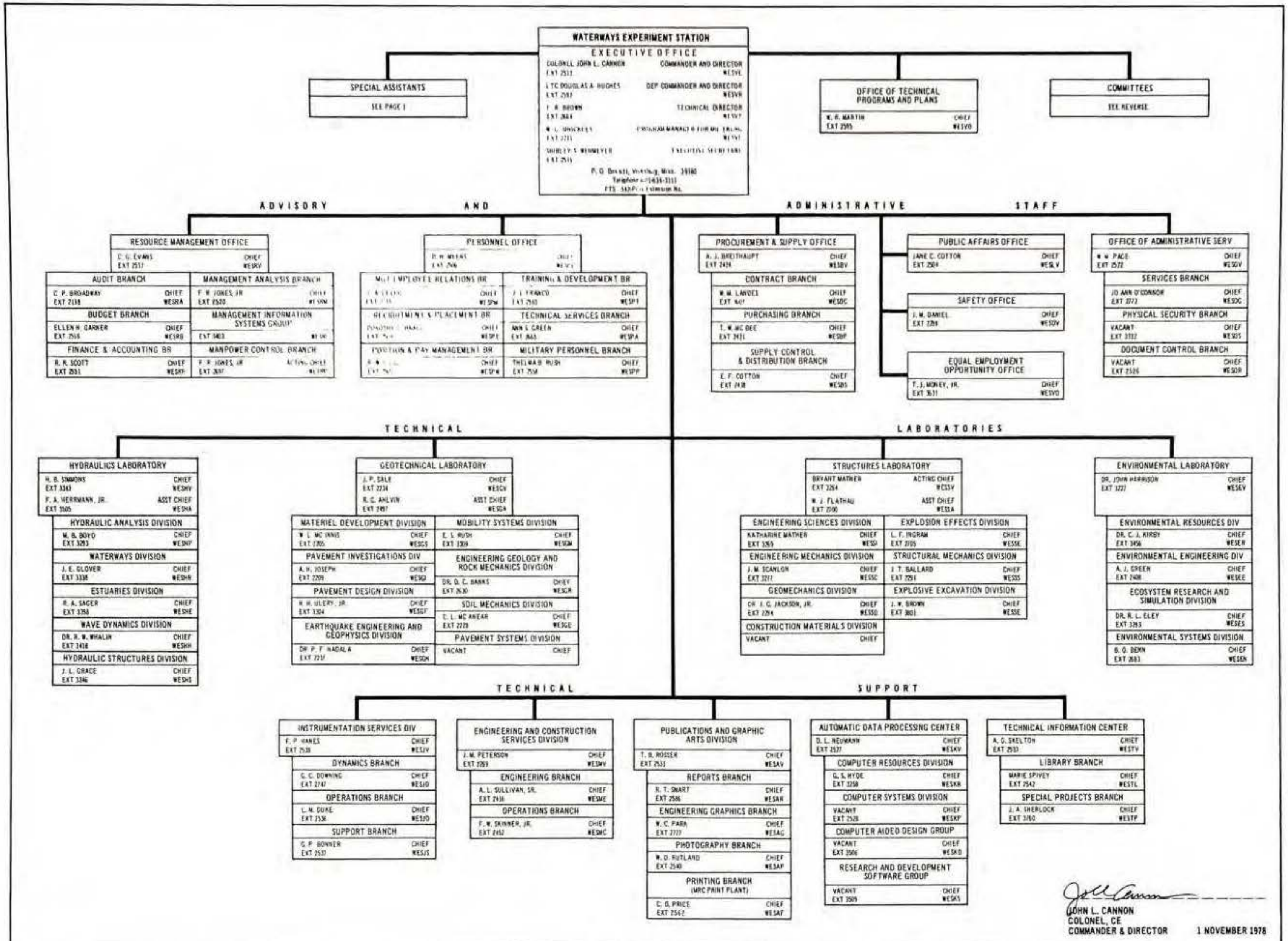

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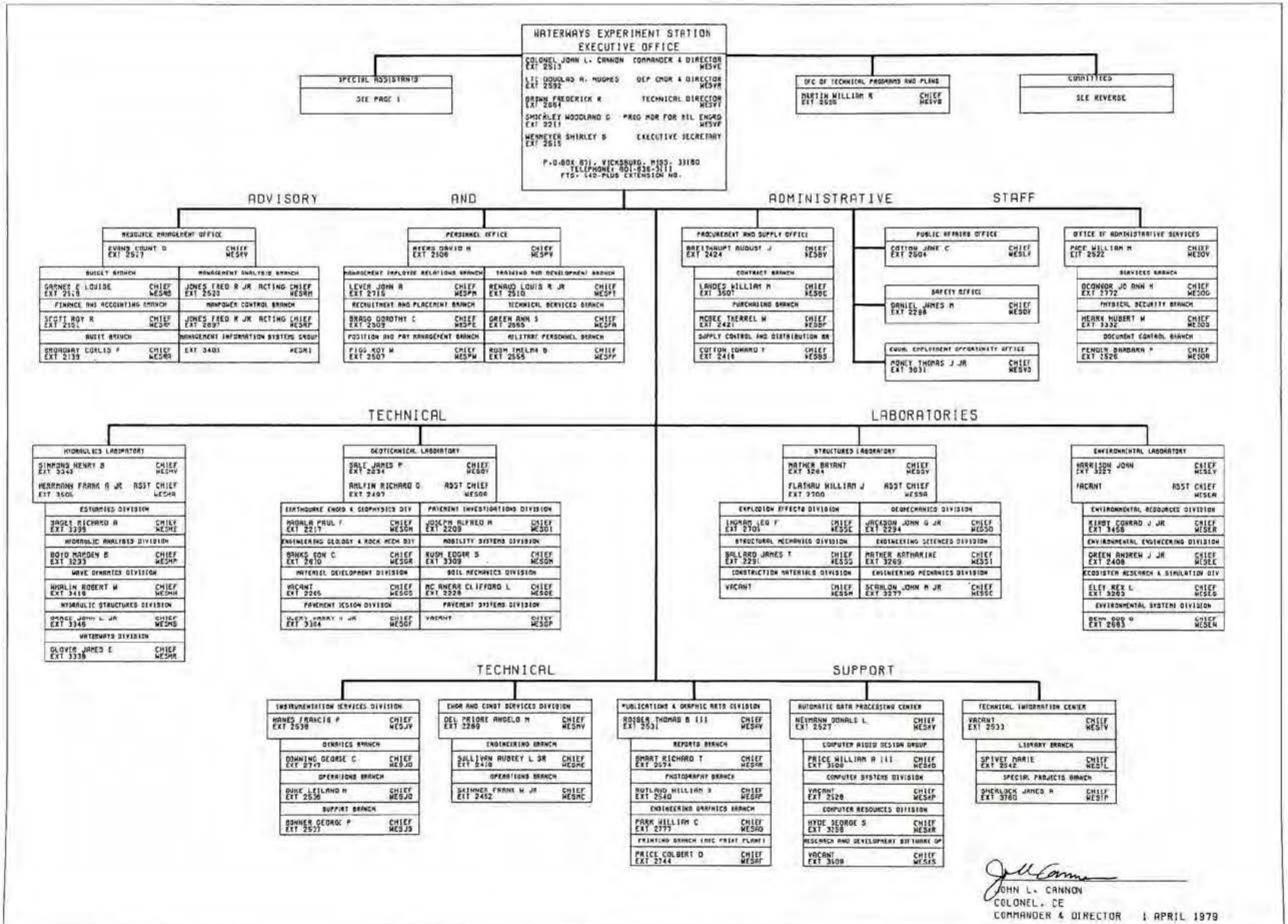

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COMMITTEES
SEE REVERSE
ADVISORY AND ADMINISTRATIVE STAFF
RESOURCE MANAGEMENT OFFICE
EVANS COUNT D CHIEF EXT 2517 WESRV
BUDGET BRANCH
GARNER E LOUISE CHIEF EXT 2518 WESRB
MANAGEMENT ANALYSIS BRANCH
JONES FRED R JR ACTING CHIEF EXT 2520 WESRM
FINANCE AND ACCOUNTING BRANCH
SCOTT ROY R CHIEF EXT 2151 WESRF
MANPOWER CONTROL BRANCH
JONES FRED R JR ACTING CHIEF EXT 2697 WESRP
AUDIT BRANCH
BROADWAY CORLIS F CHIEF EXT 2139 WESRA
MANAGEMENT INFORMATION SYSTEMS GROUP
EXT 3403 WESRI
PERSONNEL OFFICE
MEERS DAVID H CHIEF EXT 2506 WESPV
MANAGEMENT EMPLOYEE RELATIONS BRANCH
LEVER JOHN R CHIEF EXT 2715 WESPM
TRAINING AND DEVELOPMENT BRANCH
RENAUD LOUIS R JR CHIEF EXT 2510 WESPT
RECRUITMENT AND PLACEMENT BRANCH
BRAGG DOROTHY C CHIEF EXT 2509 WESPE
TECHNICAL SERVICES BRANCH
GREEN ANN S CHIEF EXT 2565 WESPA
POSITION AND PAY MANAGEMENT BRANCH
FIGG ROY W CHIEF EXT 2507 WESPW
MILITARY PERSONNEL BRANCH
RUSH THELMA B CHIEF EXT 2555 WESPP
PROCUREMENT AND SUPPLY OFFICE
BREITHAUPT AUGUST J CHIEF EXT 2424 WESBV
CONTRACT BRANCH
LANDES WILLIAM M CHIEF EXT 3607 WESBC
PURCHASING BRANCH
MCBEE THERREL W CHIEF EXT 2421 WESBP
SUPPLY CONTROL AND DISTRIBUTION BR
COTTON EDWARD T CHIEF EXT 2418 WESBS
PUBLIC AFFAIRS OFFICE
COTTON JANE C CHIEF EXT 2504 WESLV
SAFETY OFFICE
DANIEL JAMES M CHIEF EXT 2288 WESOV
EQUAL EMPLOYMENT OPPORTUNITY OFFICE
MONEY THOMAS J JR CHIEF EXT 3031 WESVO
OFFICE OF ADMINISTRATIVE SERVICES
PACE WILLIAM M CHIEF EXT 2522 WESOV
SERVICES BRANCH
OCONNOR JO ANN H CHIEF EXT 2772 WESOG
PHYSICAL SECURITY BRANCH
HEARN HUBERT W CHIEF EXT 3332 WESOS
DOCUMENT CONTROL BRANCH
PENDLEY BARBARA P CHIEF EXT 2526 WESOR
TECHNICAL LABORATORIES
HYDRAULICS LABORATORY
SIMMONS HENRY B CHIEF EXT 3343 WESHV
HERRMANN FRANK A JR ASST CHIEF EXT 3506 WESHA
ESTUARIES DIVISION
SAGER RICHARD A CHIEF EXT 3399 WESHE
HYDRAULIC ANALYSIS DIVISION
BOYD MARDEN B CHIEF EXT 3233 WESHP
WAVE DYNAMICS DIVISION
WHALIN ROBERT W CHIEF EXT 3418 WESHH
HYDRAULIC STRUCTURES DIVISION
GRACE JOHN L JR CHIEF EXT 3346 WESHS
WATERWAYS DIVISION
GLOVER JAMES E CHIEF EXT 3339 WESHR
GEOTECHNICAL LABORATORY
SALE JAMES P CHIEF EXT 2234 WESGV
AHLVIN RICHARD G ASST CHIEF EXT 2497 WESGA
EARTHQUAKE ENGRG & GEOPHYSICS DIV
HADALA PAUL F CHIEF EXT 2217 WESGH
PAVEMENT INVESTIGATIONS DIVISION
JOSEPH ALFRED H CHIEF EXT 2209 WESGI
ENGINEERING GEOLOGY & ROCK MECH DIV
BANKS DON C CHIEF EXT 2610 WESGR
MOBILITY SYSTEMS DIVISION
RUSH EDGAR S CHIEF EXT 3309 WESGM
MATERIEL DEVELOPMENT DIVISION
VACANT CHIEF EXT 2265 WESGS
SOIL MECHANICS DIVISION
MC ANEAR CLIFFORD L CHIEF EXT 2228 WESGE
PAVEMENT DESIGN DIVISION
ULERY HARRY H JR CHIEF EXT 3304 WESGF
PAVEMENT SYSTEMS DIVISION
VACANT CHIEF WESGP
STRUCTURES LABORATORY
MATHER BRYANT CHIEF EXT 3264 WESSV
FLATHAU WILLIAM J ASST CHIEF EXT 2700 WESSA
EXPLOSION EFFECTS DIVISION
INGRAM LEO F CHIEF EXT 2705 WESSE
GEOMECHANICS DIVISION
JACKSON JOHN G JR CHIEF EXT 2294 WESSD
STRUCTURAL MECHANICS DIVISION
BALLARD JAMES T CHIEF EXT 2291 WESSS
ENGINEERING SCIENCES DIVISION
MATHER KATHARINE CHIEF EXT 3269 WESSI
CONSTRUCTION MATERIALS DIVISION
VACANT CHIEF WESSM
ENGINEERING MECHANICS DIVISION
SCANLON JOHN M JR CHIEF EXT 3277 WESSC
ENVIRONMENTAL LABORATORY
HARRISON JOHN CHIEF EXT 3227 WESEV
VACANT ASST CHIEF WESEA
ENVIRONMENTAL RESOURCES DIVISION
KIRBY CONRAD J JR CHIEF EXT 3456 WESER
ENVIRONMENTAL ENGINEERING DIVISION
GREEN ANDREW J JR CHIEF EXT 2408 WESEE
ECOSYSTEM RESEARCH & SIMULATION DIV
ELEY REX L CHIEF EXT 3263 WESES
ENVIRONMENTAL SYSTEMS DIVISION
BENN BOB O CHIEF EXT 2683 WESEN
TECHNICAL SUPPORT
INSTRUMENTATION SERVICES DIVISION
HANES FRANCIS P CHIEF EXT 2539 WESJV
DYNAMICS BRANCH
DOWNING GEORGE C CHIEF EXT 2747 WESJD
OPERATIONS BRANCH
DUKE LEILAND M CHIEF EXT 2536 WESJO
SUPPORT BRANCH
BONNER GEORGE P CHIEF EXT 2537 WESJS
ENGR AND CONST SERVICES DIVISION
DEL PRIORE ANGELO M CHIEF EXT 2289 WESMV
ENGINEERING BRANCH
SULLIVAN AUBREY L SR CHIEF EXT 2410 WESME
OPERATIONS BRANCH
SKINNER FRANK W JR CHIEF EXT 2452 WESMC
PUBLICATIONS & GRAPHIC ARTS DIVISION
ROSSER THOMAS B III CHIEF EXT 2531 WESAV
REPORTS BRANCH
SMART RICHARD T CHIEF EXT 2574 WESAR
PHOTOGRAPHY BRANCH
RUTLAND WILLIAM S CHIEF EXT 2540 WESAP
ENGINEERING GRAPHICS BRANCH
PARK WILLIAM C CHIEF EXT 2777 WESAG
PRINTING BRANCH (INC PRINT PLANT)
PRICE COLBERT D CHIEF EXT 2744 WESAT
AUTOMATIC DATA PROCESSING CENTER
NEUMANN DONALD L CHIEF EXT 2527 WESKV
COMPUTER AIDED DESIGN GROUP
PRICE WILLIAM A III CHIEF EXT 3600 WESKD
COMPUTER SYSTEMS DIVISION
VACANT CHIEF EXT 2528 WESKP
COMPUTER RESOURCES DIVISION
HYDE GEORGE S CHIEF EXT 3258 WESKR
RESEARCH AND DEVELOPMENT SOFTWARE GP
VACANT CHIEF EXT 3509 WESKS
TECHNICAL INFORMATION CENTER
VACANT CHIEF EXT 2533 WESTV
LIBRARY BRANCH
SPIVEY MARIE CHIEF EXT 2542 WESTL
SPECIAL PROJECTS BRANCH
SHERLOCK JAMES A CHIEF EXT 3780 WESTP
JOHN L. CANNON
COLONEL, CE
COMMANDER & DIRECTOR 1 APRIL 1979

1 April 1979

APPENDIX II

WES TECHNICAL SUPPORT AND ADMINISTRATIVE SUPPORT ORGANIZATIONS

WES SAFETY PROGRAM

The WES Safety Program is very broad and flexible in order to meet the needs of the Station's diverse mission. Because of the many changing activities of the WES, a wide variety of hazards are encountered, including explosive testing, mobility equipment testing, tests using nuclear equipment and other radiation-producing devices, construction and shop operations, motor vehicle operations, etc. To combat these hazards, safety is made an integral part of each operation. The effectiveness of the Safety Program is evidenced by the fact that WES received Awards of Merit for Safety from the Chief of Engineers for five consecutive years.

Protective masks prevent inhalation of noxious vapors

Fire extinguisher demonstration

ENGINEERING AND CONSTRUCTION SERVICES DIVISION

The Engineering and Construction Services Division provides engineering, construction, model building, maintenance, and operations support to WES. This work is accomplished by both in-house labor and by contract. For administering its support services, the Division has a professional staff of engineers and technicians and a shop facility highly specialized for fabrication and construction of models and complex equipment for laboratory and field projects.

Engineering and Construction Services Division electricians check the insulation value of wiring in the power substation for WES' new Advanced Scientific Computer

Construction of the automated Water Resources Demonstration Model in the E&CSD shops

Pipe fitter working on the Pumping Station Research Facility

E&CSD support in bomb crater repair tests

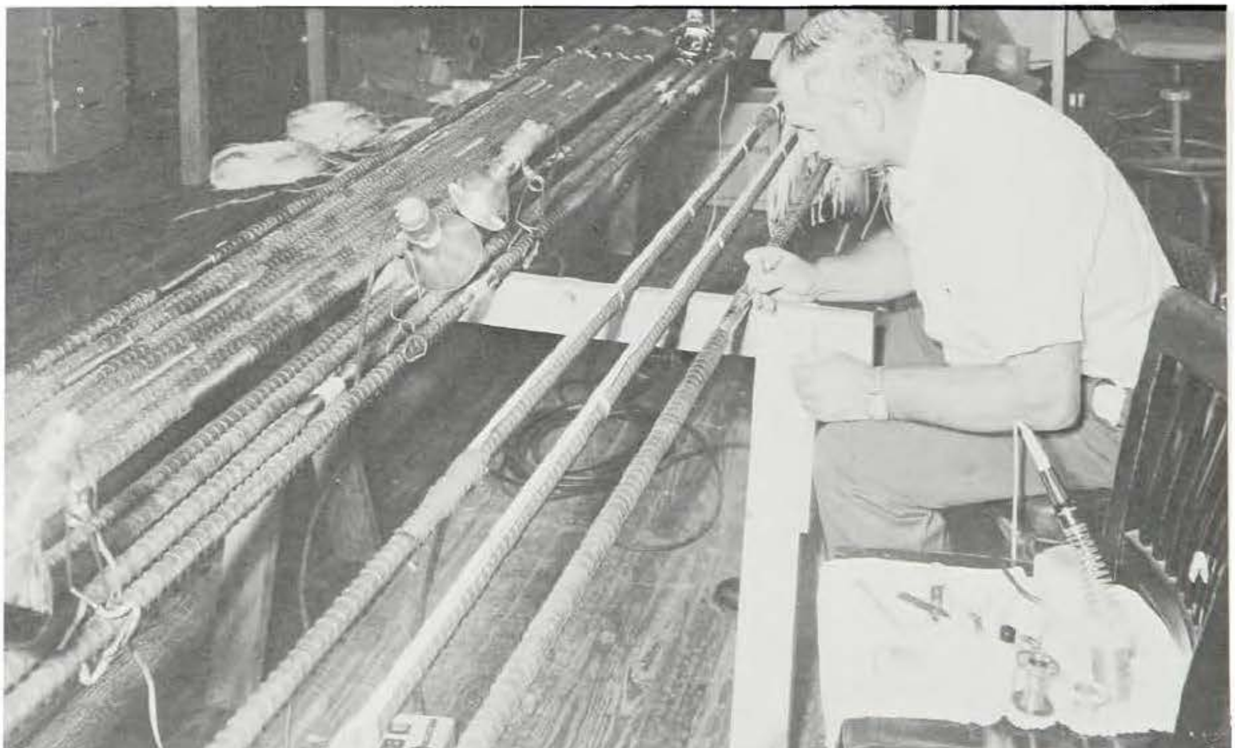
Construction of McAlpine Locks & Dam Model, Ohio River. Skilled model makers use metal templates cut to the proper scaled elevation to duplicate nature. Concrete is placed between the templates and molded to their contours to form the model surface

INSTRUMENTATION SERVICES DIVISION

Instrumentation capabilities are provided for all WES research activities through the Instrumentation Services Division. Combined efforts of the engineers, scientists, and technicians of the Division provide a wide range of skills and experience, and provide the capacity for conception, design, construction, calibration, installation, operation, and maintenance of a variety of instruments and instrumentation systems. Central facilities for specification and requisition of instrumentation hardware and for analog to digital conversion of recorded data in preparation for data processing in the WES computer facility are provided, as well as consultant services for the various WES laboratories and other Government agencies.

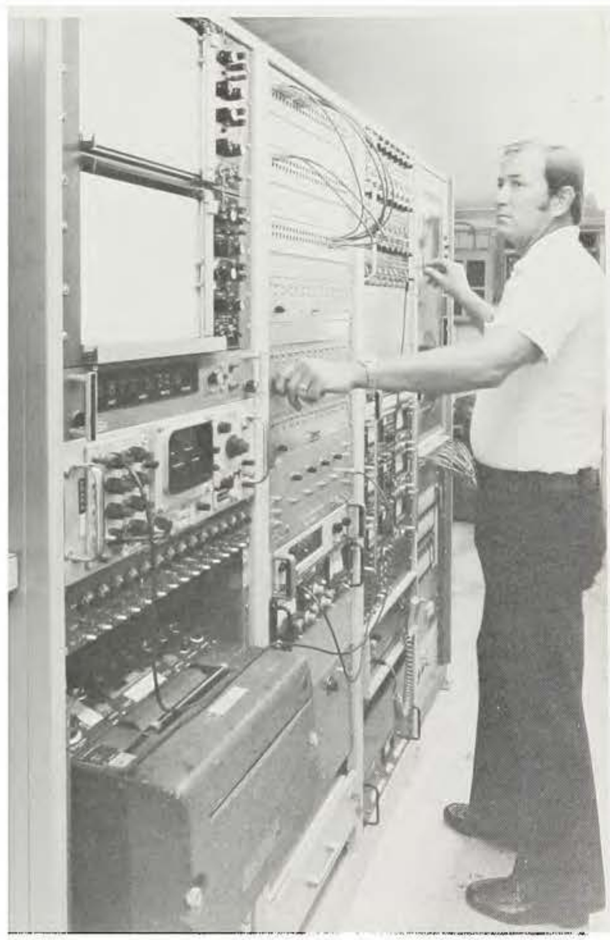
Electronics engineer at the control panel of a model pumping station research facility

Instrumentation testing of dowel joint performance in airport pavements



Instrumentation technician installing strain gages on reinforcing bars for use in a Federal Highway Administration roadway pile test in California

Instrumentation technician operating equipment used to control wave height, period, and phase of waves produced by a 14-section water wave generator

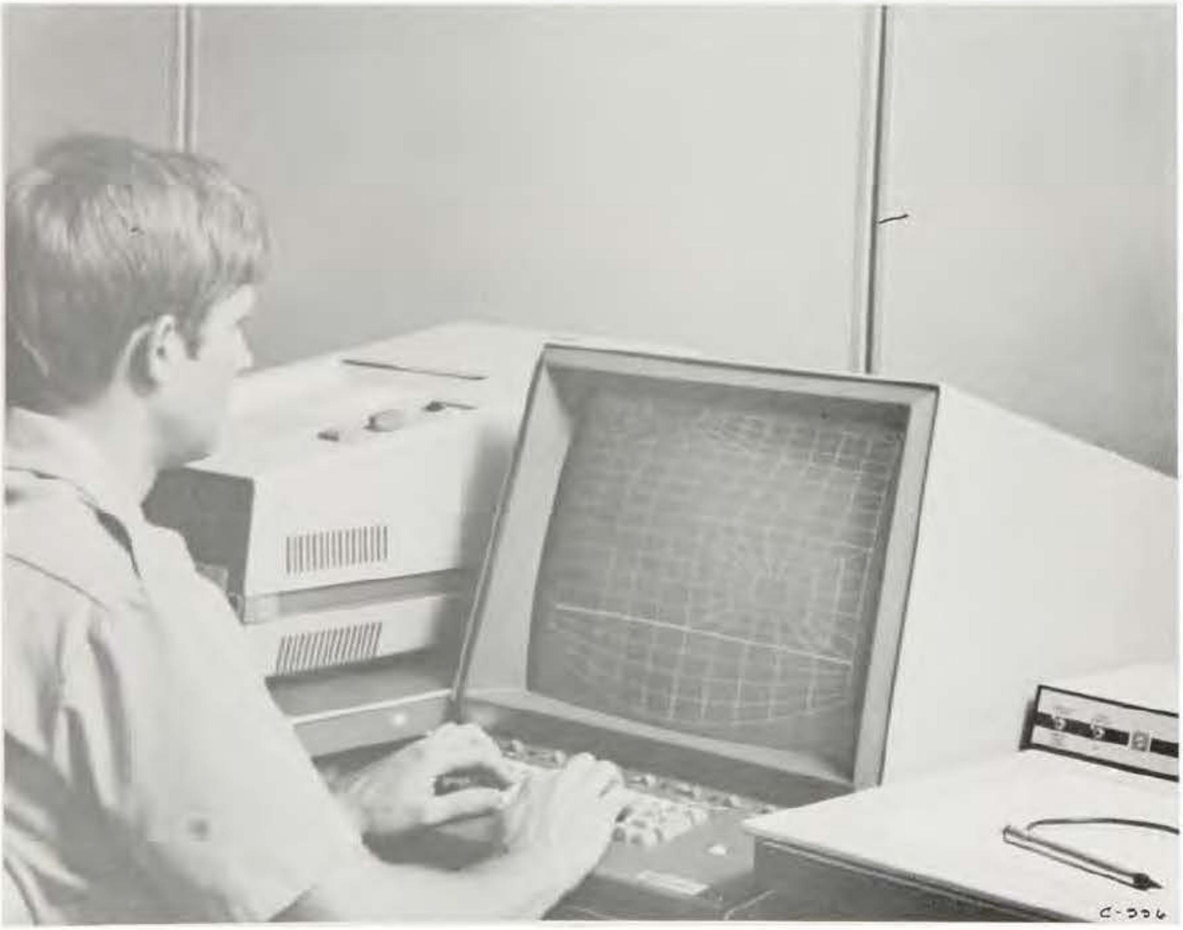


Instrumentation technician operating vibration test equipment used in determining structure mechanical impedance

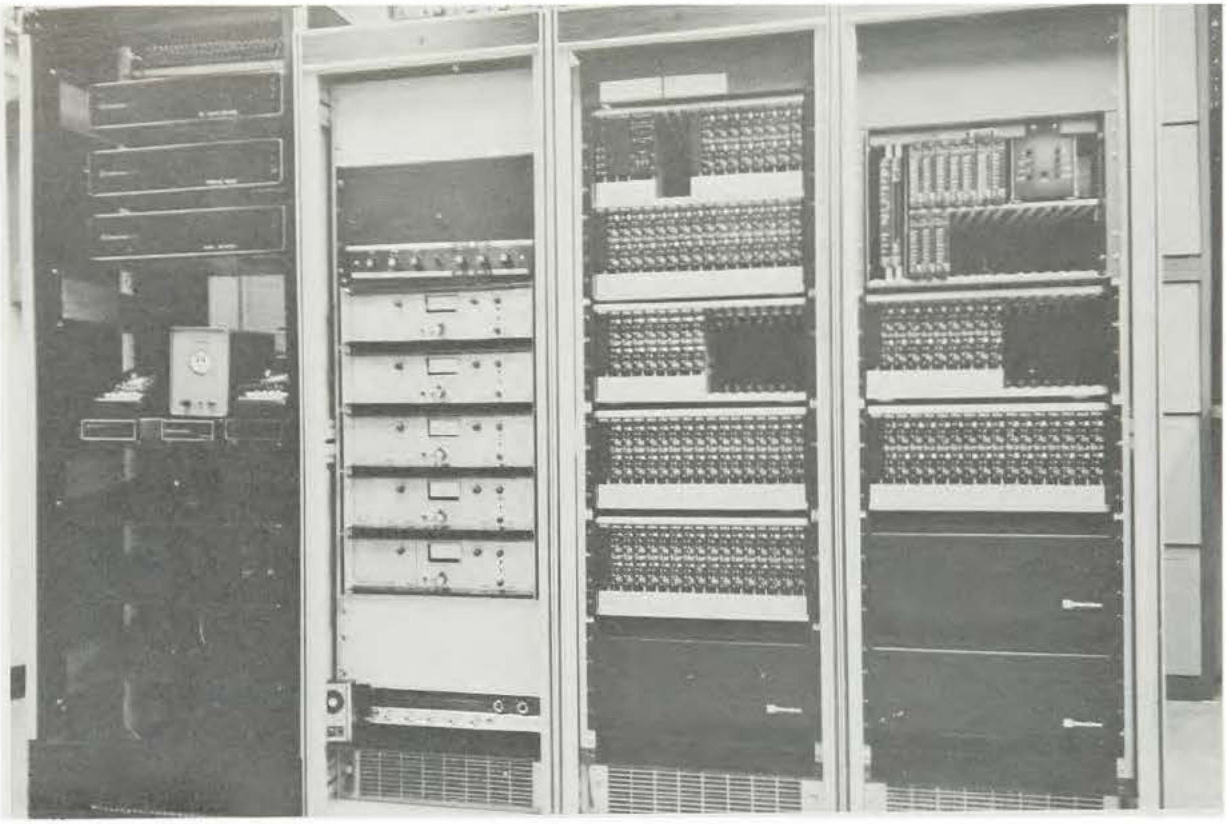
Data reduction equipment which is used for converting analog data so that it may be analyzed for use in the ADP Center and processed for reports, etc.

AUTOMATIC DATA PROCESSING CENTER

The Automatic Data Processing Center provides computer-related support and services to the WES laboratories, the Corps of Engineers, and other Federal agencies. Four types of data processing services are provided: business, scientific and engineering, research and development, and process control. Each category of data processing activity requires a different capability and level of support.



The WES ADP Center leads the Corps in interactive graphics development and application. Using the Tektronix 4012 and 4014 graphic display terminals, the engineer/analyst can enter design parameters, feature descriptions, stresses, and other variables and see a three-dimensional image of the structure under evaluation



Nationwide multiplexed data communications equipment

The ADP Center provides WES and the Corps with a total computer service capability for almost any computer application. A nationwide multiplexed data communications network called WESNET provides remote access to the WES computers. WESNET is linked to sites throughout the country and provides dependable and efficient access for time-sharing and remote batch operations

Batch terminal to remote R and D computer systems

WESNET data communications analysis center

TECHNICAL INFORMATION CENTER

The Technical Information Center serves as the central source of technical information for WES and the entire Corps of Engineers in selected engineering and scientific fields. It provides comprehensive and selective bibliographies, abstracts, literature searches, and loan services. It also furnishes central coordination and chief support for the four Department of Defense Technical Information Analysis Centers located at WES: the Concrete Technology, Hydraulic Engineering, Pavements and Soil Trafficability, and Soil Mechanics Analysis Centers.

Interior of WES library

Defense Documentation Center on-line terminal

TIC uses slowscan television in a pilot program with 14 other libraries and technical information centers developed to speed up technology transfer

PUBLICATIONS AND GRAPHIC ARTS DIVISION

The Publications and Graphic Arts Division supports the WES mission with a wide range of services, including editing, visual information layout design, copy preparation, proofreading, engineering graphics, illustrating, still and motion picture photography, and printing.

APPENDIX III

WES AWARD WINNERS

DEPARTMENT OF DEFENSE
DISTINGUISHED CIVILIAN SERVICE AWARD

Katharine Mather	1963	W. J. Turnbull	1965
Frederick R. Brown	1979		

DEPARTMENT OF ARMY AWARDS

EXCEPTIONAL CIVILIAN SERVICE

W. J. Turnbull	1946, 1964	Katharine Mather	1962
Bryant Mather	1969	Frederick R. Brown	1973

MERITORIOUS CIVILIAN SERVICE

Frederick R. Brown	1947, 1969	Robert Y. Hudson	1947
Thomas B. Kennedy	1965	Bryant Mather	1965
Kenneth L. Saucier	1965	William O. Tynes	1965
George W. Vinzant	1965	William L. Bache, Jr.	1966
George B. Fenwick	1966	Rose C. Harrell	1966
Aubrey W. Stephens, Jr.	1966 (For bravery)	Frank B. Campbell	1967
Leo F. Ingram	1969	Katharine H. Jones	1969
Guy L. Arbuthnot, Jr.	1970	Count G. Evans	1970
Eugene P. Fortson	1970	Francis P. Hanes	1970
John J. Kirschenbaum, Jr.	1970	Luther C. Marsalis	1970
Woodland G. Shockley	1970	Dr. Dean R. Freitag	1971
James P. Sale	1971	Cecil D. Burns	1973
Dr. Chandrakant S. Desai	1973	Warren E. Grabau	1973
Alfred H. Joseph	1973	Dr. Garbis H. Keulegan	1973
Henry B. Simmons	1973	Marden B. Boyd	1974
Dr. John W. Keeley	1974	Dr. Roger T. Saucier	1974
William J. Flathau	1975	Edward J. Leahy	1975
Nels J. Nyman	1975	Adam A. Rula	1977
Jane C. Cotton	1978	Dr. N. Radhakrishnan	1978
Dr. John Harrison	1979		

PATRIOTIC CIVILIAN SERVICE

William D. Rutland	1977	William O. Miller	1979

ARMY R&D AWARD

Year	Name	Achievement
1968	J. T. Ballard	Leadership in developing data for the design and construction techniques for a reinforced concrete protective arch structure in support of high-priority Southeast Asia requirements for protective military shelter systems.
1968	R. G. Ahlvin D. N. Brown H. H. Ulery, Jr. D. M. Ladd	Development of new technology in aircraft-flotation criteria which improved the Army's technical capabilities for efficient design of aircraft landing gears and airfields.
1969	Dr. G. H. Keulegan	Studies of tsunamis—giant waves that often cause a great deal of damage, as in the case of the 1964 Alaskan earthquake.
1969	Dr. M. J. Hvorslev	Significant contribution to the literature of soil mechanics in his report on "The Basic Sinkage Equations and Bearing Capacity Theories."
1969	J. G. Jackson, Jr.	Fundamental research and unique contributions to the field of soil mechanics resulting in quantitative values to improve the design of missile and hardened facilities against the blast effects of nuclear weapons.
1970	W. J. Flathau	Investigations of qualities of protective structures.
1970	J. N. Strange	Directing the development of an analytical solution to the partitioning of energy from a point explosion at a water surface.
1970	W. E. Grabau	Development of radically new ideas and concepts for solutions of many diverse problems involving interrelations between military activities on items of military equipment and the environment in which they operate.
1971	Thomas E. Kennedy	Technical achievement in the conception design, construction, and testing of two structural models that simulated the perimeter acquisition radar building of the SAFEGUARD Antiballistic Missile System.
1973	Ellis L. Krinitzsky	Development of highly valuable investigative techniques concerned with the internal structure of clays and clay shales.
1973	Adam A. Rula Clifford J. Nuttall, Jr.	Development and application of analytical model for predicting off-road performance of military vehicles.
1973	Jimmy P. Balsara	Verifying modeling relationships for buried structures subjected to dynamic overpressure and applying techniques in assessing response of structures associated with strategic missile system.
1973	W. J. Flathau	Expertise in explosive effects and structural response and assistance to Supreme Headquarters Allied Powers Europe in design of hardened underground structures.
1975	H. L. Green	Research contributions resulting in the development of two lightweight airplane landing mat systems for use as expedient surfacing on military fields.

Year	Name	Achievement
1976	H. R. Austin Dr. W. R. Barker W. N. Brabston Dr. Y. T. Chou G. G. Harvey	Research resulting in the development of an improved theoretically based flexible pavement design procedure for military roads, and civil and military airfields.
1977	Jerry R. Lundien Daniel H. Cress Bob O. Benn	Research activities leading to a system evaluation tool for defining advantages and limitations of discriminating logic designs used to activate mine warheads and intrusion-detection systems.
1978	Donald T. Resio C. L. Vincent	Research in wind climate data for coastal engineering applications.

AMERICAN SOCIETY OF CIVIL ENGINEERS

HONORARY MEMBERSHIP

W. J. Turnbull	1969	G. H. Keulegan	1969

KARL TERZAGHI AWARD

M. J. Hvorslev	1965	W. J. Turnbull	1969

RESEARCH PRIZE

M. J. Hvorslev 1957

AMERICAN SOCIETY FOR TESTING AND MATERIALS

SANFORD E. THOMPSON AWARD

Bryant Mather	1953, 1959	Katharine Mather	1961

Leonard Pepper 1961

AWARD OF MERIT

Bryant Mather	1959	T. B. Kennedy	1969

AMERICAN CONCRETE INSTITUTE
WASON MEDAL FOR RESEARCH

Charles E. Wuerpel	1946	T. B. Kennedy	1954
Katharine Mather	1954	Alan D. Buck	1968

SOCIETY OF AMERICAN MILITARY ENGINEERS

GEORGE W. GOETHALS MEDAL

Robert Y. Hudson 1972

SOCIETY OF AMERICAN MILITARY ENGINEERS

WHEELER MEDAL

W. J. Flathau 1977

PRESIDENT'S MANAGEMENT IMPROVEMENT AWARD

John J. Franco 1976

U. S. DEPARTMENT OF COMMERCE EXCEPTIONAL SERVICE AWARD FOR OUTSTANDING SERVICE (GOLD MEDAL AWARD)

G. H. Keulegan 1960

INTERNATIONAL SOCIETY FOR TERRAIN-VEHICLE SYSTEMS ST. CHRISTOPHER AWARD

C. J. Nuttall 1975

APPENDIX IV

GALLERY OF DISTINGUISHED CIVILIAN EMPLOYEES

Charles R. Warndof
Assistant Chief, Construction Services Division
1932-1957

Frank J. Musil
Chief, Shops Branch, Construction Services Division
1930-1960

George B. Fenwick
Assistant Chief, Hydraulics Division
1933-1965

George W. Vinzant
Chief, Construction Services Division
1943-1965

Thomas B. Kennedy
Chief, Concrete Division
1946-1965

William L. Bache, Jr.
Executive Assistant
1946-1966

Frank B. Campbell
Chief, Hydraulic Analysis Branch
1951-1967

Willard J. Turnbull
Chief, Soils Division
1941-1969

Joseph B. Tiffany, Jr.
Technical Director
1933–1969

Audley A. Maxwell
Assistant Chief, Soils Division
1936 - 1969

Eugene P. Fortson, Jr.
Chief, Hydraulics Division
1932–1970

Luther C. Marsalis, Jr.
Personnel Officer
1946–1972

Katharine H. Jones
Chief, Reproduction and Reports Division
1940-1972

Guy L. Arbuthnot, Jr.
Chief, Weapons Effects Laboratory
1937-1972

Robert Y. Hudson
Chief, Wave Dynamics Division
1937-1972

John J. Franco
Chief, Waterways Division
1933-1973

Thomas E. Murphy
Chief, Structures Division
1935-1973

Charles R. Kolb
Chief, Engineering Geology and Rock Mechanics Division
1949-1973

John J. Kirschenbaum, Jr.
Chief, Procurement and Supply Office
1935-1973

Dr. Mikael J. Hvorslev
Consultant to Chief, Soils and Pavements Laboratory
1947-1976

APPENDIX V

LISTING OF WES EMPLOYEES
MARCH 1979

Abbey, Robert V.
Abel, Charles E.
Abel, Dorothy L.
Ables, Jackson H., Jr.
Ables, Joseph C.
Ables, Lucille C.
Ables, Timothy D.
Abraham, Sam N.
Acuff, Hugh F.
Adamec, Stephen A., Jr.
Addor, Eugene E.
Ahlvin, Richard B.
Ahlvin, Richard G.
Ahlvin, Sue S.
Ainsworth, Donnie L.
Albert, Myrtle E.
Albritton, Gayle E.
Aldridge, Margaret Y.
Alexander, Alton M.
Alford, Samuel J.
Alford, Theda P.
Al-Hussaini, Mosaid M.
Allen, Hollis H.
Allen, James V.
Allen, Janice D.
Allen, Nancy C.
Allen, Roy E.
Alvarado, Robert J.
Amos, Joe W.
Amundson, James A.
Anderson, Adolph J.
Anderson, Charles L.
Anderson, Grady
Anderson, Robert F.
Anderson-Smith, Opal P.
Anderton, Thomas A.
Andrews, Donnie E.
Anglin, Ronald K.
Anglin, Sharon B.
Ankeny, Ralph E.
Antoine, Charles A.
Antoine, Jean H.
Aranas, Alfredo G.
Arbuthnot, Guy L., Jr.
Armstrong, Byron J., Jr.
Arnold, Helen D.
Artman, Jeffrey A.
Ashby, Steven L.
Ashe, Martha A.
Ashley, John S.
Athou, Robert F., Jr.
Austin, Harry R.
Auxier, Everett L.
Aziz, Wali A.
Bach, Donald P.
Baladi, George Y.
Ball, James W.
Ballard, James T.
Ballard, Robert F., Jr.
Balsara, Jimmy P.
Balzli, Margaret C.
Banchetti, Allen J.
Banks, Don C.
Barber, Victor C.
Barefoot, Dale L.
Barkau, Linda S.
Barker, Patricia H.
Barker, Walter R.
Barko, John W.
Barnes, Dan, Jr.
Barnes, Donald E.
Barnes, James M.
Barnes, Kathleen B.
Barnes, Larry A.
Barnett, Oliver E., Jr.
Barnette, Robert D.
Bastian, David F.
Bates, Derrick J.
Battalora, Michael S. J.
Batts, Robert L.
Baylot, Erwin A., Sr.
Baylot, James T.
Beach, Raymond F.
Beall, Loriece M.
Bean, Dennis L.
Beane, William S. R., IV
Beard, Benjamin E.
Beard, Jerry W.
Beard, Lisa A.
Beard, Robert A.
Beasley, John W.
Beasley, Marion D.
Beasley, Nora G.
Beasley, William F.
Beasley, William J.
Bell, Seymore
Benn, Bob C.
Bennett, Robert D.
Benson, Billy W.
Benson, Howard A.
Berger, Rutherford C. Jr.
Bernard, Robert S.
Bhramayana, Potong
Bibbs, Calleen B.
Biggs, Danny P.
Bingaman, June T.
Bingham, Charles R.
Birchett, Phyllis A.
Bishop, Bruce N.
Bishop, Jean M.
Black, Danny M.
Black, Larry L.
Blackmore, Leon W.
Blackwell, Robert L.
Bland, Manuel, Jr.
Boa, John A., Jr.
Bodron, Eloise H.
Boland, Robert A., Jr.
Bolden, Daniel C., Jr.
Bolden, Doris W.
Bolden, Melvin L.
Bombich, Anthony A.
Bond, Carolyn L.
Bonelli, Jeannie B.
Bonner, George P.
Booth, Dorothy P.
Booth, Vicki B.
Booth, William E.
Bopp, Frederick, III
Bottin, Robert R., Jr.
Bowes, Marilyn M.
Bowles, R. Edward, Jr.
Boyd, Jesse A., Jr.
Boyd, Marden B.
Boyd, Marian L.
Boyd, Teresa J.
Boyt, William L.
Brabston, William N.
Bradley, Alfreda M.
Brady, Lewis G.
Bragg, Dorothy C.
Brannon, James M.
Braxton, Anthony M.
Breithaupt, August J.
Brewer, Maria B.
Bride, Lonell
Brister, Douglas B.
Britt, James R.
Broadway, Corlis P.
Brock, Roger D.
Brocket, Gayle A.
Brodie, Wade M.
Brogan, James T.

Brogdon, Jim
Brogdon, Noble J., Jr.
Brooks, Rebecca M.
Broome, Lamar G.
Broughton, Jerald D.
Brown, A. B.
Brown, Ben, Jr.
Brown, Ben, Jr.
Brown, Billy R.
Brown, Bobby J.
Brown, Burrell N.
Brown, Donald R.
Brown, Elton R.
Brown, Frederick R.
Brown, Harry G.
Brown, Herman R., Sr.
Brown, Jane N.
Brown, Janice M.
Brown, Jerry W.
Brown, Kelvin E.
Brown, Lawrence
Brown, Lincoln L.
Brown, Louis J.
Brown, Ruby J.
Brown, Sam
Bryant, Robert, Jr.
Bryant, Vicky A.
Buchanan, Michael V.
Buck, Alan D.
Buford, Curtis A.
Buglewicz, Eugene G.
Bunch, Johnny F.
Bunch, Velma C.
Burke, Patricia A.
Burkes, Jerry P.
Burks, Sterling I.
Burns, Edna L.
Burns, James, Jr.
Burns, Robert F.
Burton, Glenn A., Jr.
Burton, Patricia J.
Bush, Albert J., III
Bush, Gary C.
Butler, Dwain K.
Butler, Henry L.
Butler, John B.
Butler, Mayme N.
Cahill, Sherry A.
Calais, Charles C.
Caldwell, Matthew E.
Calhoun, Charles C., Jr.
Calhoun, Jane P.
Campbell, Roy L.
Carleton, Hendrik D.
Carlin, Monica M.
Carlisle, Jeannette T.
Carlson, Melvin M.
Carnes, Benny L.
Carpenter, James
Carr, Gordon L.
Carr, James W.
Carre, Gary L.
Carroll, Joe H.
Carson, James W.
Carter, Betty M.
Cartwright, John T.
Carver, Robert D.
Case, Edward A.
Castellane, Raymond M., III
Causey, Etta M.
Caviness, Larry G.
Cessna, Emma M.
Cessna, James
Chambers, Dave W.
Chambers, Emmit
Chang, Frank K.
Channell, Claudette L.
Chatham, Claude E., Jr.
Cheek, James B., Jr.
Chekiri, Hamza
Chiplin, Viola B.
Chou, Yu T.
Clairain, Ellis J., Jr.
Clark, Alfrieda S.
Clark, Flynn A.
Cobb, Stephen P.
Coffee, Leonard
Coffie, Thomas, Jr.
Coffing, Levi R., Jr.
Cohen, Joanne L.
Cole, Richard A.
Cole, Robert A.
Coleman, Carolyn E.
Coleman, Clara J.
Coleman, Marion T.
Colenburg, Leo
Collins, John G.
Collins, Jon D.
Collins, Percy L.
Collins, Robert P.
Coltharp, David R.
Connor, Angela L.
Conrad, David C.
Conrad, Jones A., Jr.
Conway, John A.
Cook, Amos J.
Cooksey, David L.
Cooper, Mary M.
Cooper, Myra L.
Cooper, Stafford S.
Corson, William D.
Cost, Van T.
Cothran, Barbara R.
Cotton, Edward F.
Cotton, Jane C.
Countryman, Harry
Cox, Cary B.
Cox, Maxine C.
Craig, Jean A.
Crawford, Burnell T.
Creighton, Daniel C.
Cress, Daniel H.
Crist, George R.
Crosthwait, Sharon F.
Crotty, Patrick E., Jr.
Crouse, David A.
Crowson, Roger D.
Crum, Patrick C.
Crunk, Anthony W.
Crutchfield, James P.
Cuevas, Lehman J., III
Culbertson, Jackie L.
Cullinane, Murdock J., Jr.
Cummins, Caroline P
Cummins, Kenneth W.
Cummins, Reid S., Jr.
Cunny, Robert W.
Curran, Karen K.
Curren, Charles R.
Currie, Clarence D.
Curro, Joseph R., Jr.
Curry, Fred, Jr.
Curtis, Ethel P., Jr.
Curtis, John O.
Daggett, Larry L.
Dahl, Betty M.
Dahl, Jerry J.
Dahl, Morris W.
Danczyk, James
Daniel, George
Daniel, James M.
Daniels, Donnie S.
Dardeau, Elba A., Jr.

Davidson, Alvis B.
Davidson, Doyce D.
Davidson, Robert E.
Davis, Georgiann S.
Davis, Johnny
Davis, Kenny C.
Davis, Landon K.
Davis, Lemoyne
Davis, M. L.
Davis, Phyllis C.
Davis, Travis W.
Davis, William A.
Dawsey, Joseph V., Jr.
Day, Jerry D.
Decell, Joseph L.
Dennis, Mary S.
Denson, Birtnell, Sr.
Denson, Robert H.
Dent, Curtis L.
Dent, Henry B., Jr.
Derrick, David L.
Destefano, George T.
Devay, Leslie
Diaz, Robert J.
Diggs, Mildred N.
Dildine, Jack H.
Dillon, Cecil C.
Dixon, Fred, Jr.
Doiron, Phillip L.
Donaghe, Robert T.
Donnell, Barbara P.
Dorman, Charles W.
Dornbusch, William K., Jr.
Dorsey, Frank W.
Dortch, Mark S.
Dotty, Danny R.
Douglas, Donald H.
Douglas, Evelyn T.
Dowdy, Pamela J.
Dowe, Clover M.
Downey, Dorothy G.
Downing, George C.
Drake, Clyde E.
Drake, James L.
Drayton, Clarence, Jr.
Dubose, Willie G.
Duke, Jonathan C., Jr.
Duke, Leiland M
Dulaney, Charles
Dulaney, William H.
Dunlap, Esther M.
Durr, Frank J.
Eagles, Paul S.
Easley, Gerald T.
East, Thomas C.
Edris, Earl V., Jr.
Edwards, Barbara J.
Ehrgott, John Q.
Eicher, Donald E., Jr.
Eley, Rex L.
Ellerbe, Charles R.
Elliott, James F., Jr.
Ellis, Mose
Ellis, Thomas L.
Ellison, Dave A.
Ellison, Dellar M.
Elsea, Carol R.
Elsea, Darrell R.
Emerson, Ray H.
Enete, Walter L.
Engdahl, Thomas L.
Engler, Robert M.
Epps, Sterling L.
Erves, Carl R.
Eskridge, James B.
Ethridge, James D., Jr.
Evans, Count G.
Evans, Gregory M.
Evans, Martha N.
Evans, Robert A., Jr.
Fadum, Ralph E.
Fagerburg, Timothy L.
Fairley, Deborah F.
Fam, Amin S.
Farrar, Paul D.
Farrell, Betsy H.
Farrell, Warren J.
Farris, Marie D.
Fenwick, William B.
Ferguson, James L.
Ficken, Jennifer M.
Fisackerly, George M.
Fisher, Louis C.
Flanagan, Coy D., Jr.
Flathau, William J.
Fleming, Laura S.
Fletcher, Bobby P.
Flohr, Mark D.
Flowers, Edward W.
Flowers, Lester R.
Floyd, Betty J.
Folsom, Bobby L., Jr.
Forbes, Joseph A.
Ford, Alfred W.
Ford, Anna P.
Ford, Dennis E.
Ford, Loyd G., Sr.
Ford, Max B.
Ford, Melanie L.
Ford, W. Bryan, III
Ford, William B., Jr.
Fortenberry, Albert I.
Foster, Anna M.
Foster, Carol J.
Foster, Eddie B.
Foster, James E.
Foster, Michael B.
Fowler, Edward M.
Fowler, Jack
Francingues, Norman R., Jr.
Franco, Raphael A., Jr.
Franco, Sheila E.
Franklin, Arley G.
Freeman, Marando
Friar, Kathryn B.
Friar, Lonnie L.
Friesz, Richard R.
Frost, Edward A.
Fry, Zelma B., Jr.
Fuller, Ouida F.
Gaines, Charlie, Jr.
Galbreath, Donald M.
Gallaher, Walter B.
Gann, Albert R.
Garcia, Andrew W.
Gargaro, Betty H.
Garner, Ellen H.
Garner, Robert T., Jr.
Garner, Robert T., III
Garnett, John D.
Garrett, Elizabeth J.
Garrett, Mary M.
Gaskin, George L.
Gaskin, Thomas
Gatz, Joe L.
Gay, Marsha C.
Gay, Ruth M.
Gay, Wallace M.
Gentil, Daniel C.
George, Deborah P.
George, John E.
George, John F.
George, Michael E.

Gibson, Anthony C.
Gibson, Everett C., Jr.
Gilbert, Paul A.
Gill, Roy C.
Gladen, Curtis L.
Glass, Dale
Gloria, Ofelia T.
Glover, James E.
Godwin, Edith M.
Godwin, Lenford N.
Goings, Gracie B.
Goodman, Debra R.
Goss, Jean E.
Grace, John L., Jr.
Grace, Peter J.
Graham, Eloise P.
Graham, Jerry A.
Graham, Rogers T.
Granat, Mitchell A.
Granger, Minnie C.
Grau, Richard H.
Grau, Robert W.
Grau, Sally H.
Graves, Eugene A., Jr.
Gray, Louise S.
Grays, Leo
Grayson, Wiley F.
Green, Andrew J., Jr.
Green, Ann S.
Green, Charles E.
Green, Cornell
Green, Eddie
Green, Ernest A., Jr.
Green, Harvey H.
Green, Hugh L.
Greenleaf, Rebecca W.
Greer, Homer C., III
Greer, Martha G.
Griffin, Lillian C.
Griffin, Peggy J.
Griffin, Preston
Griffin, Shirley D.
Griffing, Perrin J.
Griffith, Jerry L.
Grissom, Deborah D.
Grissom, Sarah L.
Grogan, Sherry S.
Groves, Benton W.
Guider, Mary E.
Guiney, Edward E.
Gunkel, Robert C.
Gunkel, Robert C., Jr.
Gunnison, Douglas
Guy, Selwyn W.
Guynes, Thomas L., Jr.
Habeeb, Mary B.
Habeeb, Touphie G.
Hadala, Paul F.
Haddock, Mary A.
Hale, Darryl F.
Hale, Gene P.
Hale, Milburn R.
Hales, Lyndell Z.
Hall, Billy
Hall, Floyd, Jr.
Hall, George R.
Hall, James E.
Hall, Jim W., Jr.
Hall, Robert
Hall, Robert L.
Hall, Ross W., Jr.
Hall, Sharon A.
Hall, Tina A.
Hall, W. C., Jr.
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Hammer, David P.
Hammitt, George M., II
Hampton, Mary L.
Hanes, Francis P
Haney, Sammie E.
Hanisee, Laura M.
Hanks, Sharon L.
Hanks, William L.
Hansen, William J.
Harden, Joyce R.
Hardin, Dwilette G.
Harlow, Ronald W.
Harmon, Daniel J.
Harmon, John L.
Harper, William J., Jr.
Harr, Milton E.
Harried, Blackman R.
Harris, Annette F.
Harris, Deborah A.
Harris, John R.
Harris, Ramona A.
Harris, Richard L.
Harrison, Emmett R.
Harrison, John
Hart, Ellis D.
Hartley, Colon E.
Haskins, Debra S.
Haskins, Jerry W.
Hasty, Gwendolyn D.
Haulman, David R.
Hayes, Donald F.
Head, Josephine C.
Headley, Hal S., II
Hearn, Hubert W.
Heath, Clara M.
Heath, Ronald E.
Hebler, Martin T.
Hebron, Carl L.
Hebron, Freddie L.
Heggins, John M.
Helmuth, Billy T.
Helton, Mildred R.
Heltzel, Samuel B.
Henderson, Dawn E.
Henderson, Jim E.
Henderson, Luerillers W.
Henderson, Raymond R., Jr.
Hendricks, John C.
Hendrix, Harriet L.
Henry, Onquah R.
Herrington, Ann R.
Herrington, Charles R.
Herrmann, Frank A., Jr.
Hester, Kathy A.
Hicks, W. J.
Hicks, William K.
Higdon, Parker B., Jr.
Higdon, Willie L.
Hilbun, James T., Sr.
Hilderbrand, Jack
Hill, Eudora E.
Hill, James C.
Hill, Jeffrey L.
Hill, Willie
Hines, Carolyn D.
Hintson, Walter C.
Hite, John E., Jr.
Hixson, Mark D.
Hodge, Sandy M.
Hoeppel, Ronald E.
Hoff, George C.
Hogg, Elizabeth A.
Holden, Leon
Holliday, John A.
Holloway, Modell W.
Hollyfield, Noel W.
Holman, Mary B.
Holmes, Betty L.

Holmes, Charles R.
Hopkins, Patricia B.
Horstmann, Harry L.
Horz, Raymond C., Jr.
Hosemann, Robert C.
Hossley, James R.
Houston, Billy J.
Houston, James R.
Hovious, Beatrice B.
Howell, Laura C.
Howell, Leah M.
Hoxie, Dowl G.
Huell, Edward L.
Huff, William L.
Huffman, Robert T.
Huie, Jerry S.
Hulitt, Sturline
Hullum, Mary V.
Humes, Willie
Hummert, Dora J.
Hummert, Edgar A.
Hunt, Lois J.
Hunt, Paula R.
Hunt, Richard W.
Husbands, Tony B.
Hutchinson, Ronald L.
Hutto, Thomas D.
Huval, Carl J.
Hyde, George S.
Hynes-Griffin, Mary E.
Ingram, James K.
Ingram, John J.
Ingram, Leo F.
Ingram, Windell F.
Ivy, George P.
Jacks, Robert B.
Jackson, Andrew E., Jr.
Jackson, Betty T.
Jackson, David
Jackson, Earl L.
Jackson, John G., Jr.
Jackson, Lucius
Jackson, Melvin
Jackson, Ralph D.
Jackson, Robert S.
Jackson, Sherman
Jackson, Sidney
James, Otis N.
Jamison, Mary P.
Jansen, William R.
Jefferson, Earl L.
Jefferson, James R., Jr.
Jefferson, Major J.
Jeng, Yu-Shih
Jenkins, Joseph J.
Jennings, Larry J.
Joachim, Charles E.
Johnson, Billy H.
Johnson, Charles F., Jr.
Johnson, Constance M.
Johnson, Edith A.
Johnson, Edward
Johnson, Henry E.
Johnson, Lawrence D.
Johnson, Lucile R.
Johnson, Marc C.
Johnson, Pearlie M.
Johnson, Steven R.
Johnson, William H.
Johnson, William H.
Johnston, Jean T.
Jolly, Algie L., Jr.
Jones, Charles, Sr.
Jones, Clifton D.
Jones, Fred R., Jr.
Jones, Grace E.
Jones, Harvey L.
Jones, Harvey W.
Jones, James M., II
Jones, Jerry N.
Jones, Judy I.
Jones, Philip H.
Jones, Raymond E.
Jones, Walter
Jones, Wilson B., Jr.
Jordan, W. C.
Jorden, Edward
Joseph, Alfred H.
Kackley, Martha A.
Keeley, John W.
Keith, Charlotte
Kelly, Andrea L.
Kelly, Catherine B.
Kelly, James A.
Kennedy, James G.
Kennedy, Katherine M.
Kennedy, Laurens T., III
Kennedy, Robert H.
Kent, Johnnie B.
Keown, Malcolm P.
Keulegan, Garbis H.
Kiger, Sammy A.
King, Donna C.
Kirby, Conrad J., Jr.
Kirby, Donald J.
Kirkland, Mildred C.
Klar, William E.
Klein, Elizabeth K.
Kleinman, Mary O.
Klimas, Charles V.
Koestler, Thelma R.
Kolb, John F.
Kolmer, Joseph R.
Krinitzsky, Ellis L.
Krivitzky, Barbara C.
Krivitzky, Daniel G.
Kuhn, Percy F., Jr.
Kuykendall, Patrick J.
Kyzar, Thomas H.
Ladd, Donald M.
Lagarde, Victor E., III
Lamb, Jacqueline S.
Lamb, Jerry B.
Land, Wyman F.
Landers, Elsie G.
Landers, Willard R.
Landes, William M.
Landin, Mary C.
Landrum, Hollis T., Jr.
Lane, Edgar F.
Lanehart, Francis A., Jr.
Lansing, George E.
Larr, David B., Jr.
Larr, Elizabeth M.
Lavecchia, N. J., Jr.
Lawyer, Ronald L.
Layton, Alice H.
Leach, Jamie W.
Leach, Roy E.
Leake, Fredrick P., Jr.
Lebron-Rodriguez, C.
Ledbetter, Richard H.
Lee, Carol S.
Lee, Charles R.
Lee, Eddie J., Sr.
Lee, Jessie J.
Lee, Johnnie E.
Lee, R. T.
Lee, Ray C., Jr.
Lee, Tom W.
Lee, Tommie, Jr.
Lee, Willard B.
Leese, David L.

Leggett, Thomas A.
Leist, Mary F.
Leist, Sidney J.
Lessem, Allan S.
Letter, Joseph V., Jr.
Lever, John A.
Lever, Martha M.
Lewis, Cornelius, Sr.
Lewis, Hardy, Jr.
Lewis, Jack T.
Lick, Henry O.
Lieux, Charles J.
Liggins, Edward L.
Lindley, Oscar E.
Lindsey, Joseph H.
Link, Lewis E., Jr.
Liu, Tony C.
Lloyd, Cheryl M.
Lloyd, Michael K.
Lockard, Susan
Loftis, Bruce
Logue, Elma B.
Logue, Hugh L., Jr.
Logue, Norma E.
Long, Katherine S.
Lott, Barbara A.
Love, Beverly R.
Lowe, James A. G.
Lowe, James A., Jr.
Loy, Patricia C.
Loyd, Olen K.
Lundien, Jerry R.
Lunz, John D.
Lutton, Richard J.
Magee, Vessen, Jr.
Maggio, David M.
Maggio, Joseph V.
Magoun, Aubrey D.
Mahloch, Jerome L.
Main, James E.
Malone, Philip G.
Manning, Sharon K.
Marcus, Joanne N.
Marcuson, William F., III
Markle, Dennis G.
Markussen, Jerry V.
Marshall, Jerry N.
Martin, Brenda L.
Martin, Daisy M.
Martin, Deborah K.
Martin, John H., Jr.
Martin, Mary D.
Martin, Terry W.
Martin, William R.
Marzette, David
Mason, James B.
Mason, Julies
Masterson, Una M.
Mather, Bryant
Mather, Katharine
Mathews, Dan D.
Mathis, David B.
Matthews, Margaret S.
Mattingly, Betty P.
Maxey, John L.
May, Carl R.
May, Dorothy B.
May, James H.
May, John R.
Mayfield, James, Jr.
Mayfield, Oscar, Jr.
Maynord, Stephen T.
McAlpin, Dean W.
McAnally, William H., Jr.
McAnear, Clifford L.
McAneny, Colin C.
McBee, Majel R.
McBee, Theresa G.
McBee, Therrel W.
McBroom, Mary P.
McCaffrey, Patrick S., Jr.
McCaffrey, Patrick S.
McCarley, Robert W.
McCaskill, James L.
McClearen, Richard W.
McCleave, Barry W.
McCleese, William F.
McCollum, Randy A.
McComas, Dinah N.
McCoy, James W.
McCurtis, Christine E.
McDonald, James E.
McDonald, Sharon M.
McEwen, Thomas V.
McFarland, Victor A.
McGee, Henry E.
McGee, Howard W., Jr.
McGough, Thomas W.
McGregor, Johnny L.
McGuffie, Billie R.
McGuffie, James V., Jr.
McKay, Norman
McKenzie, Gerald W.
McKlemurry, Robert E.
McLemore, Eva M.
McLeod, Pamela R.
McManus, Richard E.
McMaster, Edmund E.
McMillin, Carol L.
McMullen, Albert A.
McNair, Ernest C., Jr.
McNamara, Albert L.
McNamara, Patrick J., Jr.
McNeal, Linda S.
McPhearson, James R.
McVay, Mark K.
Meeks, James H.
Meredith, Kathren R.
Merritt, David H.
Meyer, Marvin P.
Miller, Charles A.
Miller, Irene W.
Miller, Samuel P.
Miller, Wendell O.
Miller, William G.
Minder, Frank
Mitchell, Emily G.
Mitchell, Gerald B.
Mitchell, Joseph C.
Mitchell, Larry
Mize, Larry I.
Mize, Marvin G.
Mlakar, Paul F.
Mobley, David N.
Mobley, Margaret S.
Monde, Michele C.
Money, Thomas J., Jr.
Montague, Charles A.
Montgomery, Raymond L.
Moody, Vickie L.
Moore, Billy G.
Moore, Eddie L.
Moore, Terry L.
Moore, Thomas K.
Morgan, Glenda P.
Morris, Scott A.
Morris, Virginia H.
Morrow, Bobbie B.
Moses, James
Mosher, Reed L.
Muffuletto, Marietta R.
Muirhead, Marvin R.

Mullen, Robert L.
Multer, Roger H.
Murphy, Catherine F.
Murphy, Newell R., Jr.
Murphy, Thomas E., Jr.
Murphy, William L.
Murray, David B.
Murray, Dottie B.
Murrell, Donald W.
Myers, Corinne B.
Myers, David H.
Myers, Tommy E.
Naron, Lewis B.
Nassour, John A.
Naylor, Gloria J.
Naylor, Howard L.
Neal, Bennie R.
Neal, Columbus
Neilson, Frank M.
Nelson, Rickey E.
Nelson, Riley W.
Nelson, Sandra L.
Neumann, Donald L.
Newling, Charles J.
Newton, Loretta O.
Nichols, James E.
Nicholson, Darlinda P.
Nicholson, Glenn A.
Nickles, Charles R.
Niederhauser, David E.
Norman, Charles D.
Norris, Samuel A.
Norton, Joseph L.
Nuttall, Clifford J., Jr.
O'Connor, Jo Ann H.
O'Connor, Kent A.
Odom, Priscilla S.
Oldham, Jessie C.
Oldham, Patricia P.
O'Neal, Carnet W., Jr.
O'Neal, Elzie
O'Neil, Edward F., III
Oswalt, Noel R.
Outlaw, Douglas G.
Ouzts, Carolyn P.
Pace, Carl E.
Pace, William M.
Paintin, David R.
Palermo, Michael R.
Palermo, Virginia G.
Palmer, Shelby, Jr.
Palmer, Shelby R.
Palmerton, John B.
Palmertree, Billy G.
Park, Arden P.
Park, William C.
Parker, Billy C.
Parker, Colleen A.
Parker, Harrell E.
Parker, Linda S.
Parks, Herman P.
Parman, Joseph W.
Parrette, John E.
Parris, Stephen D.
Parsons, Eloise W.
Partridge, Janice S.
Patin, Thomas R.
Patrick, David M.
Patrick, Douglas A.
Patrick, Robert W.
Pavlov, Barbara A.
Payne, Bertha J.
Pearson, Catherine F.
Peatross, James T., Jr.
Peck, Rose Mary T.
Peddicord, Richard K.
Peeples, Audrey L.
Pender, Barbara P.
Pendergrass, Margaret S.
Pennington, Carlos H.
Pennington, Judith C.
Perkins, Benjamin
Perkins, James D., Jr.
Perkins, Thelma J.
Perrier, Eugene R.
Perry, Edward B.
Perry, Jack, Jr.
Peters, Robert E.
Peterson, Frederick E.
Peterson, Richard W.
Phifer, Ira L., Jr.
Phillips, Bruce R.
Piazza, Erlene G.
Pickens, Ethel L.
Pickens, Hossley
Pickens, James L.
Pickering, Glenn A.
Pickett, Ellis B.
Pickett, Jack E.
Pigg, Roy W.
Pikul, Mary B.
Pirches, Robert L.
Pittman, Catherine J.
Poindexter, Marian E.
Pokrefke, Thomas J., Jr.
Ponder, Flossie B.
Poore, Aubrey B.
Porter, Willie L.
Potter, Michael E.
Potts, Margaret M.
Pownall, Pamela F.
Prentiss, Albert
Preston, Karen M.
Price, Colbert D.
Price, Edgar R.
Price, Henry D.
Price, Sherman B.
Price, William A., III
Prosser, Agnes H.
Puckett, Grover D.
Pugh, Carolyn B.
Quasebarth, Thomas F.
Radhakrishnan, N.
Ragan, Steven A.
Ragsdale, Danielle S.
Ragsdale, Halley J.
Ragsdale, Sidney B.
Randall, Charlie A., Jr.
Randolph, Donald D.
Raner, Betty M.
Raney, Donald C.
Rankins, Eddie
Ransome, Bettie B.
Ransome, Joseph T.
Rathburn, Donald W.
Rather, Laura D.
Ratliff, Carl M., Jr.
Rawlings, Clarence
Ray, Charles E.
Ray, David E.
Ray, Tommy G., Jr.
Reaves, Anne M.
Redd, Sylvia F.
Redmond, Sadie B.
Reece, Charlotte M.
Reed, Bobby E.
Reed, David
Reed, Donald
Reed, Pansy C.
Reeves, Terry W.
Regan, Inda J.
Regan, Jesse M.
Register, Paul J.

Reid, Gwendolyn W.
Reinhold, Ronald E.
Rekas, Anthony M. B.
Renaud, Louis R., Jr.
Resio, Donald T.
Reynolds, Walter L.
Rhett, Richard G.
Rhoderick, Jay E.
Rhodman, Eddie C.
Richardson, James
Richardson, Sue E.
Richardson, Thomas W.
Richter, Rudolf E.
Ricks, Jonnie P.
Rigby, Wilbur A.
Riley, James H., Sr.
Ring, Jeanette J.
Ring, William C., Jr.
Ritter, Delores R.
Robbins, Chauncey L.
Roberson, Albert C.
Roberts, Edna P.
Robey, Donald L.
Robinson, Anthony C.
Robinson, Barbara B.
Robinson, James H.
Rockwell, Christopher H.
Rogers, Elizabeth C.
Rohani, Behzad
Rollings, Raymond S., Jr.
Rone, Carlton L.
Rook, Jewell P.
Rooke, Allen D., Jr.
Ross, Amos
Ross, Lorraine S.
Rosser, Thomas B., III
Rothwell, Edward D.
Rubin de la Borbolla, George S.
Rush, Edgar S.
Rush, Elouise S.
Rush, Thelma B.
Rushing, Gloria F.
Rushing, Rome D.
Rushing, William N.
Russell, Robert M., Jr.
Russo, Vincent J., Jr.
Russum, Scott J.
Rutland, Amy D.
Rutland, William D.
Sadler, Edward L.
Sager, Richard A.
Sale, James P.
Sanderford, Henry C.
Sanderford, Loretta A.
Sanderford, Thomas M.
Sanders, Dana R., Sr.
Sanders, Irene C.
Sanders, Larry G.
Sanders, Una C.
Sanders, Willard
Sargent, Howard L.
Saucier, Kenneth L.
Saucier, Roger T.
Saul, Gary E.
Savage, Monroe B., Jr.
Scanlon, John M., Jr.
Schaff, Rosemary M.
Scheffner, Norman W.
Schneider, Herman A.
Schneider, Robert D.
Schreiner, Barton G.
Scoggins, Randy K.
Scott, Johnie C.
Scott, Joseph B., Jr.
Scott, Mary L.
Scott, Roy R.
Seabergh, William C.
Seeley, Elaine M.
Sennett, Linda S.
Senter, Paul K.
Shafer, Richard A.
Shamburger, John H.
Sharp, E. Dianne
Shaw, John M.
Shaw, Juanita L.
Shelton, Alice F.
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Sherlock, Ann R.
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Sherman, Walter C., Jr.
Shields, Fred D.
Shine, Mary Jo
Shingler, John H. G.
Shipley, Lawrence E.
Shirley, Samuel O.
Shockley, Woodland G.
Shore, James S.
Shows, Louis J.
Shows, Pat A.
Shows, Ruth L.
Sigler, Estelle S.
Silva, Janet S.
Simmers, John W.
Simmons, Billy E.
Simmons, Cecil C.
Simmons, Henry B.
Simmons, Joey K.
Sims, Michael B.
Sink, Forrest A.
Skinner, Billie H.
Skinner, Frank W., Jr.
Skogerboe, John G.
Slaton, Dean B.
Sloan, Richard C.
Smart, Dana L.
Smart, Katherine M.
Smart, Richard M.
Smart, Richard T.
Smart, Sylvia M.
Smith, Billie J.
Smith, Carroll J.
Smith, Dennis R.
Smith, Eddie L.
Smith, Eilene H.
Smith, Frederick L.
Smith, George E., Jr.
Smith, Hanley K.
Smith, Hubert R.
Smith, Isaac, Jr.
Smith, Jerry L.
Smith, Leon, Jr.
Smith, Lonnie L.
Smith, Margaret H.
Smith, Mary E.
Smith, Marye P.
Smith, Morgan D.
Smith, Nathan
Smith, Ottis E.
Smith, Patricia A.
Smith, Perry A.
Smith, Richard
Smith, Robert P.
Smith, Thomas A.
Smith, Vincent
Smithhart, Lewis B.
Snethen, Donald R.
Spates, Linda J.
Speake, Jean B.
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Spivey, Alston C., Jr.
Spivey, Marie
Squire, Albert, Sr.
Stabler, James R.

Stabler, Marjorie H.
Stanfield, Booth F.
Stephens, Aubrey W., Jr.
Stept, Kathryn B.
Stevens, Charles E.
Stevens, Gordon J.
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Stewart, Carol A.
Stewart, Carolyn D.
Stewart, Dave M., Jr.
Stewart, Edwin S., Jr.
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Stewart, Frank S.
Stewart, J. Phillip
Stewart, Mary V.
Stewart, Ozell, Jr.
Stewart, Robert M.
Stewart, Van E.
Stiles, Elizabeth C.
Stirgus, Connie A.
Stoll, Jack K.
Stone, Harry E., Jr.
Stout, John H.
Stowe, Richard L.
Strahan, William C., Jr.
Strange, John N.
Straughter, Deborah W.
Stringer, Faye M.
Strohm, William E., Jr.
Strong, Gay M.
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Stroupe, Wayne A.
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Stukes, Thomas E., Jr.
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Taccarino, Paul A.
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Taylor, Emmit, Jr.
Taylor, Hugh M., Jr.
Taylor, Joseph
Taylor, Maury S.
Taylor, Perry A.
Temple, Robert G.
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Terrell, Donald H.
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Terry, James H., Jr.
Tew, Tom
Theobald, Marion B.
Theriot, Edwin A.
Theriot, Russell F.
Thomas, George L., Jr.
Thomas, Oscar W.
Thomas, William A.
Thomas, Willie C.
Thomason, Doris L.
Thompson, Charles N.
Thompson, Douglas W.
Thompson, Freddie J.
Thompson, Mildred L.
Thomson, Catherine W.
Thornton, Henry T., Jr.
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Torrey, Victor H., III
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Ulery, Harry H., Jr.
Vance, Beverly C.
Van Etten, Lena F.
VanLandingham, L. B.
Varnado, Terrence L.
Varnell, Samuel E.
Vavra, Edabeth F.
Vazquez, Alfonso
Vazquez, Luis A.
Vedros, Dorothea L.
Vedros, Philip J., Jr.
Vernon, Del R.
Vispi, Mark A.
Vollor, Timothy W.
Wade, Alberta M.
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Wahl, Ronald E.
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Waites, Marjorie L.
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Walley, Donald M.
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Warriner, James B.
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Watson, Beatrice W.
Watson, Lyman T., Jr.
Watt, James M., Jr.
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Wehmeyer, Shirley S.

Weiss, Richard A.
Welch, Charles R.
Welch, Joann A.
Wells, Bobby R.
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West, Harold W.
Westerdahl, Howard E.
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Whalin, Robert W.
Wharton, Edward F.
Wheeler, Harry M.
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White, Dewey W., Jr.
White, Douglas M.
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Williams, Ernest B.
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Williams, Rebecca A.
Williams, Roy L.
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Williamson, Albert N., Jr.
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Williamson, Mary M.
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Wilson, Barbara A.
Wilson, Dan E.
Wilson, Gertrude H.
Wilson, Hugh K.
Wilson, Irvin
Wilson, James R.
Windham, Jon E.
Wlosinski, Joseph H.
Wong, Ging S.
Wood, Arthur C., Jr.
Wood, Mary H.
Woodbury, Patricia A.
Woods, Harry K.
Wooley, George E.
Wooley, Lonnie T.
Wooley, Marvin J.
Wooley, Ronald T.
Wooley, Sarah H.
Wright, Billy R.
Wright, Brenda J.
Wright, Thomas D.
Yff, Virginia R.
Young, Brenda A.
Young, Rhonda B.
Young, Robert F.
Youngblood, Mae W.
Zelasko, Joseph S.

APPENDIX VI

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Deputy Directors

Lt. Col. Marion I. Guest
Nov 1963 - Jan 1966

Lt. Col. Guy E. Jester
Jan 1966 - Jul 1967

Lt. Col. Levi A. Brown
Jul 1967 - Jun 1968

Lt. Col. F. M. Anklam
Aug 1968 - Aug 1971

Maj./Lt. Col. Ronald E. Hudson
Sep 1971 - Nov 1973

Lt. Col. Robert K. Hughe
Dec 1973 - May 1976

Lt. Col. Douglas A. Hughes
Aug 1976 - Present

Mr. J. B. Tiffany
Oct 1940 - Nov 1968

Technical Directors

Mr. Frederick R. Brown
Mar 1969 - Present