Stanford's Environmental Engineering & Science Program: The First Fifty Years

by Perry L. McCarty

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Preface

One never knows what opportunities and challenges will arise over a lifetime, what forces will govern the choices that will be made, nor what will be the consequences. Some fifty years after being offered the opportunity to come to Stanford University to start an environmental engineering program, it appeared worthwhile to examine and report on the issues that shaped the evolution of this particular program, leading it to become among the most highly rated in the country. One factor of importance was observations made while teaching in the graduate sanitary engineering program at the Massachusetts Institute of Technology, where I had received my Sc.D. degree. While an excellent program, it became apparent that the students graduating all had essentially the same civil engineering backgrounds, and because of forces that prevailed, they all received the same graduate education. They were well prepared for applying modern treatment technology to the water quality problems of the time, but were quite limited in educational breadth to address the more complex and broad environmental problems that were becoming apparent even 50 years ago. Even attempts to offer the students civil engineering fluid mechanics and hydrology courses failed because of stringent prerequisite requirements imposed by other instructors.

Thus, when Professor Rolf Eliassen described the broad water resources program at Stanford University with emphasis not only on the technical aspects of hydrology and fluid mechanics, but also on social, economic, and planning aspects, and then told of Stanford's desire to broaden the program with a stronger emphasis on environmental aspects, he caught my attention. He indicated he was offered a position there and planned to leave MIT, would I care to join him? The choice was obviously guided by my frustration with limited opportunities for students at MIT. I said yes immediately, and my wife, Martha, agreed without hesitation.

What I had not expected was the great breadth of change that Stanford was undergoing at the time. Aided by the receipt of Ford Foundation funds, Provost Fred Terman transformed Stanford through his concept of building steeples of excellence throughout the university. There was much excitement about the changes; flexibility in programs was being allowed, and integration with the water resources program took place effortlessly. Also not anticipated was the breadth of course offerings available throughout the university on environmental issues of various types, and the unique openness and willingness of faculty throughout the university to the education of students in our program. Because of the broad offerings available throughout the university, a graduate curriculum was created that had considerable flexibility, but built upon a core of water science and technology courses. The program became attractive to a broad range of students with other science and engineering backgrounds, and they were admitted to the program as well. The program hit an obvious need, and was an immediate success.

Stanford was the right place at the right time. I feel so fortunate to have had the opportunity Stanford presented to me when it did, and also to have had the prior brief exposure as an MIT professor to gain the wisdom that led me to accept Eliassen's offer immediately. The years at Stanford for the program were not always easy, but opportunities kept coming that allowed the program to grow and flourish. We have been blessed with the finest of students who as graduates are making a significant difference in protection of the environment. The flexible program and broad background of the students has provided a diversity of skills that collectively are having

significant impacts in environmental policy, education, research, and technical application. Well over a thousand of our graduates are active throughout the world.

In writing this history, I felt it necessary to recognize not only Stanford's long history in addressing water issues, but also the political and economic setting in the country that made it possible for Stanford as well as the environmental engineering and science program to come alive and grow. Thus, some background on this aspect is provided. Then the many challenges and opportunities faced in keeping the program going are addressed, as are the difficulties in dealing with the unprecedented growth in research and teaching activities that immediately and continuously have taken place.

There are many faculty members and staff, besides those associated with environmental engineering and science, who have contributed to the strong program that we have. Faculty members from other groups and departments who have been of great significance are mentioned for the most part in the report itself. But inadequate attention is given to the many staff members who have aided so much in building the program and keeping everything afloat. Susan Stone came to the civil and environmental engineering department shortly after I arrived and became Department Manager while I was Chairman. She was of enormous value to me and other Chairman since in running the Department, looking after and keeping us informed of all departmental needs, directing all the Departmental staff, and insuring that our budget remained balanced. She was always helpful in support of the EES program, support that has been so important to the programs operation.

Gary Hopkins came to work with us as a research technician in the 1970s when we began field studies on groundwater remediation, and has been with us every since. With a B.S. in chemistry, he learned fluid mechanics, computer programing, how to construct sophisticated electronic systems for automatic chemical analysis of groundwater, and the operation and maintenance of pilot plants. Our numerous highly successful field studies have been possible only through Gary's efforts. He has been a uniquely qualified individual. We owe so much to him.

In more recent years, Dr. Sandy Robertson was highly influential in helping Prof. Leckie to develop the successful collaborative educational program with Nanyang Technological University in Singapore, and since has been highly active with the other general laboratory programs and running the summer educational program at Stanford. Dr. Royal Kopperud has taken a major role in maintaining our expanding research and teaching laboratory and helping to educate students in laboratory operation and maintenance. Dr. Colin Ong has provided valuable services with the Stanford Singapore program and educational outreach. Weimin Wu has been of immeasurable assistance in running field and laboratory studies. Considering others, the program would be nearly impossible to operate efficiently without the many capable administrative assistants that we have had over the years, Jan Dyche and Marilyn King in the past, to Duc Wong, Julie Stevens, Jill Nomura, and Pamela Foster in the present. I wish to extend my special thanks to them all.

Finally, I would like to acknowledge the comments and additions made by others to the report that follows, especially to Profs. Gil Masters, Dick Luthy, Jeff Koseff, and Jim Leckie. Also, special thanks go to Hannah Doyle, a short time employee of the Department who volunteered her editorial skills to help improve the language in this report. Finally, thanks go to our many

exceptional students who elected to attend our program - we undoubtedly receive more credit than deserved for their many successes for they are the ones who are largely responsible for whatever recognition we may have. We are most grateful and thankful to them all.

Perry L. McCarty
Silas H. Palmer Professor of Environmental Engineering, Emeritus
1 September 2013

Stanford's Environmental Engineering and Science Program
The First Fifty Years

Introduction

The graduate degree-granting program in environmental engineering and science (EES) at Stanford began with the arrival of Professor Rolf Eliassen in 1961 from the Massachusetts Institute of Technology. The following year, he brought over his former MIT colleague, Perry McCarty, and together they created the EES graduate program, as it is known today. They envisioned a new type of program, one that would bring together engineers and scientists from different disciplines with the opportunity for each to fashion a unique interdisciplinary curriculum that would best met their background and career goals. However, Stanford had a long history even before that time of educating scientists and professionals with expertise in water science and engineering. Thus, the environmental engineering and science program that formed after their arrival built upon a long tradition at Stanford in related subject matter. This brief history opens with a short description of early Stanford activities in water and the transition period in universities following the end of World War II. It then describes in more detail the EES graduate program that evolved since its 1961 beginnings.

Early Stanford Activities in Water

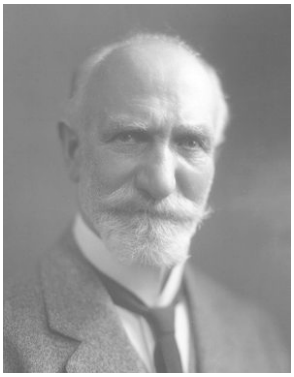
Interest in water came with the first professor of engineering at Stanford, Charles David Marx, known as "Daddy" Marx to generations of students who were inspired by his teachings [1]. He was the first engineering faculty member, and established the Civil Engineering Department when Stanford opened in 1891 [2]. Marx occupied a spacious office on the second floor of Engineering Corner in the outer quad when it was opened in 1905 [1]. "Marx emphasized two goals: that the engineer must be broadly educated in language, social science, and writing as well as in technical subjects, and that the engineer's vision must extend beyond narrow professionalism to the needs of the whole society…He challenged …[students] to bring 'structures into harmony with their surroundings' and to strive for 'the pure air, the pure earth, the pure water.'"

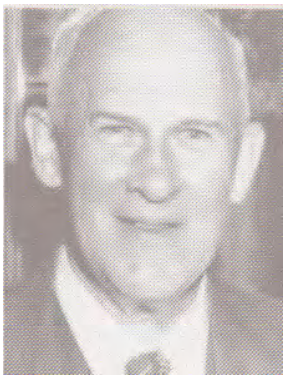
Marx received a Bachelor of Civil Engineering degree at Cornell University in 1878, and in 1884 became an assistant professor at Cornell [2]. He later headed the civil engineering department at the University of Wisconsin, and in 1891 became among the first ten faculty appointments at Stanford. He retired from Stanford in 1923.

> During his period of active service at the University, Professor Marx acted as consultant on a great number of projects, particularly in the fields of hydraulic and sanitary engineering. At one time or another he was called in as a consultant for every large California municipality. He was the first chairman (1912-1915) of the California State Water Commission, and aided in framing the water laws of this state.

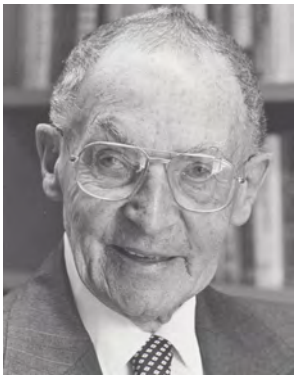
Professor Marx became President of the American Society of Civil Engineers in 1915, and received an honorary LL. D. degree from the University of California in 1918 and that of Doctor

of Engineering from the Karlsruhe Technische Hochschule, Germany, in 1926. He was termed by Stanford President Wilbur as "one of the real pillars of Stanford University."


Charles David Marx


Leon Benedict Reynolds


Cyrus F. Tolman


Eugene L. Grant

Another notable early faculty member was Leon Benedict Reynolds, who joined the Department of Civil Engineering in 1923 as Professor of Hydraulic and Sanitary Engineering, a position he held until his retirement in 1950 [3]. He received an A.B. degree from Hillsdale College in Michigan in 1906 and an A. B. degree in Civil Engineering from Stanford in 1909. From 1944 to 1947 he was acting Executive Head of Civil Engineering.

> Professor Reynolds taught hydraulic and sanitary engineering in the Civil Engineering Department for 27 years, and was lecturer on environmental hygiene for the Stanford Medical School for much of that time….In 1944, he received the Kenneth Allen Award for Outstanding Service of the Federation of Sewage Works Associations….He was a talented professional man, and was one of the first registered civil engineers in California. He was author of numerous technical articles in the field of sanitary engineering and wrote the chapters on Water Purification, Sewage Treatment, and Refuse Disposal in "Essentials of Public Health", by William P. Shephard (J.P. Lippencott, 1948). He also served as sanitary engineering consultant to San Francisco and numerous other California communities [18].

Many well-known sanitary engineers in California were students of "Pop" Reynolds as he was affectionately called by them.

An additional early Stanford faculty member with interests in water was Cyrus F. Tolman, a member of the Stanford Geology Department. An 1896 graduate from the University of Chicago, he served as a professor of economic geology at the University of Arizona before Dr. Branner in 1912 invited him to Stanford as associate professor of economic geology [4]. As with the above two former Stanford professors, the affectionate pseudonym "Chief" was used by the students because he was director of the summer geology field course [5]. He made important contributions in an unusual variety of subjects in geology, and in his later years he became one of the two leading American authorities on groundwater hydrogeology [4]. He was involved in many consulting studies devoted to groundwater, including for the Los Angeles Metropolitan Water District and the State of California with respect to a saltwater barrier proposed for upper San Francisco Bay [5]. Tolman's course in groundwater was unique at the time, the syllabus was eventually incorporated

into a book titled *Ground Water,* published by McGraw-Hill in 1937 and reprinted several times. For many years it was the standard book on that subject [4]. Although he retired from Stanford in 1938, Tolman's course and program continued to the present time and set the framework for Hydrogeology at Stanford. Because of joint interests in water, close ties between the Civil Engineering Department and the Hydrogeology program in the School of Earth Sciences formed early and have continued to the present time.

The Post World War II Years

During World War II most of the country's manpower and resources, including that of the universities, were devoted to the war effort, an effort that demonstrated the great value of scientific and technological abilities to the security of the country. Following WW II, the 1944 GI Bill of Rights was passed, providing federal aid to help veterans adjust to civilian life and featured support for tuition, fees, books and supplies, and living expenses for a college education. Within seven years, approximately 8 million veterans received educational benefits, of which approximately 2,300,000 attended colleges and universities [6]. This great influx of students to universities throughout the country resulted in rapid university growth.

Vannevar Bush's report to the President, "Science - the Endless Frontier," set a course towards continuing scientific research on a level comparable to that done during the war [7]. The report stressed the renewal of scientific talent and the relationship between science and the public welfare. It featured a strong emphasis on the war against disease. A rapid growth in research support at universities began, spurred by heightening tensions with the Soviet Union during the Cold War. On October 4, 1957, the Soviet Union successfully launched Sputnik I, igniting a space race between the U.S. and the U.S.S.R. [8]. The U.S. public feared the Soviet Union might develop the ability to launch ballistic missiles towards the U.S. carrying nuclear weapons. In response to this perceived crisis, President Eisenhower established the President's Science Advisory Committee, chairing it with James R. Killian, Jr., then President of the Massachusetts Institute of Technology; greatly increased financial support for university research followed. Concerns continued with the Soviet successes in a satellite circling the moon in 1959 and Yuri Gagarin's first man in space flight in 1961. This led to President Kennedy's 1961 announcement of the U.S. goal to land a man on the moon within the decade, and further funding for research.

Not only did the above foster much greater federal support for universities, but Foundations began lending their support as well. One of the leaders during the 1950s was the Ford Foundation, which was funded in 1936 by Henry and Edsel Ford. By 1959 the Ford Foundation had a deep commitment to education because of its relationship to the wellbeing of American society. That year it made its first major grants in science and engineering programs, concentrating on urgent problems in engineering education [9]. The largest individual grant by far that year went to the Massachusetts Institute of Technology with $4.5 million for curriculum development and experiments and $4.775 million for faculty recruitment and development. The following year the Ford Foundation developed a special program in education totaling $46 million. The largest recipient of that was Stanford University with a grant of $25 million, which required Stanford to raise $3 for every $1 received from the Foundation over a five-year period. Thus, both MIT and Stanford were major beneficiaries of the Ford Foundation, funds that transformed each of

them significantly. These funds also played an important part in the development of Stanford's environmental engineering and science program.

Another program that was crucial to the establishment of Stanford's EES program was that of the U.S. Public Health Service (PHS). As summarized by Lewis [10], "In the first years of the 20th Century, preventive federal statutes were written to regulate the quality of food, drinking water, and sewage treatment. A large part of the PHS's early work had to do with the prevention of waterborne disease, such as typhoid; in later years, that mission was expanded to include standard setting for air quality in the industrial workplace. These early PHS water and air standards became the prototype for the first federal water and air programs of the 1950s and 1960s – both of which originated at the PHS." With the growth of federal research funding and Vannevar Bush's emphasis on disease prevention in 1945, research support for universities through the PHS expanded greatly. This support included matching funds for developing new facilities as well as student fellowships and traineeships and general research support.

Stanford's Transition

According to Prof. Bart Bernstein [11], a Stanford historian of public policy, Stanford was a very good university in the early 1930s, perhaps ranking among the top 15 to 18 in the country. At the time, the faculty members were suspicious of federal funding as they felt it might result in control of university processes. However, with growing federal support for universities in the 1950s, this philosophy changed at Stanford. A major force for this change was Fred Terman, who strongly embraced federal funding.

Fred Terman

Terman grew up on the Stanford campus, the son of Professor Lewis M. Terman, the psychologist who developed the Stanford-Binet intelligence quotient [12]. He earned a Bachelor's Degree in chemical engineering and Engineers Degree in electrical engineering at Stanford, and then in 1924, a doctorate at MIT under Vannevar Bush. He returned to Stanford as Assistant Professor in 1927 and became head of the Electrical Engineering Department in 1937. He became well known for a series of textbooks on radio engineering. During WW II, Terman organized an 800-person government laboratory at Harvard University to develop anti-radar devices. He returned to Stanford in 1946 as Dean of Engineering and in 1955 became Provost. He and President Sterling proved a remarkably effective team at transforming Stanford.

Federal support grew rapidly and represented about 40% of Stanford's operating budget by 1960 [11]. This, combined with funding from the Ford Foundation, radically transformed Stanford. Terman promoted a philosophy of "steeples of excellence," which the university used to attract outstanding faculty, often in areas where the university had little expertise previously. The Environmental Engineering and Science program was an outcome of these efforts. By the early 1960s Stanford was ranked in the top handful of universities, and by the 1980s, certainly in the top 10 [11].

The Water Resources Program

The first water-related area to grow in the Civil Engineering Department following the end of WW II was the water resources program. The first faculty appointment was Jack Vennard in 1946. He received an S.B. degree in 1930 and an S.M. degree in 1932 in civil engineering from MIT [13]. He remained there for research and teaching until 1935 when he became a faculty member and head of the fluid mechanics program at New York University. In 1940 Vennard published with John Wiley & Sons *Elementary Fluid Mechanics*. This was the first of many editions of this classic and widely used textbook. In 1946, Vennard joined Stanford's CE faculty as Associate Professor of Fluid Mechanics. Following the retirement of Prof. Reynolds in 1950, Joseph Franzini was hired to continue an emphasis in hydraulic and sanitary engineering. Franzini obtained a bachelor's degree in 1942 and a civil engineer degree in 1944 from Caltech, and had just completed a Ph.D. at Stanford in 1950 when he was hired. In the same year, Ray Linsley, a hydrologist, joined the faculty as an Associate Professor [14]. He received a B.S. in civil engineering from Worcester Polytechnic Institute in 1937. He worked for three years with TVA conducting hydrologic analyses and reservoir operation studies, and then for ten years with the Weather Bureau, where he wrote a manual on "River Forcasting Methods." Just prior to joining the Stanford faculty, he had written the textbook, *Applied Hydrology*, which was published by McGraw-Hill in 1949. Linsley's background and expertise complemented that of Franzini and Vennard, providing the foundation of Stanford's water resources program.

Another faculty member of most importance to the development of the water resources program, as well as to other branches of civil engineering and several other Stanford engineering departments was Eugene L. Grant, Professor of Economics of Engineering [15]. Grant graduated with a B. S. degree from the University of Wisconsin in 1917, and in 1920 became a member of the faculty at Montana State University where he was asked if he would teach a course in engineering economics, a subject that was new to him. The agreement to do so changed his life. He became deeply interested in the subject, and with a sabbatical leave in 1927-28 earned a master's degree in economics from Columbia University. In 1930 Grant was invited to join Stanford's CE Department by Professor J. C. L. Fish, the Department Head, who was due to retire in about five years and wanted a faculty member who would continue Fish's work in engineering economics. Grant was asked to also teach an elective course in statistics. The year 1930 was also when Grant's textbook on *Principles of Engineering Economy* was first published; when he died in 1996 it was in its eighth edition. His textbook on *Statistical Quality Control*, first published in 1946, was in its seventh edition. He also authored *Basic Accounting and Cost Accounting* in 1956, and co-authored *Depreciation* in 1949 and the *Handbook of Industrial Engineering and Management*.

Grant was the Executive Head of the Department of Civil Engineering from 1947 to 1956, during the formative years of the water resources program, and had much impact in its structure and emphasis. Grant was also directly or indirectly responsible at Stanford for the development of the Departments of Industrial Engineering, Engineering Economic Systems, and Operations Research. These three departments were joined together in 2000 into a single department of Management Science and Engineering.

The team with Vennard, Franzini, Linsley and Grant lead to the formation of a broader water resources program in the CE department that included social, political, and economic factors affecting public works, as well as the more traditional technical aspects of project design. School of Engineering requirements often discouraged program access by hydrologists in the School of Earth Sciences. However, Stanford offered an interdepartmental degree program that provided a method to get around this problem, and so within it, the graduate Hydrology Program was developed. This program had its own set of Ph.D. requirements so that students with background in either earth sciences or engineering could join the program and obtain their degree without all the required prerequisites by their original disciplines. Linsley and Stanley Davis, a hydrogeologist in the School of Earth Sciences, led this program. In 1959, En Yun Hsu was added to the CE program to increase the strength in fluid mechanics. Hsu received a B.S. degree in 1937 from Tsinghua University in China and M.S. and Ph.D. degrees from the University of Iowa, the latter in 1950. He had much industrial experience, particularly with Lockheed Missile and Space program before joining the CE faculty.

It soon became apparent that the water resources program critically lacked expertise in water quality. While Franzini was fulfilling the teaching role in this area, a more concentrated effort was needed. With Stanford seeking to develop steeples of excellence, addition of such expertise to strengthen the water resources program became a logical target. A search began for a senior individual to head this discipline. This led to Rolf Eliassen, then a professor at MIT who headed the sanitary engineering program there, and in1960 was acting head of MIT's Department of Civil and Sanitary Engineering.

The MIT Sanitary Engineering Program

Rolf Eliassen [17] obtained B.S. (1932), M.S. (1933), and Sc.D. (1935) degrees from MIT [16]. He worked in practice until 1939 when he became an Assistant Professor at the Illinois Institute of Technology, and then in 1940 he moved to New York University where he became an Associate Professor of Sanitary Engineering. During WW II he served four years as a Major, and then returned to NYU until 1949, when he left to Head the Sanitary Engineering Division of the CE Department at MIT [16, 17].

Perry McCarty received a B.S. degree in civil engineering from Wayne State University, and in 1957 an M.S. degree in sanitary engineering from MIT. Subsequently, two faculty members left the program for retirement or to teach elsewhere. While then pursuing the Sc.D. degree, McCarty was invited to become an instructor to teach sanitary chemistry and to jointly teach a design course with Eliassen. When another faculty member decided not to return in 1959, McCarty had fortuitously just received his Sc.D. degree and accepted an offer made to become an Assistant Professor there.

Increasing funds were then becoming available from the U.S. Public Health Service for establishing new sanitary engineering programs and laboratories at universities throughout the country. The field of sanitary engineering was changing rapidly, and a broader, more interdisciplinary educational approach became an apparent need. The fluid mechanics and hydrology faculty in civil engineering at MIT were the logical group to work with more closely, but they were located in a far removed building across campus, and had a course requirement structure that all but excluded the possibility for cross over by the graduate sanitary engineering students. There was little, if any, desire on the part of the fluids faculty to change the program. Eliassen's interests were changing towards policy issues in water, and McCarty was greatly concerned that MIT's sanitary engineering program was much too narrow to fit well with the growing environmental needs in water. Little opportunity seemed available at MIT either to expand the program faculty or to gain support within the civil engineering department itself or with other departments at MIT. For these reasons, when Stanford made Eliassen an offer to join Stanford's much broader water resources program and to add a water quality component to it, he accepted.

Stanford's Graduate Environmental Engineering Program Emerges

In order to develop a water quality effort, Stanford received a matching grant from the U.S. Public Health Service in 1960 to help remodel building 520, one of the original high single story engineering laboratories, by separating it into two floors, and to build a sanitary engineering laboratory on the second floor. The total cost of the laboratory was estimated at $200,000, with $96,835 coming from the U.S. PHS and the remainder from a gift to aid in the remodeling of the building by George Havas. Together with this new laboratory, Eliassen was offered the possibility to bring two new faculty members along with him to begin a new sanitary engineering program. He asked McCarty in 1960 if he would come with him to Stanford to help build a program with a broader vision offering opportunities in water resources with a complement of social, political, and economic factors. This was just the type of program that McCarty felt was in great need and he accepted the offer immediately without hesitation. McCarty told his wife that evening that they were moving to Stanford. Fortunately she accepted immediately as well. It was quite a change in direction to take in one short eight-hour period.

The plan was for Eliassen to leave MIT in the fall of 1961 to lay the groundwork for the program at Stanford. The new laboratory would be under construction then in building 520, with completion set for fall of 1962. McCarty would then follow and join the Stanford program in the fall of 1962.

After arriving at Stanford, Eliassen chose a second new faculty member for the program, Paul Kruger, a chemist with much experience in nuclear chemistry. This certainly was not a typical area of great concern in water quality control, but was of growing interest and an area that Eliassen had actively developed himself while at MIT. His research there was concerned with ways to complex high-level radioactive wastes into ceramic materials for long-term safe storage. Kruger had a B.S. degree in chemistry from MIT and a Ph.D. from the Institute of Nuclear Studies at the University of Chicago. Kruger then worked for industry, conducting research on radioactive fallout from nuclear explosions. In addition to understanding nuclear contaminants in water, he had expertise on the use of nuclear methods for chemical analyses. Kruger's interest was also in working with Linsley to add an experimental water quality component to hydrological modeling.

With that addition, both McCarty and Kruger arrived at Stanford in 1962, and the Stanford program in environmental engineering and science was born. Interestingly, the original vision they had was that the graduate program in sanitary engineering, the recognized name for water quality control programs then, would have no more than 10 total graduate students. This was about on par with the number of M.S. degree seeking students that the MIT program had. The laboratory was designed with this number in mind, but time proved that this part of their vision was extremely faulty - the program rapidly grew well beyond that number.

The Early Years

McCarty found that Stanford, with its flexibility and cooperative attitude available throughout the university, was the ideal place to transform the narrow traditional graduate sanitary engineering curriculum fostered at most universities into a broad interdisciplinary program open to B.S. graduates from all branches of engineering and science. Stanford was also growing more flexible and presented few barriers for the faculty to allow graduate students to obtain an M.S. degree by electing courses outside of the traditional sanitary or civil engineering fields, and indeed many appropriate courses were available throughout the university. The new program, which took advantage of the opportunity afforded, featured a core of traditional environmental engineering and science courses together with selective relevant courses from other departments and schools. The program was advertised as part of a broad environment and water studies program with many linkages between the new sanitary engineering and the existing water resources programs. The result was very attractive to many M.S. applicants - the program was an immediate success.

During the six years following its start in 1962, the program grew rapidly with many more students than originally expected. The number of sanitary engineering M.S. candidate students in the first class (1962-1963) was 10. Eliassen taught two graduate and one undergraduate courses: CE270, Water Quality Control I (12 students); CE272, Water Quality Control II (11 students); and CE170, Man and His Environment (30 students). McCarty taught three graduate courses and one undergraduate course: CE272, Water Resources Chemistry (9 students); Water Resources Microbiology (7 students); a laboratory course, CE274, Water Quality Control Processes (7 students), and CE166, Elements of Sanitary Engineering (9 students). Also, sanitary engineering graduate students immediately began selecting a broad range of elective courses, such as in Industrial Engineering (Operations Research), Electrical Engineering (Systems Analysis), Law (Water Law), Business Administration, Political Science, Economics, Statistics, Mathematics, and Chemistry, as well as Biochemistry and Medical Microbiology from the School of Medicine. In addition, students in water resources planning began taking many of the graduate EES courses then offered. Unlike the former MIT sanitary engineering program, where M.S. graduates essentially had the same background and skills, those from Stanford had a diversity of backgrounds and skills, and were collectively capable of filling a broader range of needed capabilities that were required to address environmental problems of growing complexity.

By the end of the first academic year, Eliassen already had 4 Ph.D. candidates to supervise and McCarty had 3. During the first year, the laboratory was near its capacity. Within a few years the capacity was greatly exceeded, and the student body continued to grow. Eliassen's undergraduate course, Man and His Environment, was being well received and had 40 students from many

different departments, including some interested in the Peace Corps. By the third year there were several M.S. students and 16 Ph.D. candidates, well beyond the 10 that had been envisioned as maximum when the program was formed.

This unexpectedly rapid growth presented problems - the staff had not anticipated such large groups in the laboratory courses in designing the laboratory. Two sections of each laboratory course had to be given by McCarty. Several students from other departments contributed to the increased loads in the various classes. This indicates both the success of the interdepartmental emphasis at Stanford, as well as the difficulty of accurately anticipating class sizes. There was no desire to prevent a good flow of students, the interchange helped to broaden the outlook of the sanitary engineering students and introduced them to water quality problems of interest in other departments. However, additional equipment and supplies were needed to adequately handle all of the students.

Another concern was that applications for doctoral work flooded in from all over the world. However, only one foreign Ph.D. student could then be accepted because the facilities and faculty numbers were hardly able to handle even the well-qualified United States students who applied. The PHS had already expanded its support for the program, because of the growing need, by providing supplemental funding and an additional training grant in nuclear chemistry, taught by Professor Kruger. And yet, there was glaring need for more support.

Faculty Evolution

Table 1 contains a list of Stanford EES faculty members during the first 50 years of the program's existence. In 1968, McCarty took a one-year sabbatical leave to study with Prof. Werner Stumm, who was then at Harvard University. George Tchobanoglous was then a Ph.D. student working with Eliassen, and consented to take an appointment as an Acting Assistant Professor to teach McCarty's courses while away. Upon McCarty's return, Eliassen decided that he himself preferred not to teach graduate courses any longer, but to concentrate on his increasingly popular elective undergraduate course, Man and His Environment. To help with the graduate teaching load, Prof. Tchobanoglous agreed to continue teaching and took charge of Eliassen's former graduate water and wastewater treatment courses.

However, Stanford's policy was that an Acting Assistant Professor was a temporary position that could be held no longer than two years. Generally, it was awarded to a new assistant professor who had not yet completed Ph.D. requirements. In order to keep Tchobanoglous beyond this two-year period, or to conduct a search for a new assistant professor to help with the growing graduate program, a request was made to Engineering Dean Joseph M. Pettit to provide a new tenure-line faculty position for EES. However, Pettit stated that he considered the growing concerns for the environment to be a short-term fad and so did not give approval. In 1970 when finishing his Ph.D. research, Tchobanoglous received an offer for a faculty position at the University of California, Davis. Without clear opportunity at Stanford, he accepted. His leaving caused the EES program to become further understaffed, and so another alternative was sought.

Table 1. Stanford Environmental Engineering and Science Faculty Members

Name	Year Appointed	Year Retired or Left	2013 or Final Position
Eliassen, Rolf	1961	1974	Silas H. Palmer Prof.
McCarty, Perry	1962	1999	Silas H. Palmer Prof.
Kruger, Paul	1962	1986	Professor
Tchobanoglous, George	1968	1970	Acting Assistant Prof.
Leckie, James (Jim)	1970		C. L. Peck, Class of 1906 Prof.
Young, Lily	1972	1981	Assistant Prof.
Masters, Gilbert	1974	2002	Professor
Reinhard, Martin	1976	2012	Professor
Roberts, Paul	1976	2000	C. L. Peck, Class of 1906 Prof.
Zehnder, Alexander	1980	1981	Acting Assistant Prof.
Grbić-Galić, Dunja	1983	1993	Associate Professor
Hildemann, Lynn	1989		Professor
Spormann, Alfred	1994		Professor
Criddle, Craig	1998		Professor
Luthy, Richard (Dick)	2000		Silas H. Palmer Prof.
Boehm, Alexandria (Ali)	2002		Associate Prof.
Davis, Jennifer (Jenna)	2006		Associate Prof.
Mitch, William (Bill)	2013		Associate Prof.

While at Harvard, McCarty came to better know James Leckie, one of Stumm's Ph.D. students. Jim had received a B.S. degree in civil engineering from San Jose State University. Indeed, in the early 1960s Leckie worked briefly in Stanford's EES laboratory to help with water quality sampling and analysis for an advanced treatment pilot plant study ongoing at the Palo Alto wastewater treatment plant. The objective of that study was to find a method for removing nitrogen and phosphorus from the treated wastewater so that it could be transported and used to supplement Stanford's Lake Lagunita, allowing it to remain open year around for swimming and boating. The process worked, but was never put into practice. Following Leckie's completion of Ph.D. studies at Harvard, he accepted a temporary assistant professor position at San Jose State University. He had the background and expertise needed at Stanford, and so was invited to accept the Acting Assistant Professor position soon left vacant by Tchobanoglous's leaving. Leckie accepted the offer and left San Jose State in 1970, even though for another temporary position.

Funding was needed for this temporary position, and so McCarty applied for this from the new Federal Water Pollution Control Administration, which was formed in the Department of the Interior by transfer of water related activities from the PHS in 1966. The funding was provided, indicating the value the federal government placed on Stanford's EES. With additional pleading, Dean Pettit finally agreed to provide a tenure-line incremental assistant professor position for the

program. A search for an individual to fill this new position was then conducted, as required by the university, with Leckie emerging as the obvious winner.

The Stanford EES program continued to grow, and this, combined with other changes that were occurring, made it increasingly important to have additional faculty. Kruger, who had been teaching nuclear chemistry, became interested in a new program termed Project Plowshare operated by the Department of Energy, which strove to use nuclear explosions for peaceful purposes, shifting his research and teaching interests in that direction. This caused a further decline in environmental engineering course offerings.

An opportunity opened when Stanford began an affirmative action program to attract highly qualified women to faculty positions at Stanford. A potential for such an appointment was Lily Young, another Ph.D. student at Harvard. Lily studied under Prof. Ralph Mitchell, a microbiologist, and was interested in joining the Stanford EES program. Faculty appointment papers were prepared, approval was granted by the university, and Young joined the EES program in 1972.

Shortly after joining the Stanford faculty McCarty met George Parks, Professor of Mineral Engineering and Geochemistry in the School of Earth Sciences. George was an MIT graduate, and although in a field quite different from sanitary engineering, he had physical and chemical process interests similar to McCarty's in microbiology. They felt a joint need for a course in surface chemistry, and so asked Eric Hutchinson, Professor of Chemistry, if he would teach one for them, which he did. This illustrates best how simple and effective it was at Stanford to collaborate interdepartmentally.

Just as Leckie was arriving at Stanford, NSF issued a call for interdisciplinary projects through a new initiative called RANN (Research Applied to National Needs). Parks and one of his colleagues, Prof. Frank Dickson, had mineralogical experience with mercury, an element of growing concern since the Minamata disease outbreak in the 1950s. The New Almaden old mercury mines were a source of mercury pollution in local streams, and presented a research problem needing to be addressed. An Exploratory and Planning Proposal with Parks as Project Director, and Dickson, Leckie, and McCarty as Co-Principal Investigators was submitted to NSF in May, 1971, and accepted. This began a significant interdepartmental collaboration at Stanford. However, the NSF project director wanted program directions to change every few months. Congress often sent letters asking who was making use of the research findings, and how much money the country had been saved by the research? But the research was just getting underway. After a couple years, the Stanford group felt research could not be done in this manner and so rejected further funding for it. While this was not a pleasant ending as far as funding was concerned, the joy of participating in and learning from interdisciplinary research was felt. The interest in doing more of such cooperative research was established.

Early Environmental Engineering and Science Faculty members from top row, across, and down: Rolf Eliassen, Perry McCarty, Paul Kruger, George Tchobanoglous, James Leckie, Lily Young, Gilbert Masters, Paul Roberts, and Martin Reinhard.

More recent Environmental Engineering and Science Faculty members, from top, across, and down: Alexander Zehnder, Dunja Grbić-Galić, Lynn Hildemann, Alfred Spormann, Craig Criddle, Alexandria Boehm, Richard Luthy, Jennifer Davis, and William Mitch.

In 1974, Eliassen decided to retire. By this time a general interest in the environment was growing nationwide, and Eliassen's course was attracting a third of Stanford's undergraduates. It was a course the EES program did not want to lose. Fortunately, a perfect fit to teach the course had become available, Gilbert Masters.

Masters earned his B.S. and M.S. engineering degrees from UCLA in 1961 and 1962 and his Ph.D. in electrical engineering from Stanford in 1966. After two years at Fairchild Research Labs (during which time colleagues spun off Intel) and a year as an Assistant Professor teaching computer design at the University of Santa Clara, he found his career path unsatisfying and decided to follow Timothy Leary's advice to "tune in, turn on and drop out." And then along came Earth Day 1970, at which point Masters decided that that was the future he wanted to pursue. Living in his Volkswagen bus, he sat in on most of the environmental courses that Stanford offered at the time, including Eliassen's CEE 170: Man and His Environment. The University of Santa Clara then hired him back in 1971 to teach an undergraduate environment course similar to Eliassen's, which he did for several years. While doing so, he wrote an entry-level textbook on environmental science and technology, published by Wiley in 1974.

When Eliassen decided to retire, Stanford asked Masters to take on CEE 170 as a part-time Lecturer, which he was ready and eager to do. Under his direction, the course continued to grow in popularity, reaching a peak enrollment at one point of almost 600 students (meeting at 8:00 am, no less, to control enrollment). Over time, his title changed from Lecturer, to Adjunct Professor, to Professor (Teaching). His textbook *Introduction to Environmental Engineering and Science*, now in its 3rd edition, has become one of the most widely used environmental textbooks around the globe, with Chinese, Korean and Spanish translations as well as a special Indian Subcontinent edition. Masters continued to teach this course until his retirement in 2002, but the course continues now as CEE 70 under the able instruction of Royal Kopperud.

The 1970s was an exciting time for those with interest in the environment, beginning with the first Earth Day in 1970. There was little technical information that might be useful for addressing environmental issues at the local level, and so Leckie, Masters, Harry Whitehouse, a mechanical engineer, and Young decided to create a SWOPSI course (Stanford Workshops on Political and Social Issues) called "Designs for Alternative Lifestyles." It was immensely successful and led to their writing a textbook that would address activities that the ordinary citizen could do to improve their local environment, such as home architecture, renewable energy generation, water and wastewater treatment, agriculture, and aquaculture. They proposed Better Homes and Garbage as the title of this new book, but the magazine Better Homes and Gardens objected. Thus, they changed the title to Other Homes and Garbage: Designs for Self-Sufficient Living, and the Sierra Club published it in 1975. It was an instant hit and was adapted by many universities for the growing number of undergraduate environment-and-energy related courses being developed. They later produced an expanded edition, which was published in 1982 and titled this time, More Other Homes and Garbage: Designs for Self-Sufficient Living.

Out of the original SWOPSI course, in 1975 Masters created CEE 176, originally called Designs for Alternative Lifestyles and later changed to Small-Scale Energy Systems. The idea was to connect environmental problems driven by energy demands to solutions that were emerging in the area of

renewable and efficient energy systems. That course continued to grow over the ensuing decades into two courses: Energy-Efficient Buildings and Electric Power: Renewables and Efficiency.

Expanded research and need for more space.

The original laboratory facilities were clearly incapable of accommodating both the expanded research and teaching activities. In order to help meet the need, the CE Department gave the EES program an unused concrete laboratory, which was converted into the new teaching laboratory so that use of the original laboratories could be reserved just for research. However, laboratory benches and equipment for this space was needed, and some discarded equipment from the Medical School was found. A group of volunteer fundraisers for the University happened to be making a tour of Stanford facilities to learn of University needs, and came to visit the teaching laboratory. As an indication of the sorry state of the facilities, one of the fundraisers reported on this to Lucille Packard, wife of David Packard of the Hewlett and Packard Company. Mrs. Packard gave $5,000 to EES to fix up the poor teaching laboratory facilities. While that may seem little today, it was a great benefit, allowing the purchase of a refrigerator for BOD analysis, an incubator, and a few other items of great importance. However, space continued to be a pressing issue.

A significant research opportunity arose in 1974 - the Santa Clara Valley Water District approached the EES program to explore a possible joint interest in studying the movement and fate of chemicals in highly treated Palo Alto domestic wastewater intended to be injected into the aquifer near San Francisco Bay. That provided an attractive opportunity for EES to become a leader in the evaluation of remaining organic chemicals in treated wastewater. By 1976 sufficient studies had been conducted, research proposals were prepared and submitted, and finally, research funds were obtained from the U.S. Environmental Protection Agency to begin studies. Not only had sufficient funds been obtained to evaluate the movement and fate of organic chemicals at the Palo Alto site, but also for evaluating the effectiveness of Orange County Water District's new Water Factory 21 in Southern California. Water Factory 21 was the first treatment plant anywhere to use reverse osmosis for effluent polishing. This followed use of chemical treatment, air stripping, multimedia filtration and activated carbon adsorption of biologically treated wastewater from the Orange County Wastewater Treatment Facility.

The greatly expanded research activities again necessitated new staff. One very attractive individual to help direct the Palo Alto project was Paul Roberts, who was then on the staff and head of the Engineering Department at the EAWAG, a water and wastewater institute at the Swiss Federal Institute of Technology (ETH) in Switzerland, then headed by Dr. Werner Stumm, who was formerly at Harvard where he was also Leckie's Ph.D. advisor. Roberts had received a Ph.D. in chemical engineering from Cornell University, and then worked for several years, one of his later jobs was with SRI in Menlo Park. However, he lost interest in working for the chemical industry and wanted to turn to the environmental sector. He took advantage of the Honor's Cooperative Program in Stanford's School of Engineering, allowing him to study part time towards an M.S. degree in environmental engineering, which he completed in 1971, the year he left SRI and joined Stumm's program in Switzerland.

At the time when Roberts was offered a Research Professorship at Stanford (the only appointment that the Dean's Office would allow) he was head of Stumm's engineering program. Stumm countered by offering him a full Professorship at ETH. While this caused hesitation, Roberts finally decided to join Stanford and head up the Palo Alto wastewater reuse study. This involved advanced treatment of Palo Alto wastewater in a one million gallon per day pilot plant, and then injection into the groundwater. The Stanford effort was concerned primarily with the movement and fate of remaining organics in groundwater. To do this required detailed organic analyses, which had just become possible through the invention of gas chromatography-mass spectrometry (GCMS) for analysis of complex organic matter.

No one in the EES program had expertise in GCMS analysis, and indeed the program did not have the equipment for the analysis. Prof. Carl Djerassi in the Chemistry Department had a high-level GCMS system and agreed to let EES use it. Unknown was that Djerassi's equipment was unsuitable for analysis of complex wastewaters, but EES naively advertised for a GCMS expert. A graduating Ph.D. from MIT's chemistry department applied, visited Stanford, looked at Djerassi's system, listened to the need, reviewed EES facilities, and left, never to be heard from again - a sign of trouble.

Roberts, still at ETH, was asked for advice. Stumm had a graduating Ph.D. student, Martin Reinhard, who had expertise in the kind of GCMS system that was needed and so was offered the job at Stanford as a Research Associate, and he accepted. Reinhard had been working with Prof. Kurt Grob, who taught him how to make and use capillary columns for GCMS analysis, and also how to concentrate trace organics from water to make sensitive and accurate analyses. He brought this technology to the U.S., and even conducted classes on how to make the columns, once with the participation of Prof. Grob himself. However, when Reinhard arrived at Stanford and saw the facilities, he too felt like the MIT graduate, and wondered why he had accepted the position, sight unseen. He immediately indicated that the proposed study could not be accomplished without a proper GCMS instrument, which was too expensive for the budget. But one could be obtained with a lease-buy agreement costing about $25,000 per year, which was scraped together by 1976. With the facilities and staff now available, research in trace organics, wastewater reuse, and groundwater began.

However, success came with a major problem. Collectively, with several new research grants, staff, faculty, and students, space was inadequate to put it all. The Dean's office had allowed further expansion into a former engineering mechanics laboratory in Building 521, but this was still totally inadequate. With inadequate control of hazardous chemicals and with electrical wires scattered around the lab, the staff was operating under dangerous and likely illegal conditions. The Dean's office offered little help. Becoming discouraged, McCarty seriously considered an invitation from the University of North Carolina, Chapel Hill, to become Director of their program, and discussed this possibility with the Dean. Opportunity sometimes comes when needed. William Hewlett and David Packard had just given funds for a building to honor their former professor, Fred Terman. A decision was being made by Dean Kays on what activities should be put there. He wondered if EES would accept having a new laboratory in the new building? That offer was quickly accepted.

The Terman Engineering Center Years

The Terman Engineering Center was functional from 1977 to 2008, a period of 30 years. It was in Terman that the environmental engineering and science program saw some of its greatest growth in both students and faculty numbers. Research activities also expanded rapidly as the needed high quality laboratory space and equipment quickly became available. Moving into the new building were Professors McCarty, Kruger, Leckie, Young, Masters, Roberts, and key staff members, Martin Reinhard, soon to become a Professor Research, and Gary Hopkins, a Research Technician who was largely responsible for the successful development and operation of most of the major field projects undertaken during the Terman years.

Environmental and Water Studies 1977 spring picnic.

The major objectives of the Palo Alto and Orange County field projects were to evaluate the trace and hazardous organic compounds that may remain in highly treated municipal wastewater, and to better understand the potential health risks from use of reclaimed wastewater for domestic use. The Orange County project was to obtain information on what organics remained after advanced treatment through reverse osmosis, while the Palo Alto project was to investigate the movement and fate of remaining organics as the water was injected into groundwater. Important among the findings was the relatively high concentrations of toxic chlorinated solvents and BTEX compounds (benzene, toluene, ethylbenzene, and xylene) that remained in the highly treated wastewater. Also of significance was the finding that chlorinated solvents disappeared as treated water moved through the ground. Studies to evaluate the reason for the disappearance of these compounds, which was highly unexpected as the literature indicated they were biologically refractory, led to the finding of anaerobic degradation through reductive dehalogenation. Shortly after finding of soil contamination in a schoolyard near Love Canal, the federal government launched a Superfund program that provided major funding for groundwater contamination research. The Stanford

program was already at the forefront in understanding of the issues involved, and so the focus of the research program was switched from water reuse towards understanding of the movement, fate, and control of toxic compounds in groundwater.

In 1979, Young took a year leave-of-absence to join her husband, who had received a faculty appointment at New York University. At the end of that year, she was offered a Research Associate Professor at the New York University Medical Center, which she accepted. Alexander (Sasha) Zehnder, a recently graduated environmental microbiologist from ETH, a well-known individual to Stanford faculty, was invited to fill Young's spot for the year, and he accepted. A permanent replacement for Young was then requested and a search was began.

Just before Young took her leave-of-absence, she had accepted an application from Dunja Grbić-Galić, a post-doctoral graduate in microbiology from the University of Zagreb, to study the anaerobic degradation of aromatic compounds. But Young then left for New York, and so - had no one available for direct advice on her research. She also had no training with advanced instruments of any type, but quickly became competent at GCMS analyses and anaerobic microbial techniques. When she gave a seminar of her research after one year in the spring of 1980, what she had accomplished during her Stanford year startled everyone.

Grbić-Galić had returned to Yugoslavia before the faculty search commenced, but she applied for the position. While her Zagreb research was quite primitive, largely because of the lack of research facilities there, her outstanding capabilities displayed while at Stanford convinced the faculty that she was the correct choice and it strongly recommended her for the position, which was reluctantly accepted by the administration. She became an assistant professor in 1983, proved her competence, and excelled in research. One of her major accomplishments was the finding and then proof that BTEX compounds can be biodegraded anaerobically, a finding that contradicted the long-held belief by biochemists. Xylene's disappearance in anaerobic waters had been observed earlier by Reinhard, but journal reviewers did not accept his belief that it was the result of anaerobic biodegradation. Grbić-Galić's later definitive proof of anaerobic biodegradation was an important scientific discovery as it explained why BTEX compounds were disappearing in groundwater everywhere, even when oxygen was not present. This justified reducing the very costly external efforts to engineer the removal of BTEX pollution from groundwater rather than let nature take its less costly approach.

In 1980 McCarty was picked by the Dean to become the next Chairman of the Civil Engineering Department, following eight years of Chairmanship by Bob Street. He served in this capacity for five years, and then decided that was sufficient and stepped down so that he could concentrate more on research.

Up until 1989 the EES program concentrated on water issues, largely because of the small faculty size. Expanding into other areas would have reduced the depth in water, which did not appear advisable. However, in 1989 the EES program was given the opportunity to expand into air pollution through the addition of a new faculty member, Lynn Hildemann. She had B.S., M.S., and Ph.D. degrees from Caltech, where she specialized in theoretical and experimental research on regional air pollution problems. Later, the environmental fluid mechanics and hydrology

program, the other component of Stanford's Environmental and Water Studies Program, added a faculty member with specialty in global atmospheric problems, Mark Jacobson, complementing Hildemann's research and teaching in air quality.

Susie Stone together with the CEE Departmental Chairmen she had served. Left to right are: Stephen Monismith, Jeffrey Koseff, Haresh Shah, Susie Stone, Robert Street, Perry McCarty, Bob Tatum, and Richard Luthy.

Another advance in the EES program in 1989 was the establishment of the Western Region Hazardous Substance Research Center, one of the five such centers established through a competitive process by the U.S. Environmental Protection Agency. The Center was a cooperative activity between Stanford and Oregon State University. McCarty served as Center Director and Kenneth Williamson, a Stanford Ph.D. graduate and OSU Professor, served as Director in charge of training and technology transfer activities. The objective of the WRHSRC was to promote through fundamental and applied research the development of alternative and advanced physical, chemical, and biological processes for treatment of hazardous substances in the surface and subsurface environments. The Center remained at Stanford through 2001, when the initial program ended. Extensive studies on groundwater contamination were conducted by the Center, which over the nine year period expanded the total EPA support of about $12.6 million to $31.7 million through cooperative grants and contracts from other governmental and industrial groups. The Center supported 21 faculty and 4 staff members who represented an integral research team representing five different schools (engineering, science, earth sciences, medicine, and veterinary medicine), and many different disciplines (chemical engineering, chemistry, hydrogeology, hydrology, medicine, microbiology, and petroleum engineering). A total of 204 student-years of financial support were

provided by the Center to carry out research on 94 separate competitive projects, including 128 Ph.D. student-years and 27 post-doctoral scholar-years. Center activities were guided by a Science Advisory Committee and a Training and Technology Transfer Advisory Committee with external members representing government, industry, consulting firms, and academia.

Groundwater biological remediation study at Edwards Air Force Base, Gary Hopkins, Perry McCarty, Steve Gorelick.

After the ending of the original WRHSRC program, a new hazardous substance research centers solicitation was than made by EPA, and Lewis Semprini, another Stanford Ph.D. graduate and OSU Professor, put in a proposal to continue the WRHSRC, and was one of only two of the original Centers to be selected for further continuation. Unfortunately, Congress soon withdrew its support for the HSRCs, and the program lasted only a few more years. However, during its time of operation, it was highly successful in addressing some of the most difficult issues facing groundwater cleanup.

A tragic event for the EES program was that at the peak of her career and just 10 years as a faculty member, Dunja Grbić-Galić developed scleroderma, an auto-immune disease, and died in 1993. Approval was requested and then given to search for a microbiologist replacement, and Alfred Spormann became the leading candidate. Spormann was then working as a post-doctoral scholar in Stanford's Department of Biochemistry after obtaining a Ph.D. in Biochemistry from Phillips University, Marburg, Germany, where he studied under Prof. Rudolf Thauer, an expert on the biochemistry of methanogens. Spormann was offered an Assistant Professor position, and accepted.

In the late 1990s, both McCarty and Roberts decided to become emeritus professors. This would leave on the EES faculty only Leckie as an engineer with expertise in water. To correct this major deficiency, and with the very strong support of the CEE Departmental Chairman, Jeff Koseff, support was sought from the relatively new Dean of Engineering, John Hennessy, for two new senior faculty positions. A strong plea was also made for upgrading the environmental engineering

laboratories. Fortunately, following much pleading about the importance of the program, he did agree both to the two new senior faculty positions and to seeking funds for the laboratories. Hennessy indicated that funds for the laboratories might be obtained from industry, but was cautioned that industry was not likely to be interested in supporting an environmentally oriented program. After some effort, he agreed, and then funds from foundations was sought, and again through much effort, good support from the Packard Foundation and the Ford Motor Research Foundation was found. The Terman Laboratories soon took on a welcome new look.

In about 1996 a replacement for McCarty was sought, and Craig Criddle, a Stanford Ph.D. recipient and one of McCarty's former students, was offered an Associate Professor position, and accepted. Criddle had obtained a B.S. degree in civil engineering from Utah State University. After graduating from Stanford, he became an Assistant Professor at Michigan State University in their civil and environmental engineering department, but worked very closely with Prof. James Tiedje in his NSF Center on Microbial Ecology. Criddle became quite knowledgeable in molecular methods of analysis, and had become Associate Director of the Center before leaving to join the Stanford faculty.

Next sought were candidates for the Roberts position - the leading candidate here became Richard Luthy. Luthy's youth was spent in Palo Alto, moving here in 1957 and attending junior and senior high school. But rather than coming to Stanford, he attended UC-Berkeley and obtained B.S., M.S., and Ph.D degrees from there. After receiving the Ph.D. degree in 1976, he joined the Carnegie-Mellon University faculty, and worked up the ranks to become the Thomas Lord Chair Professor of Environmental Engineering in 1996. He served as Head of the Department of Civil and Environmental Engineering there from 1989-1996. From 1996-97 he came to Stanford as the Shimizu Corporation Visiting Professor, and came to know Stanford quite well. Luthy was offered a full professor position at Stanford, and after some soul searching, decided to leave Carnegie-Mellon University and join the faculty here. He soon took on the Silas Palmer Professor of Civil and Environmental Engineering position. After urging the whole Department, not just environmental engineering and science, to take on sustainability as a theme, the Dean appointed him as Chairman, a position in which he served until 2009.

In 2000 the EFMH faculty were searching for a new faculty member. One applicant, Alexandria Boehm (Ali) did not fit the specifications of the search, but instead offered a new direction for the Department that fit as an exceptional bridge between EES and EFMH. Boehm received a B.S. degree in Applied Science from Caltech, and conducted graduate studies at UC Irvine, earning a Ph.D. in Environmental Engineering in 2000. Her research on water quality in coastal waters addressed the influence of hydrodynamic forces on sanitation. This was a mix of talents that had long been desired. Approval for her appointment to the faculty was sought and fortunately obtained. Boehm is officially a member of the EES faculty, but participates in teaching and research on both sides. Ali has added an excellent component on field research in both her teaching and research.

The New Millennium

Prompted in part by declining undergraduate student enrollment in Civil and Environmental Engineering (CEE) and the potential impact of external factors (such as the Earth Systems Program and formation of the new Bioengineering Department) on the CEE Department, a task committee chaired by Luthy was formed in 2002 to study the undergraduate program offerings in CEE. This effort included a review of the curriculum, interviews with undergraduates, and reflection on the future directions and challenges in CEE, and resulted in a comprehensive report and faculty retreat in May 2003 [19]. The review and discussions occurred at a time when the CEE department, and many CEE departments were struggling for identity as the diverse sub-specializations led to fragmentation of departments.

Civil and Environmental Engineering 2006 faculty retreat.

CEE is a broad field, encompassing areas ranging from biochemistry of ground water and coastal margins to computational mechanics and integrated design/construction of civil infrastructure. Early on, the committee crafted a mission for the department around the theme of "Engineering for Sustainability" –which focused and articulated the important role CEE had in addressing the critical needs of society. While sustainability is much in the news today, back in 2003 it was an emerging concept. Tom Friedman was still making the final edits on "The World is Flat"

(he had not yet conceived of the sequel – Hot, Flat and Crowded), and Al Gore's "Inconvenient Truth" was still a couple years in the future. The outcome was the recognition of the connections between the built and the natural environment, and that CEE would be stronger by addressing the fact that important activities in the 21st century will include sustaining the environment and the natural cycles on which all life depends, while providing the necessities for human life, including energy, shelter, food, water, and clean air in more efficient and renewable ways than today. This need was an important challenge that served as rallying point for the CEE profession and the CEE department. The theme was embraced by CEE faculty in 2004 as a future plan for focusing teaching and research, and served as the basis for the Department's 2006 "Mission, Goals and Vision" [20}. Thus, beginning in 2002, the EES program and the Department was at the forefront and helped lead a wave of re-invention to make civil and environmental engineering relevant to the needs of the 21st Century.

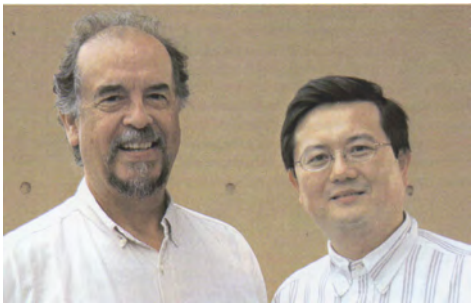
Asian Activities

Because of initial requests from Asians, several cooperative programs were begun in Asia by the EES faculty at the turn of the Century. First was the Singapore-Stanford Partnership that was started by Leckie in 2003. This was a joint effort between Nanyang Technological University's School Civil & Environmental Engineering and Stanford's EES program. The purpose was to help build a world-class environmental engineering and science program at NTU. Many Stanford faculty from both EES and environmental fluid mechanics and hydrology programs were involved in the joint teaching effort between the two schools. Classes were videoconferenced between the two universities, and NTU students attended a summer educational program at Stanford. This highly successful program was continued for six years, during which many NTU graduates received educational experiences with Stanford faculty and courses. An important outcome of this program was the establishment of the current Stanford Environmental & Water Studies Summer Program, which offers a group of courses to both matriculated Stanford students and non-matriculated students from all over the world.

From 2004 to 2007, four EES faculty - Luthy, Leckie, Criddle, and McCarty - were named Chaired Professors at Tsinghua University in Bejing, China, and each year taught a course together on Hazardous Chemicals in the Environment – Movement, Fate, and Removal to graduate students in Tsinghua's environmental science and engineering program. Several students from this program later became Ph.D. candidates at Stanford.

In 2006, Leckie developed the Stanford-China Executive Leadership Program in collaboration with the Development Research Center of the State Council of China. The goal was "…to help the participants study sustainable development from the combined perspectives of cultural, social, economic, business and engineering, thus providing them with effective, practical means to put the vision of sustainability into execution in future business development in China." In 2009 this program under Leckie's leadership was broadened into the Stanford Center for Sustainable Development and Global Competitiveness. It maintained the aims of the former program, but expanded them to provide support to facilitate the discovery of solutions to some of China's environmental problems. This is being accomplished by its Fellows, a group of Stanford faculty, and researchers with wide-ranging expertise who will partner with Chinese industrial affiliates.

Dr. Jie Wang was appointed as the Center's Executive Director.



Jim Leckie with Jie Wang, Executive Director of Stanford-China Executive Leadership Program

In 2009, McCarty became a World Class University Professor to teach and conduct research towards anaerobic treatment of domestic wastewater with a former student, Professor Jaeho Bae, at Inha University, South Korea. The five-year appointment required spending two months per year in Korea, and was funded together with research from the Korean Research Foundation. The studies lead to successful pilot studies in Korea of the anaerobic fluidized-bed membrane bioreactor that they invented. Pilot studies on the process are now beginning in Singapore and by others in the U.S. as well.

Environmental Fluid Mechanics and Hydrology

While this report is focused primarily on the development of the environmental engineering and science program, it is clear that its success is related in a large extent to its close working relationship with the Environmental Fluid Mechanics and Hydrology (EFMH) program, the current name for the water resources program. The success is also strongly related to the surprising ease at Stanford with which one can work with other departments and faculty throughout the university, the School of Earth Sciences in particular. But it certainly was the highly successful water resources program, the forerunner of EFMH, that brought Eliassen and McCarty to Stanford. They saw the necessity for working across interdisciplinary lines to address the growing environmental problems, and that Stanford offered an excellent alternative for doing so. The ease with which this was possible at Stanford was a very welcome surprise. Soon after arrival the Stanford Environmental and Water Studies Program was developed, and is still the framework for those with an interest in environmentally-related cross-disciplinary study and research. While not the focus of this report, it is very appropriate to highlight some of the individuals involved in EFMH.

A listing of EFMH faculty members since 1962 is provided in Table 2. A notable early member with strong support and interactions with EES students and programs is Bob Street. Street became an Acting Assistant Professor in the water resources program when Eliassen and McCarty came to Stanford in 1962, and then Assistant Professor when he completed his Ph.D. requirements at Stanford. He was soon chosen to become the Associate Chair of the Department, where he quickly demonstrated his skills at administration. Thus, when Jim Gere stepped down from Chairman in 1972, Street was selected to serve as chair, which he did until 1980 when McCarty took over for five years. Street served as Associate Dean of Engineering, and Vice Provost and Vice President

of Stanford. In 1985, Street and Jeffrey Koseff founded the Environmental Fluid Mechanics Laboratory, which built on the original Hydraulics Laboratory and heralded the emergence of theoretical and experimental research on environmental fluids research in rivers, lakes and oceans. Street served as the director for five years, followed by Koseff. Stephen Monismith took over in 1996 and still serves as the laboratory director.

Prof. Len Ortolano is another of the Harvard group that joined the Stanford program in the 1970s. While interested in optimization techniques when he graduated from Harvard, he soon turned to environmental assessment and planning, comprising his most significant work at Stanford. When Franzini retired, David Freyberg, a Stanford graduate, replaced him and contributed to the hydrology offerings of the program. Shortly after that, Peter Kitanidis joined the hydrology component of EFMH. Peter received his Ph.D. from MIT, and taught previously at the University of Iowa and the University of Minnesota. His interest in groundwater hydrology and statistical analysis resulted in much collaborative research with the EES group.

Table 2. Environmental Fluid Mechanics and Hydrology Faculty Members over the Past 50 years.

Name	Expertise	Years of Service
Jack Vennard	Fluid Mechanics	1946-1969
Joseph Franzini	Hydraulics, Water Resources	1950-1986
Ray Linsley	Water Resources, Hydrology	1950-1975
En-Yun Hsu	Fluid Mechanics	1959-1986
Berne Perry	Fluid Mechanics	1957-1970
Robert Street	Fluid Mechanics	1962-2005
Leonard Ortolano	Water Resources	1970-present
David Freyberg	Hydrology	1980- present
Peter Kitanidis	Hydrology	1987- present
Jeffrey R. Koseff	Fluid Mechanics	1983- present
Stephen Monismith	Fluid Mechanics	1987- present
Mark Jacobson	Atmospheric Science	1994- present
Oliver Fringer	Fluid Mechanics	2003- present

Jeff Koseff's Stanford education was a cross product of the EES and EFMH programs. Following receipt of his Stanford Ph.D. in environmental fluid mechanics in 1983, he joined the EFMH faculty in 1984. Like Street, he became Chairman of the Department in 1995 while still quite young. He was quickly promoted from Associate to full Professor so that he could take on that job. In 1999 he was appointed as Senior Associate Dean in the School of Engineering, working with Jim Plummer, the then Dean of Engineering. This was an exceptionally good relationship for EES, which Koseff strongly supported, helping to convince Plummer and the then Provost, John Hennessy, of the program's importance. Later, through Koseff's close interactions with Hennessy, when Hennessy became President, the Woods Institute for the Environment was established, and Y2E2 became a reality. More of this is discussed later.

Environmental Fluid Mechanics and Hydrology faculty, top, across, and down: Jack Vennard, Joseph Franzini, Ray Linsley, En-Yun Hsu, Robert Street, Leonard Ortolano, David Freyberg, Peter Kitanidis, Jeffrey Koseff, Stephen Monismith, Mark Jacobson, and Oliver Fringer.

Stephen Monismith joined the environmental fluid mechanics group after receiving a UC Berkeley Ph.D. degree in 1983. His major interest in the fluid mechanics/biology interface in natural waters and the strong environmental interactions between the two has offered another strong complement to the EES program. Monismith became CEE Chairman in 2009, following Luthy's retirement from that role. Mark Jacobson joined EFMH in 1994 after receiving his Ph.D. degree from UCLA in air pollution control. Interestingly, Jacobson received his M.S. degree in environmental engineering from Stanford. While officially an EFMH faculty member, his strong interest in environmental problems is obvious. But his research is highly fluid mechanics based, and thus closely associated with EFMH overall interests, justifying his association there. Jacobson's interest is in global atmospheric problems, and his contributions towards a better understanding of climate-change phenomena have been exceptional. The most recent appointee to EFMH is another Stanford Ph.D. graduate, Oliver Fringer, also researching in environmental fluid mechanics in the water area.

School of Earth Sciences

While it is difficult to mention all the interactions that occurred between EES faculty and others throughout the university, it was the School of Earth Sciences that was of most importance. Beginning with the early Hydrology program, Profs. Stan Davis and Irwin Remson were quite interactive, especially with the EFMH faculty. Parks has already been mentioned as one of the earliest to interact with the EES faculty, and those interactions continued, especially with Leckie, throughout the period when Parks was active at Stanford. His colleague, Professor Gordon Brown, Department of Geological and Environmental Sciences, arriving at Stanford in 1986, has carried on similar interactions, particular with Leckie, and more recently with Spormann. Professor Steven Gorelick joined the School of Earth Science faculty in 1988, having obtained a Ph.D. degree here in hydrology in 1981. Because of his interest in groundwater modeling, a very close relationship was developed between Gorelick and EES, particular with McCarty. Gorelick is a member of the Department of Environmental Earth System Science. Also newer members of that Department, who interact frequently with EES faculty, especially Criddle, are the geochemical-microbiologists Scott Fendorf and Chris Francis. The numerous interactions with these and other School of Earth Science faculty have been an important part of the EES program over the Stanford years.

The Woods Institute for the Environment

The Stanford Woods Institute for the Environment is one of the broadest interdisciplinary environmental activities undertaken by Stanford in 2004 with heavy involvement of Environmental and Water Studies faculty from its formal beginnings. Since then it has been co-Directed by Koseff of the CEE-EFMH faculty and Buzz Thompson, Professor of Environmental Law. The Woods Institute is the focal point of the Initiative on the Environment and Sustainability led by Jeff, Buzz, and Pamela Matson, Dean of the School of Earth Sciences. A forerunner to the initiative was the Environmental Forum, a weekly gathering of individuals from many disciplines at Stanford to listen to invited speakers and to hold discussions of environmental interests. Little support was obtained from Stanford for expanding this effort until Hennessy became Provost and gave encouragement for the group to think more broadly. This led to forming the Initiative on the Environment and

Sustainability. When Hennessy later became President, the expansion of environmental efforts became one of his top priorities, which led in 2006 to obtaining support from Ward Woods, a Stanford graduate, and his wife Priscilla to name the Institute as the Woods Institute.

The Woods Institute is a policy center, not a department, and as such can make Academic Council appointments such as Fellows and Senior Fellows. One of its most important roles has been in recruiting environmental scholars to Stanford where they are jointly appointed between departments and the Institute. The President initially provided the Institute with a single billet to be used for this purpose. Since then, the Woods Institute has been very successful in raising endowments for a number of additional joint faculty appointments. The goal has been to seek new faculty members who can lead new interdisciplinary activities between major units in the University and the Woods Institute.

Barton (Buzz) Thompson and Jeffrey Koseff, co-Directors of the Woods Institute.

In 2004, the Woods Institute began an open search for new faculty from the broad environmental community. One person nominated was Jennifer (Jenna) Davis, who was then visiting Stanford (and in particular Len Ortolano's group) while on leave from MIT. Davis rose to the top of the Woods Institute list and the CEE department was approached with the idea of making a joint appointment. The Dean of Engineering agreed to provide a half-billet to enable her appointment. Davis conducts research on water supply and sanitation in developing countries in Africa and Asia. Her field research in this important area offered a radically new direction, one of much interest to students, and in keeping with a particular interest with the Woods Institute. Davis was offered the position, and accepted. She is currently an Associate Professor of Civil and Environmental Engineering and the Higgins-Magid Senior Fellow in the Woods Institute, and co-leads (with Steve Luby) the Woods Program on Water, Health and Development.

The Woods Institute from the outset focused on teaching and research on freshwater, land use and conservation, climate and energy, oceans and estuaries, and the sustainable built environment, areas of much interest to all of civil engineering, not only the water studies program group. It also has brought in broad interests from numerous faculty members from across the university. The important issues of energy attracted a critical mass of faculty and students, which gave rise to its own organization in 2009, the Jay Precourt Institute for Energy, and then in 2009, the TomKat

Center for Sustainable Energy, and in 2010, the Taylor Center for Energy, Policy, and Finance to push clean energy.

The Woods Institute now has about 148 fellows and affiliated faculty from Stanford's seven schools (business, earth sciences, education, engineering, humanities and sciences, law and medicine) to work on environmental and sustainability issues. The Leopold Leadership Fellowship program supports mid-career academic environmental researchers from around the world. Within the Woods Institute, are several broad Centers, the Center for Ocean Solutions - a joint venture with the Monterey Bay Aquarium and the Monterey Bay Aquarium Research Institute, the Center on Food Security and the Environment, the Global Freshwater Initiative, the Natural Capital Project, the Osa & Golfito Initiative, Water Health and Development, and Water in the West, among others. The Woods Institute is housed in the Y2E2 Building in the new Stanford science and engineering complex.

The Move to Y2E2

The Terman Engineering Center was functional from 1977 to 2008, a period of 30 years. At the end of that period, Terman was torn down, and all civil and environmental engineering activities moved to the new Jerry Yang and Akiko Yamazaki Environment and Energy Building, affectionately known as Y2E2. The reason for the demise of the Terman Building was its wood construction. Wood rot became a continuous problem, and the university decided that it was too costly to continue the repairs. A new building was the best solution. Y2E2 was the first of four new engineering buildings housed in Stanford's new engineering and science west campus; its construction was financed primarily by a gift from Jerry Yang, co-founder of Yahoo Inc. and his wife, Akiko Yamazaki. This new building not only houses the Woods Institute for the Environment, but a great deal of the faculty with interests in environment and energy from numerous disciplines and departments throughout Stanford. All of the Civil and Environmental Engineering faculty and research facilities, except for the Blume Earthquake Engineering Center, are housed in this facility. Within its stone walls, covered arcades, and red clay roof tiles, the building resembles the architectural theme of the original Stanford campus, but was designed with an emphasis on sustainability and low energy utilization. The concept of the new building was to bring faculty together from around the campus who have dedicated interests either in the environment, energy, or both so that they could more easily meet together and discuss and conduct research on problems of mutual interest. This facility illustrates well the major shift towards important environmental issues for a world with growing population and limited resources. Indeed, seeking solutions to the many difficult but important problems presented is of paramount importance for the Earth, its ecosystems, and humanity. In 2013 the United States Green Building Council conveyed a Platinum certification on Y2E2 under its LEED-EBOM program.

The 2009 Environmental and Water Studies students, faculty, and staff.

Re-inventing the Nation's Urban Water Infrastructure (ReNUWIt)

The move to Y2E2 did indeed promote interdisciplinary collaborations and open up opportunities for the EES Program. With sponsorship from the Woods Institute and the Bill Lane Center for the American West, Luthy and historian David M. Kennedy chaired dialogues in November 2008 and March 2009 on our nation's western water challenges. This brought together thought leaders from leading western utilities, industries, government agencies, universities and non-profits to discuss the breadth of issues facing water supply, management and infrastructure, and the potential role of the university in seeking solutions to these challenges. These dialogues together with a number of Environmental Ventures Projects funded by the Woods Institute were influential in the formation of the Water in the West program, a joint activity between the Woods Institute and the Bill Lane Center in which several EES faculty are actively engaged. Another outcome was the laying of groundwork for the new NSF Engineering Research Center (ReNUWIt).

With the Water in the West dialogues as background, and aging infrastructure and water scarcity as overarching themes, Luthy teamed in 2009 with colleagues David Sedlak at Berkeley and Jörg Drewes at the Colorado School of Mines to lead a proposal for an NSF Engineering Research Center on Re-inventing the Nation's Urban Water Infrastructure (ReNUWIt, renuwit.org). The Center was approved and funded by NSF and formally established in August 2011 with Stanford University as the lead institution with Berkeley, the Colorado School of Mines and New Mexico State University as partners. Now in its third year, ReNUWIt involves more than 30 faculty and more than 80 graduate students and post doctoral scholars. The Stanford contingent includes EES and EFMH faculty as well as faculty from Chemical Engineering, Environmental Earth System Science, Geophysics, Law and Business. Interdisciplinary and cross-campus teams are divided into three thrust areas: (1) Urban Systems Integration and Institutions, for developing tools needed

to make sound decisions about future investments in urban water infrastructure; (2) Efficient Engineered Systems, for developing new, modular technologies, overcoming barriers that prevent the wider application of existing but underutilized technologies and collecting data on technical performance; and (3) Natural Water Infrastructure Systems, for developing technologies for managing natural systems to treat and store water while simultaneously improving urban aesthetics. As with all ERCs, ReNUWIt has a very active industrial advisory board and substantial educational and outreach programs, including work with underserved and economically disadvantaged K-12 scholars.

ReNUWIt Research Director Jörg Drewes (Colorado School of Mines), Director Richard Luthy, and Associate Director David Sedlak (UC Berkeley).

The 50th Anniversary of Environmental Engineering and Science at Stanford

This brings us up to the 50th year following the start of Stanford's Environmental Engineering and Science program, which began with the arrival of Eliassen in 1961 and McCarty and Kruger in 1962. The initial program was then called sanitary engineering, the name that engineers working in water supply and wastewater treatment were then called. The expansion of environmental problems beyond the narrow focus were growing rapidly, with the need for the educational and research activities of the program to expand as well. With that recognition and the changing direction required, the name was soon changed to environmental engineering, and then with the recognition that new solutions required interactions with scientific thought, the name of Stanford's program was changed to environmental engineering and science. The formation of the Environmental Forum several years ago represented a realization by the university at large that environmental issues are broad with wide impact. The numerous interdisciplinary activities now occurring in Y2E2 are believed essential for addressing and helping to solve some of the most difficult environmental problems being faced in the world today. Water issues of course have not and will not go away, water is one of the most vital resources for humanity in all of its activities. Efforts to address the growing water issues confronting the world are increasingly imperative.

At the end of year 2013, after half a century, the EES program welcomed the arrival of its latest faculty member, Bill Mitch. Mitch will replace the EES chemistry faculty, Martin Reinhard, who retired in 2011, and Jim Leckie, who will be retiring from the program soon. Thus, all the EES faculty members appointed during the first 25 years of the program will have retired and been

replaced by newer faculty members. Mitch is a 2003 Ph.D. graduate from UC Berkeley where under Sedlak, Deputy Director of ReNUWIt, he studied the formation of N-nitrosodimethylamine (NDMA) in wastewater effluents and recycle streams. He is coming to Stanford from Yale, where he has been a faculty member since earning his Ph.D. He has expertise in trace organic chemistry, which has been a major center of Stanford's research for many years, but otherwise would have been lost when Reinhard retired. Also, Mitch has the expertise needed to carry on the teaching in the area of environmental chemistry that would otherwise have vanished when Leckie retires. The younger faculty now in charge, the Stanford program appears poised to help ensure that the country has the talented professionals and creative approaches needed to sustain future populations and the ecosystem well into the future.

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