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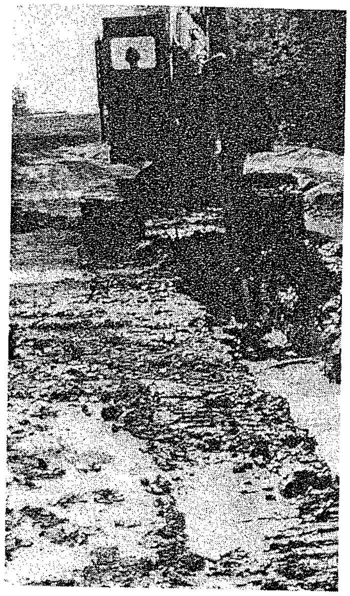

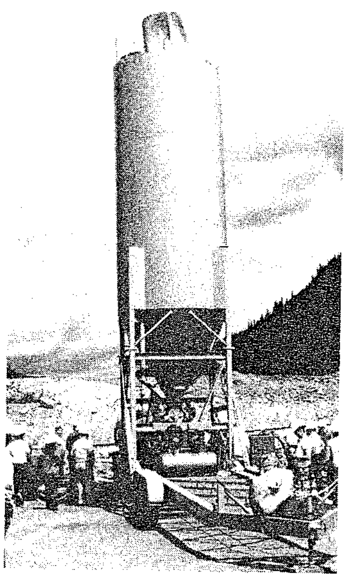

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The REMR Bulletin

News from the Repair, Evaluation, Maintenance, and Rehabilitation Research Program

VOL 1, NO. 4 INFORMATION EXCHANGE BULLETIN OCT 1984

Memphis District Turns Riverward for Levee Rehabilitation

by
Joseph E. Keithley, Jr., US Army Engineer District, Memphis
S. Paul Miller, US Army Engineer Waterways Experiment Station

Mississippi River main-line levees protect millions from the threat of flooding but are frequently threatened themselves by underseepage which must be controlled to prevent undermining and breaching. Memphis District is responsible for many miles of main-line and tributary levees and in the past has used berms constructed on the landside of levees almost exclusively for underseepage control.

As land values and development of areas near levees have increased, berm right-of-way, purchased by local levee districts, has become progressively more expensive. Consequently, other underseepage control measures which require less right-of-way on the landside of levees are needed.

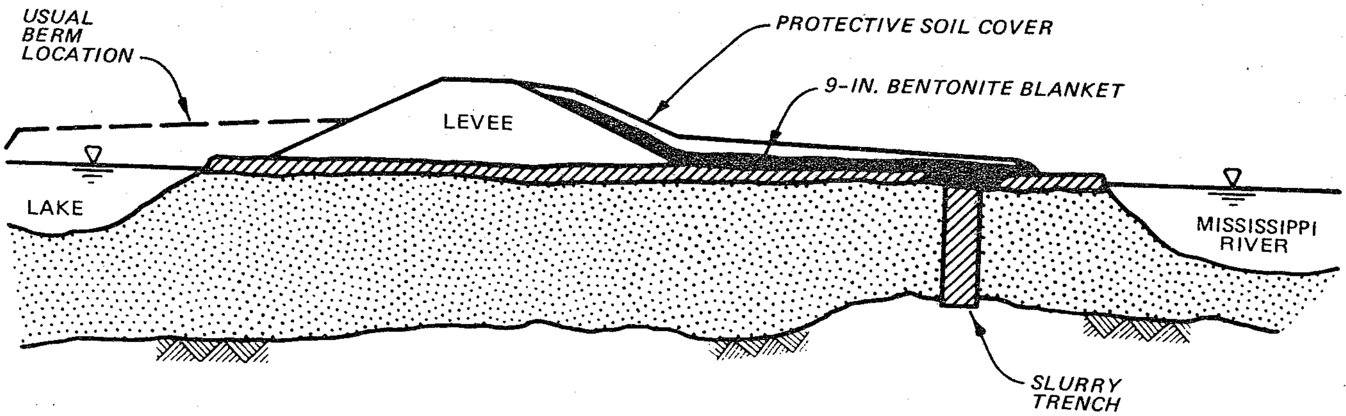
Typical examples of this problem are levees at Porter Lake, Arkansas, and Caruthersville, Missouri, which had experienced distress in the form of sand boils and large amounts of seepage. In both cases, an analysis indicated that excessive gradients would occur during high river stages and that a large landside berm was required.

In the case of Porter Lake, however, the presence of a lake just landward of the levee made use of a landside seepage berm uneconomical due to the large quantity of borrow required. To compound the problem, the levee embankment materials at the site were sandy, meaning that a riverside slope blanket was also needed to prevent through seepage.

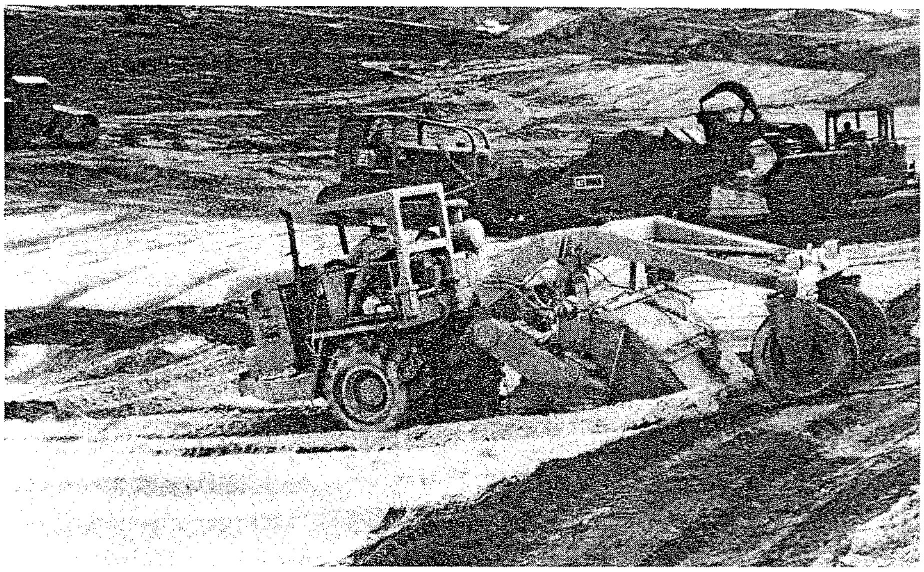
The first alternative to the berm, a large natural clay blanket on the riverside bank and levee slope, was also uneconomical because natural clay sources were too far away. Riverside blankets of man-made membranes were also considered but rejected. A sand-bentonite blanket tied to a slurry trench barrier was selected as the most economical solution.

A 3-foot-wide slurry trench was excavated about 100 feet riverward of the levee toe. The slurry trench was connected to a 9-inch-thick bentonite blanket which extended from the slurry trench to the levee and for a distance up the riverside levee slope. A clay stratum 10 to 30 feet below ground provided a tie-in for the bottom of the slurry trench, thus forming a barrier to excessive groundwater pressure from high river stages. A 5-foot-thick soil layer was placed over the blanket and slurry trench to prevent damage from traffic and erosion. During construction, the contractor was required to cover each day's production of blanket to protect it from rainfall and erosion.

The Caruthersville levee posed a similar problem because a landside berm would have required relocation of a state highway near the landside toe and costly real estate purchases in the city of Caruthersville. A combination of bentonite and natural clay blankets connected to a slurry trench again provided the solution.



Cross section illustrating site limitations and basic approach for levee rehabilitation at Porter Lake, Arkansas



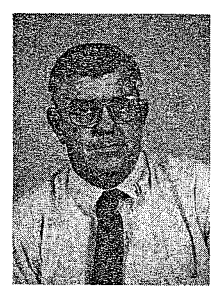
Mixing of the sand-bentonite blanket on the levee slope, Porter Lake, Arkansas

Unit costs per square foot for the slurry trench and bentonite blanket items for these two projects were:

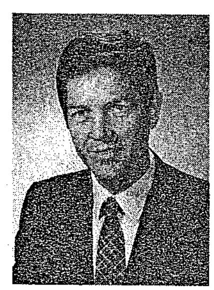
	Slurry Trench	*Blanket*
Porter Lake	$2.68	$0.48
Caruthersville	2.96	0.38

Completed within the last year, both projects experienced their first high water in the spring of 1984. Local residents reported significant reductions in seepage activity. These observations were verified by comparing photographs of the sites taken during this year's high water with photos from previous high water periods. During future high river stages, recently installed piezometers will provide data for project evaluation.

Joe Keithley is Chief of the Geotechnical Engineering and Survey Branch, Memphis District, and has been with the Corps of Engineers for 19 years. He holds both B.S. and M.S. degrees in civil engineering from the University of Arkansas, and he has taught at the University of Arkansas, Christian Brothers College, and the State Technical Institute at Memphis.



Paul Miller has been employed as a research civil engineer in the Soil Mechanics Division, Geotechnical Laboratory, WES, since 1974, and is currently REMR principal investigator for Work Unit 32274, "Rehabilitation Alternatives to Control Adverse Effects of Levee Underseepage." He received a B.S. in civil engineering in 1967 from the University of Missouri at Rolla and an M.S. in civil engineering in 1970 from the University of Texas.



CAGE Project Can Aid Data Gathering and Analysis for Geotechnical Applications

by
Wipawi Vanadit-Ellis
Waterways Experiment Station

The Computer Applications in Geotechnical Engineering (CAGE) Project is sponsored by Corps headquarters to develop the application of computers for storage, retrieval, analysis, and display of geotechnical information. Computer programs that have been developed under CAGE are designed to aid Corps Divisions and Districts in geotechnical and construction investigations and in post-construction monitoring activities at Corps project sites.

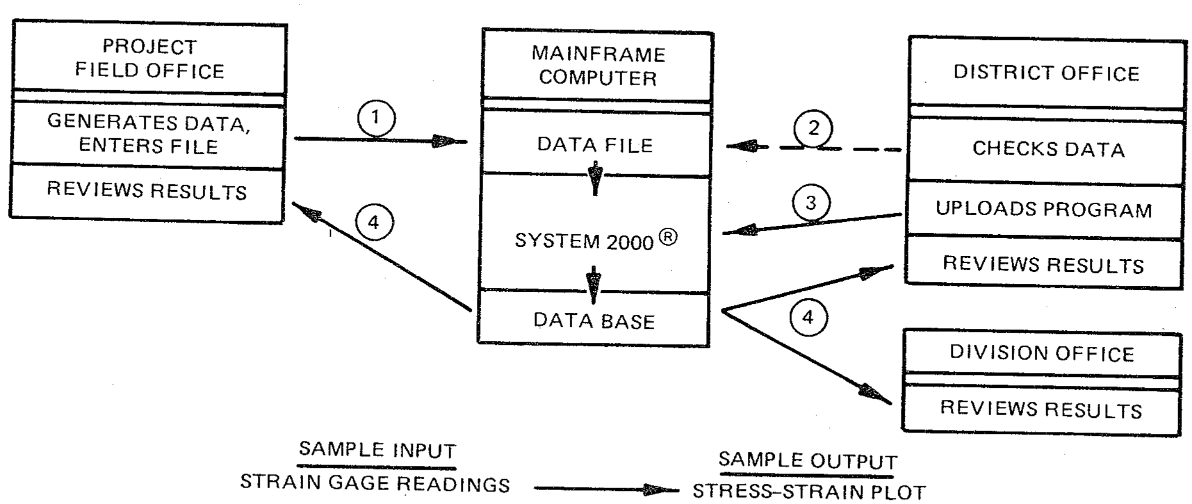
Packages which consist of interactive, automatic data entry and load programs have been designed for these specific applications:

1. Instrumentation Data
   - Piezometers
   - Strain gages
   - Carlson pressure meters
   - Inclinometers
   - Settlement points
   - Surface movements
2. Construction Control (Quality Assurance) Data
3. Boring Information and Subsurface Data

The data entry programs are designed so that personnel not familiar with computers can easily input data. Each offers a question-and-answer format or a mass data entry procedure (for data previously recorded in a data file). The data can then be transferred by a single command to a data base management system called System 2000® (a 52K system developed by Intel Systems Corporation). Calculation of engineering values for entered raw data (stress, strain, pore pressure, X-Y displacement, etc.) is automatic in the transfer of information by the load program to the data base.

The system is accessible to Corps field personnel through the Corps-wide time-sharing system operated by Control Data Corporation (CDC). The primary justification for using it is the capability it provides for rapid retrieval and analysis of stored data in a variety of formats. In providing virtually instant recall and analysis capabilities, the system proves itself a very useful and time-saving tool.

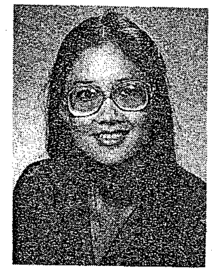
A number of report-writing and graphics programs that read stored data under System 2000® have been developed under the CAGE Project to quickly produce summary tables and plots of data in standard formats. The user can specify the data to be summarized or plotted along with specific titles. These tables and plots can be extremely useful for instrumentation monitoring systems, especially for REMR-related projects.



Flowchart for an instrumentation data base package

To implement one of the packages, District personnel should contact Bill Strohm, CAGE principal investigator at WES (601-634-2604 or FTS 542-2604), or Wipawi Vanadit-Ellis (601-634-3183 or FTS 542-3183). A meeting will then be arranged to discuss details of the package and how it can be adapted to the user's specific needs. CAGE personnel will set up the package in the user's CDC account as well as train the user in application of the package.

Wipawi Vanadit-Ellis works in the Soil Mechanics Division, Geotechnical Laboratory, WES, specializing in data base development under the CAGE Project. She holds a B.S. degree in civil engineering from Rutgers and was previously employed by Bechtel.



4th Field Review Group Meeting Held at WES

The 4th Field Review Group (FRG) meeting for REMR was held August 28-30 at the Waterways Experiment Station. Principal investigators for proposed FY 85 work units briefed the FRG members and management officials from Corps headquarters on research accomplishments to date and plans for the coming year. In addition, a management plan and technology transfer plan for the program were presented and have since been officially approved.

The next FRG meeting will be hosted in Portland by North Pacific Division in March or April. Watch for details about this meeting in future issues of *The REMR Bulletin.*

Request for Articles

Future issues of *The REMR Bulletin* will focus on field experience in structural, hydraulics, and coastal aspects of Corps civil works projects. If you have experience in these areas, we would appreciate your drafting an article describing your work or contacting us for assistance in doing so. If so desired, we can provide editorial assistance in preparation of your article. Along with the article, please furnish accompanying illustrations (original glossy photographs, slides, or line drawings).

Articles by persons outside the Corps are welcome and will be considered for publication so long as they are relevant to REMR activities of the Corps.

Write to: Commander and Director, US Army Engineer Waterways Experiment Station, ATTN: WESSC, PO Box 631, Vicksburg, MS 39180-0631. Or call: Tim Ables at 601-634-2587 (FTS 542-2587).

Construction of Soil-Cement Columns by Jet-Injection Grouting

by
Max A. Gibbs, Halliburton Services
Paul J. Pettit, Halliburton Industrial Services, Inc.
Georgio Guatteri, Novatecna, Brasil

A new technique for in-place construction of load-bearing columns in soil, most commonly known as the CCP (Compagnia Consolidamenti c Pali) process, has been developed by CCP Italia and its Brazilian affiliate, Novatecna. The CCP process has the advantage that it can be used to control the placement of grout and to construct a grouted soil mass of predictable shape and location. During the past six years, the CCP process has been applied in a number of countries in Europe and South America, with about 2 million feet of column having been placed in a broad range of conditions.

Applications of the technique include:

- Installation of structural foundations, particularly in repair of existing structures which are in distress.
- Installation of diaphragm walls.
- Solidification of weak soils around excavations such as tunnels and vaults.
- Tensile anchorage of soil.
- Soil slope stabilization where the columns are used to form points of resistance to movement of small slides.

Erosion protection of river channels and shorelines and remedial treatment of liquifiable foundations under existing structures may be important future applications.

Basic steps in the CCP process are drilling, column formation, and repetition. First, a flush O.D. drill pipe with a special bit 1/8 to 1/4 inch larger than the drill pipe is used to drill to a design depth. Drilling fluid circulates through the bit during the drilling.

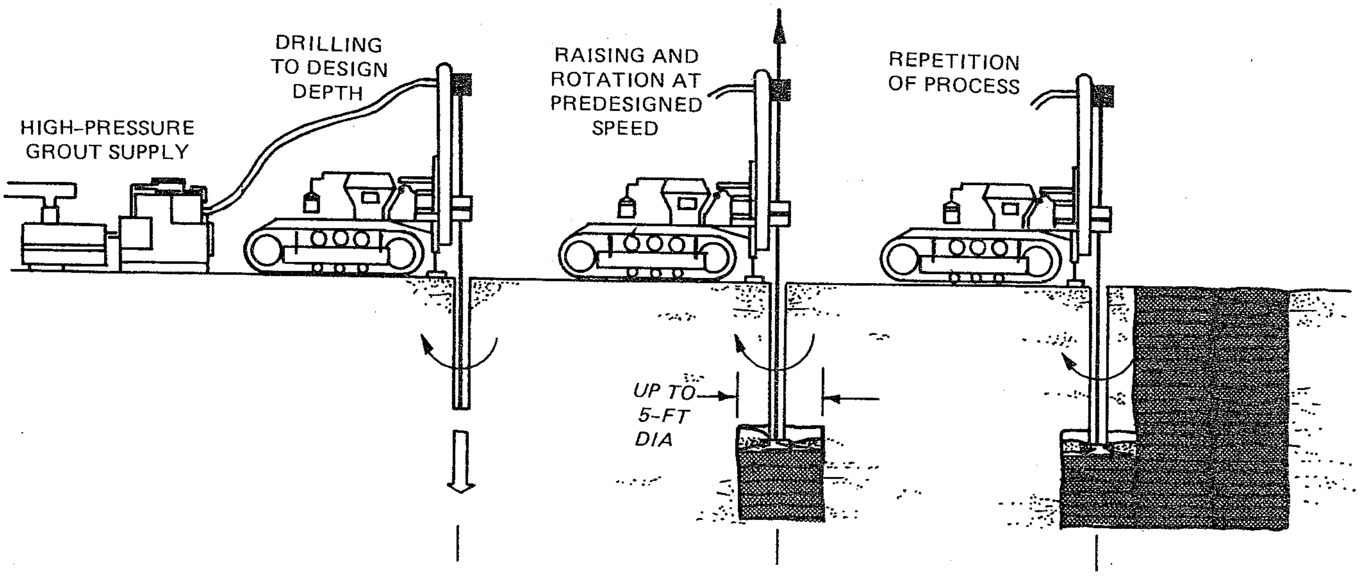
Next the bit is closed to flow, and grout is forced out laterally through jets immediately above the bit. Grout jetting pressure varies with design requirements but is typically between 4000 and 6000 psi. The drill pipe is then rotated continuously and withdrawn at a predetermined rate, usually about 1 foot per minute.

The grout slurry exiting the jets at a very high velocity impinges on the soil and shatters it for some distance from the jets. At the same time, the grout slurry is uniformly and very intimately mixed with the soil particles. As the jets are moved upward, a nearly cylindrical column of grouted soil is generated.

The diameter of the column is a function of soil strength (standard penetrometer test), soil type (sand, clay, silt, or mixtures), jetting pressure, jetting time, nozzle diameter, grout density, and rotational speed of the jets. Typical diameters range from 24 to 48 inches, although larger and smaller diameters can be placed if desired. Most significant is that columns of a set diameter can be designed and predictably placed for a given soil condition and design requirement.

Predictable column diameters permit quite unique applications of the CCP process, such as in forming in-place "walls". If, when a column has been formed the next drill hole is spaced slightly less than the column radius, the second column will "join" the unset slurry of the first column. The third will "join" the second, etc., in any configuration desired. A row of such columns, or a diaphragm wall, can be made impermeable to water

Typical CCP columns revealed by excavation



CCP jet-injection grouting process

and can have substantial structural integrity. It is possible to install a diaphragm wall completely around an excavation site and also form an impermeable bottom for the excavation to control groundwater.

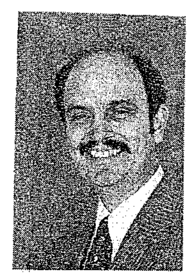
Equipment required for the CCP process includes (1) a grout storage or bulk material tank, (2) a mixing system, (3) a high-pressure pump capable of up to 10,000-psi water pressure and sufficient engine horsepower for maximum injection rates, (4) a drill unit modified for precise control of lift rate and rotational speed, and (5) a high-pressure swivel, drill pipe, jet nozzles, and bit assembly.

Grout material used in the process can be any pumpable material that solidifies when mixed with soil. Portland cement is commonly used and bentonite and pozzolans have been used, both with cement and alone for special applications. Silicates, asphalt emulsions, and heated paraffin may also have specific uses.

Compressive strengths of the resulting soil-cement mixtures are lowest in clays and highest in clean sands, typically varying from 500 to about 3000 psi, respectively, at ordinary cement ratios. Increasing the concentration of cement increases compressive strength. It is particularly interesting to note that the CCP process can be successfully applied in clay soils. In this respect, it is believed to be unique.

Max Gibbs is Technical Supervisor, Domestic Operations, for Halliburton Services, Duncan, Oklahoma, which supplied the high-pressure pumping equipment used by CCP Italia and Novatecna. He received his B.S. degree in mechanical engineering from Oklahoma State, and his primary efforts are in new equipment and process development.

Paul Pettit is Manager of Soil Services for Halliburton Industrial Services, Inc., and is responsible for services such as grouting and soil stabilization. He received a Ph.D. in chemical engineering from McMaster University and until recently headed Halliburton's nuclear services department.



Georgio Guatteri is founder and president of Novatecna, Brasil. He is a civil engineer and has worked for a number of years in developing the CCP process for implementation in commercial operations.

Workshop Scheduled on Underwater Inspection and Repair

As previously reported, a REMR-sponsored workshop devoted to an assessment of the current state of knowledge in underwater inspection and repair of hydraulic structures will be held November 27 and 28, 1984. The location, however, has been changed from the Waterways Experiment Station to the Radisson Hotel, St. Louis, Missouri.

Discussions the first day will focus on currently available survey and repair techniques. Presentations will be given by Corps of Engineers personnel on their field experiences and by other government personnel on the fielding of new systems.

Speakers will include Mel Stegall, St. Louis District; Steve Tatro, Walla Walla District; Lloyd Schell, Huntington District; Roger Johnson, Mobile District; Dan Hokens, Omaha District; Gene Nelson and Paul Johnson, Seattle District; Mike Hemsley and Gary Howell, Coastal Engineering Research Center; Ed Rice, Naval Explosive Ordnance Disposal Technology Center; Wade Casey, US Navy Facilities Engineering Command; and Dan McGee, Virginia Highway and Transportation Research Council.

On November 28th, there will be presentations by the principal investigators for FY 85 REMR work units that address underwater problems. Also, a three-hour field trip will be taken to observe ongoing underwater repairs at Lock and Dam 25, hosted by St. Louis District.

Attendance is not restricted to Corps personnel, but the number of participants will be limited to a maximum of 80. Anyone wishing to attend should contact Gail Walker at 601-634-2906 or FTS 542-2906. Attendance will be on a "first come, first served" basis, so call today. Hotel reservation forms and other details will be mailed to prospective attendees.

Grout Workshop Held

A REMR-sponsored workshop, "Grouting for Repair and Rehabilitation—A Technology Assessment," was held August 13-16 in Park City, Utah. Sixty engineers and geologists from the Corps of Engineers, other federal agencies, academia, and the private sector gathered to discuss the present state of the art in remedial grouting as well as to review current and future grouting requirements of the Corps.

Among topics discussed were advantages of microcomputer monitoring of grouting operations, including real-time monitoring of flow pressure and take, and generation of more and better data to give both the operator and the inspector clearer representations of downhole events. To illustrate this concept, the third day of the meeting featured a field trip to Duchesne, Utah, where a microcomputer system developed by the Bureau of Reclamation for monitoring grouting at its Upper Stillwater Dam Project was inspected. (Partial funding for development of the system was provided under REMR Work Unit 32276, "Grouting Practices for Repair and Rehabilitation of Rock Foundations.") Implementation of this system has greatly enhanced data acquisition and analysis for the project, and timely interpretation and reports made possible by it are expected to improve the quality of the grouting operation.

During the closing session of the workshop, several other innovative concepts were discussed, including the monitoring of grout movement using acoustic emission systems, and jet-injection grouting (see the above article on this subject). Based on a discussion of research needs, four areas will be focused on in REMR grouting research: detection and prediction of grout distribution, measuring grout durability, grout hole drilling methods, and new grouting materials.

Jerry Huie, Geotechnical (Rock) problem area leader for REMR and workshop coordinator, has announced that a proceedings of the workshop will be published in the near future.

COVER PHOTOS

Excavation of a slurry trench barrier during levee rehabilitation at Caruthersville, Missouri.

Grout batch plant viewed by REMR workshop participants during a field trip to the Bureau of Reclamation's Upper Stillwater Dam project near Duchesne, Utah.

The REMR *Bulletin*

The REMR Bulletin is published in accordance with AR 310-2 as one of the information exchange functions of the Corps of Engineers. It is primarily intended to be a forum whereby information on repair, evaluation, maintenance, and rehabilitation work done or managed by Corps field offices can be rapidly and widely disseminated to other Corps offices, other US Government agencies, and the engineering community in general. Contributions of articles, news, reviews, notices, and other pertinent types of information are solicited from all sources and will be considered for publication so long as they are relevant to REMR activities. Special consideration will be given to reports of Corps field experience in repair and maintenance of civil works projects. In considering the application of technology described herein, the reader should note that the purpose of *The REMR Bulletin* is information exchange and not the promulgation of Corps policy; thus, guidance on recommended practice in any given area should be sought through appropriate channels or in other documents. *The REMR Bulletin* will be issued on an irregular basis as dictated by the quantity and importance of information available for dissemination. Communications are welcomed and should be made by writing the Commander and Director, US Army Engineer Waterways Experiment Station, ATTN: T. D. Ables (WESSC), PO Box 631, Vicksburg, MS 39180-0631, or calling 601-634-2587 (FTS 542-2587).

ROBERT C. LEE
Colonel, Corps of Engineers
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