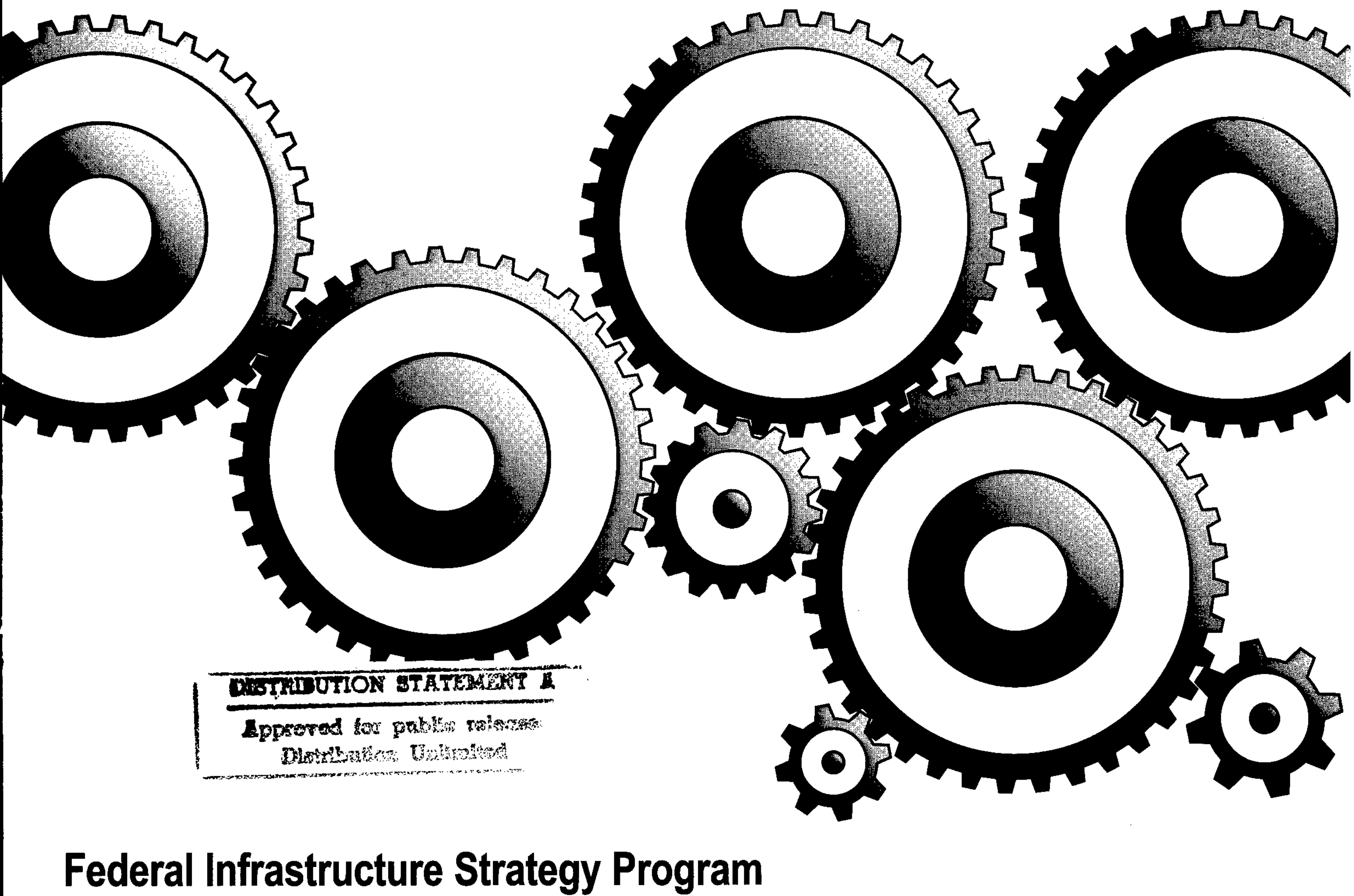
US Army Corps
of Engineers®

Executive Summary Report

Federal Infrastructure R&D:
Meeting State and Local Public Works Needs



Federal Infrastructure Strategy Program

June 1995

IWR Report 95-FIS-21

Federal Infrastructure Strategy Reports

This is one in a series of reports published by the U.S. Army Corps of Engineers as part of the Federal Infrastructure Strategy (FIS) program, a three-year intergovernmental effort which explored the development of integrated or multi-agency Federal infrastructure policies. The FIS study agenda followed-up on the work of the National Council on Public Works Improvement, the Congressional Budget Office, and other related efforts. The program was aimed at developing principles for improving the performance and efficiency of Federal Infrastructure investments, including those ultimately made at state and local levels.

This document provides an executive summary of an interagency study entitled: *Federal Infrastructure R&D: Meeting State and Local Public Works Needs*. This study, which was facilitated by the Corps of Engineers and conducted under the auspices of the Construction Engineering Research Foundation (CERF), utilized a five-stage technology transfer process which identified promising public works technologies in Federal laboratories and matched them with public works needs in the private sector. A companion document of the same title (IWR Report 95-FIS-22) provides the complete documentation for the study. Other FIS reports that address infrastructure R&D issues include:

Framing the Dialogue: Strategies, Issues and Opportunities (IWR Report 93-FIS-1);

Challenges and Opportunities for Innovation in the Public Works Infrastructure, Volumes 1 and 2, (IWR Reports 93-FIS-2 & 93-FIS-3);

Federal Public Works Infrastructure R&D: A New Perspective (IWR Report 93-FIS-5);

Corps of Engineers Technology Transfer: Nondestructive Testing, Evaluation, and Rehabilitation Strategies for Roadway Pavements (IWR Report 94-FIS-11)

Meeting State and Local Public Works Needs: Federal Infrastructure Technology Transfer, An Interim Report (IWR Report 94-FIS-17);

For further information on the Federal Infrastructure Strategy program, please contact:

Mr. Robert A. Pietrowsky
FIS Program Manager
703/428-8073

Dr. Eugene Z. Stakhiv
Chief, Policy and Special
Studies 703/428-6370

U.S. Army Corps of Engineers
Institute for Water Resources
Casey Building, 7701 Telegraph Road
Alexandria, VA 22315-3868

The Institute's study team included Dr. Cameron E. Gordon, Economic Studies Manager and Mr. James F. Thompson, Jr., Engineering Studies Manager. The program was overseen by Mr. Kyle E. Schilling, Director of the Institute. Reports may be ordered by writing (above address) or calling Mrs. Arlene Nurthen, IWR Publications, at 703/428-9042, or fax (preferred) at 703/428-8435.

The Federal Infrastructure Strategy Program

EXECUTIVE SUMMARY REPORT

FEDERAL INFRASTRUCTURE R & D: MEETING STATE AND LOCAL PUBLIC WORKS NEEDS

Prepared by

Civil Engineering Research Foundation
1015 15th Street, N.W., Suite 600
Washington, DC 20005

Prepared for

U.S. Army Corps of Engineers
Water Resources Support Center
Institute for Water Resources
Alexandria, VA 22315-3868

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ACKNOWLEDGMENTS

This report presents the results of an inquiry into issues surrounding transfer of infrastructure technologies undertaken for the U.S. Army Corps of Engineers under a broad administrative directive aimed at the development of a Federal Infrastructure Strategy (FIS). This *Executive Summary Report* provides a synopsis of a study undertaken by the Civil Engineering Research Foundation (CERF) to critically examine the process whereby technologies developed in Federal laboratories can be more successfully transferred to the nation's large public works community. Complete documentation of the study is presented in the companion technical report of the same title.

The study presented here was conducted by Carl Magnell and Lisa Diehl of CERF. They have been assisted through critical review, supervision and suggestions provided by Harvey Bernstein and CERF management. The Corps of Engineers expresses its sincere appreciation to CERF and all who participated in the study. Special thanks to the study advisory panel (see below) and the agencies that hosted the various coordination case studies.

The Corps Institute for Water Resources (IWR) had detailed management responsibility for the FIS program under the direction of Kyle Schilling, Director of the Institute and Eugene Stakhiv, Chief, Policy and Special Studies Division. This study was managed by James Thompson, now with the Department of Energy. The final report was prepared under the direction of Cameron Gordon and Robert Pietrowsky, FIS Program Manager. Special thanks are given to Arlene Nurthen, IWR, for her efforts in editing and formatting the final report.

Policy guidance for the FIS program was provided by the Office of the Assistant Secretary of the Army (Civil Works), while program execution was overseen by the Corps of Engineers Directorate of Civil Works through Donald Kisicki, Chief, Office of Interagency and International Activities.

In accomplishing this study, CERF has interacted with numerous public works directors and personnel across the nation, Federal laboratory personnel and private sector companies focused on provision of public works related equipment and services. Their participation and contributions were essential and are deeply appreciated. The support and assistance of the American Public Works Association (APWA) and CERF's public and private sector members is noteworthy and is gratefully acknowledged.

In addition, the special contributions of individuals serving on the Study Advisory Group (SAG) convened for the study should be recognized as having significantly influenced this report. The SAG has provided invaluable direction and feedback during the course of this study. They include representatives of the following agencies, laboratories, and organizations:

- Bureau of Reclamation, U.S. Department of the Interior
- U.S. Environmental Protection Agency
- Federal Highway Administration, U.S. Department of Transportation
- National Institute of Standards & Technology, U.S. Department of Commerce
- U.S. Army Corps of Engineers
  - HQUSACE Research and Development Directorate
  - Construction Engineering Research Laboratory
  - Institute for Water Resources
  - Waterways Experiment Station
- American Consulting Engineers Council Research & Management Foundation
- American Public Works Association.

The SAG members and their alternates who attended SAG meetings included:

Jack Brynda
Bureau of Reclamation, U.S. Department of Interior

Janet Coleman
U.S. Department of Transportation

Lou Colucci
Federal Highway Administration, U.S. Department of Transportation

Ray Griffith
Federal Highway Administration, U.S. Department of Transportation

Steve Jackson
U.S. Environmental Protection Agency

Tom Kern
American Consulting Engineers Council

Moonja P. Kim
USACE, Construction Engineering Research Laboratory

Jim Kreissl
U.S. Environmental Protection Agency

Marty Manning
American Public Works Association

David Matthis
U.S. Army Corps of Engineers, Headquarters, R &D Directorate

William F. McCleese
USACE, Waterways Experiment Station

Alan Moore
USACE, Construction Engineering Research Laboratory

Timothy Oppelt
U.S. Environmental Protection Agency

Tom Pasko
Federal Highway Administration, U.S. Department of Transportation

James Pierce
Bureau of Reclamation, U.S. Department of Interior

Lisa Pogue
American Public Works Association

Stanley Ponce
Bureau of Reclamation, U.S. Department of Interior

Steve Polk
American Consulting Engineers Council

Noel Raufaste
National Institute of Standards and Technology, U.S. Department of Commerce

William Roper
U.S. Army Corps of Engineers, Headquarters, R & D Directorate

Howard Rosen
American Public Works Association

Wayne Schmidt
USACE, Construction Engineering Research Laboratory

Charles (Chuck) Smith
U.S. Army Corps of Engineers, Headquarters, R & D Directorate

Other participants in SAG activities included Albert Grant, Consulting Engineer; Steve Lehrman, Research Engineer, Research Triangle Institute; and Howard Hagler, Consultant.

FEDERAL INFRASTRUCTURE R & D: MEETING STATE AND LOCAL PUBLIC WORKS NEEDS

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FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

> A widely shared "vision" and specific public works infrastructure goals are needed.

Many factors impact the quality of the nation's public works infrastructure. One of these, documented repeatedly over the past several decades, is the "adequacy" of the technologies utilized in the creation or renewal of infrastructure components. The widespread perception is that the infrastructure in the United States is often based on dated, but proven technologies, leading to less durability and thus greater maintenance and resource requirements over the facility life-cycle. In this era of advanced technology development, the question must be asked, "can this situation be improved, particularly through identification and application of technologies developed or sponsored by the nation's Federal laboratory system?"

A five step process was used to address this question: 1) identification of the most significant public works problems and needs (as defined by public works directors, elected officials and city/county managers from all sections of the nation), 2) identification of Federal technologies to meet the problems and needs, 3) evaluation of their market potential, 4) identification of potential private sector demonstration partners, and 5) recommendations for demonstrations of technologies with partnerships. The technologies that emerged from this process are as shown in Figure 1.

This report presents a summary of the findings resulting from an ambitious study of the transfer of public works technologies undertaken by ASCE's Civil Engineering Research Foundation (CERL) as part of the Federal Infrastructure Strategy Program (FIS).

TECHNOLOGY DEMONSTRATION RECOMMENDATIONS

TRANSPORTATION & BUILDINGS-RELATED:

- PAVEMENT DESIGN FOR SEASONAL FROST CONDITIONS.
- RUT RESISTANT ASPHALT MIXTURES.
- RESIN MODIFIED PAVEMENT.
- GROUND PENETRATING RADAR (pavement application).
- EXTERNAL COMPOSITE REINFORCEMENT FOR CONCRETE STRUCTURAL MEMBERS.

ENVIRONMENTAL-RELATED:

- ENVIRONMENTAL COMPLIANCE ASSESSMENT AND MANAGEMENT PROGRAM.
- WEIGHT-BASED COLLECTION OF SOLID WASTE.
- GROUND PENETRATING RADAR (buried object application).
- NUTRIENT SEDIMENT CONTROL SYSTEM.
- DEVICE FOR SORTING PLASTICS.
- LANDFILL AS A BIOREACTOR.
- SLUDGE TO OIL REACTOR SYSTEM WITH NITROGEN REMOVAL (*STORS/NITREM*).

COMPUTERIZED MANAGEMENT TOOLS:

- PAVEMENT MANAGEMENT SYSTEM (*Micro PAVER*).
- MANAGEMENT SYSTEM FOR WATER PIPES (*W-PIPER*).
- MANAGEMENT SYSTEM FOR BUILDINGS (*BUILDER*).
- CATHODIC PROTECTION (CP) DIAGNOSTIC FOR UNDERGROUND AND ELEVATED STORAGE TANKS, AND FOR PIPING (*CP Diagnostic*).
- MANAGEMENT SYSTEM FOR UNDERGROUND STORAGE TANKS (*Tankman*).

Figure 1 - Technology Demonstration Recommendations

For additional information on this study please refer to the companion technical report of the same title (IWR Report No. 95-FIS-22) which provides the complete documentation of the study.

The study yielded three types of insights into infrastructure R&D in America:

- **Findings** about the existing public works environment in the United States, the challenges which are faced within that environment, and the barriers to meeting those challenges;

- **Conclusions** regarding the relationship between Federal R & D and local public works applications which are suggested by the findings; and

- **Recommendations** for changes in Federal R & D policy and technology transfer practice which follow from the findings and conclusions.

FINDINGS AND CONCLUSIONS

There are many players in the public works technology arena, including the Federal laboratories, state and local public works departments and infrastructure component manufacturers. The study found that:

- ❑ Public works infrastructure related technologies are a very minor component of the overall Federal research effort. As noted in an earlier FIS study, less than 2 percent of Federal R&D focuses on such technologies.[1]

- ❑ Paradoxically, this Federal funding constitutes a majority of the total national expenditure for infrastructure related research, at approximately 63 percent.[2]

- ❑ The state and local public works community is diverse and fragmented. There are over 83,000 local governments, consisting of counties, municipalities, townships, school districts and special districts. Infrastructure-related state agencies number over 150 and each state implements environmental, transportation and other infrastructure-related issues somewhat differently in accordance with its own perspective and sovereignty.

- ❑ There is also a large number of manufacturers with a public works focus.

- ❑ A number of nonprofit and trade organizations keep at least partial track of developments within the infrastructure community; mechanisms within organizations such as the American Public Works Association (APWA), the Rebuild America Coalition, the Infrastructure Technology Institute (ITI), CERF and many others allow for exchange of various data, including data on research and innovation.

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[1]Civil Engineering Research Foundation, p. 1.

[2]Civil Engineering Research Foundation, *A Nationwide Survey of Civil Engineering-Related R&D*, Report #93-5006, Washington, DC, 1993, p. 4.

Within this environment, the study found numerous policy challenges to both public works providers and technology developers. These challenges were unearthed using a survey sent to approximately 2,500 public works directors in randomly selected municipalities across all fifty states of the United States. A separate, smaller survey of Chief Appointed Officials (CAO) and Chief Elected Officials (CEO) was also conducted. Taking the different surveys together, over 800 responses were finally received.

These surveys revealed some interesting findings about the adequacy of infrastructure in most local communities:

- ❑ Local public works directors and elected officials generally consider their own public works infrastructure to be in average or better condition.

- ❑ In the intense competition for scarce resources, almost 75 percent of public works directors believe that public works infrastructure has an average or higher local budget priority, with a mean of just under 25 percent of the local government's budget applied to public works.

- ❑ However, almost 70 percent of public works directors and elected officials believe that current funding levels are not adequate, with a majority pessimistic regarding future funding increases.

- ❑ Public works issues identified as priority problems include:
  - Maintenance of materials, particularly asphalt;
  - Environmental protection challenges such as sludge and solid waste sewage disposal, especially as related to groundwater protection;
  - Regulatory compliance with such Federal statutes as the Americans With Disabilities Act (ADA), Clean Water Act, and National Pollutant Discharge Elimination System (NPDES); and
  - Financial management and safety concerns.

A number of barriers to meeting existing challenges were identified, however:

- ❑ A majority of public works departments do not have a process in place to facilitate the adoption of new technologies, and only a quarter are testing new technologies that address one of their high priority needs.

- ❑ Although the technology needs of the public works community are significant, these needs are, at present, generally not periodically assessed, synthesized nor evaluated on a comprehensive or coordinated basis. Thus it is difficult for Federal technology developers to ascertain which public works problems are the most urgent and need to be addressed by their laboratories.

- ❑ Although many public works-focused manufacturers exist, many of them lack the capital and technological capabilities required for innovation.

- ❑ The interaction among Federal, state, and local governments, except for compliance, is minimal with respect to innovation and future requirements.

The Federal laboratory community faces its own challenges as well:

- ❑ There is no central location, publication or database for accessing information on Federal infrastructure technologies. Where avenues for finding technologies were explored, they were often found to be user-unfriendly or incomplete and almost always uncomprehensive. The lack of a central location, publication, or database for accessing information on Federal technologies, and the general difficulty which they often present to the potential user has hampered the transfer of ideas and general communication between Federal laboratories which develop infrastructure technology, and public works departments which use them.

- ❑ Some, and perhaps even most infrastructure research and development projects for Federal agencies and laboratories are not based on needs assessments nor on market potential surveys. This may result from the fact that much research is driven by agency mission requirements, thus making market potential of secondary importance. This can make it difficult to commercialize Federally-developed infrastructure technologies that were not developed specifically around state and local public works needs.

- ❑ The fragmentation of the local public works community relative to the Federal laboratory community suggests that an information dissemination and coordination role might be more effectively be led at the Federal level.

- ❑ There are existing public and nonprofit entities which can be used as a foundation for building a more coordinated and free exchange of technologies and ideas between the Federal and non-Federal sectors.

RECOMMENDATIONS

Broad study recommendations which follow from the findings and conclusions above include:

- ❑ The infrastructure needs and problems of the public works community should be periodically assessed. In this way infrastructure research and development can be focused on solving the most critical and frequent needs and problems.

- ❑ Federal infrastructure research and development should be periodically catalogued to detect gaps and overlaps, dual-use technologies that can benefit the public works community, and technologies "sitting on the shelf" that could be applied. This database should be on-line and user-friendly, with fast and simple information retrieval.

- ❑ Because the Federal research community is more centralized than the state and local public works community, and the focus of this study is on the transfer of Federal technology to outside users, the Federal government should consider action on development of both a database and a process for exchanging information and ideas.

- ❑ A national strategy or "game-plan" for infrastructure technology should be developed concurrent with and as a result of enhanced communications between all relevant stakeholders. Such a strategy should include increased emphasis on private sector involvement, including incentives, as appropriate, and trade and professional association participation.

- Existing efforts and institutions for technology transfer should not be ignored or duplicated in developing both a strategy and a process. The President's National Science and Technology Council can serve as a focal point for strategy development, while mechanisms within the American Public Works Association (APWA), the Rebuild America Coalition, the Infrastructure Technology Institute (ITI), the National Technology Transfer Center (NTTC), CERF, and others should be the starting point for developing any one-stop database.

For Federal laboratories in particular, the structure for effective transfer of infrastructure-related technologies has been in place since passage (and later amendment) of the 1986 Federal Technology Transfer Act (P.L. 99-502). Such transfer is anchored in the network of ORTA personnel and the Federal Laboratory Consortium (FLC). While the structure is in place, two prerequisites for success require more emphasis and constitutes an important recommendation:

- ORTA personnel must become much better informed regarding the nature and scope of public works infrastructure, especially the technical problems and needs.

- Laboratory directors and agency technical management must likewise gain familiarity with public works operations and, most important, become effective advocates for the application of appropriate technologies to meet pressing public works needs.

Both of these prerequisites will be priority issues for the implementing body. Moreover, effective communications between the implementing body and the FLC must be established and maintained, including appropriate presentations during FLC sponsored events and regular access to FLC publications, such as *Newslink*.

FEDERAL INFRASTRUCTURE R & D: MEETING STATE AND LOCAL PUBLIC WORKS NEEDS

EXECUTIVE SUMMARY REPORT

OVERVIEW

BACKGROUND

> ...infrastructure is too often a hidden and ignored national asset.

Among the many conditions that set industrialized nations apart from both developing and underdeveloped nations is the existence and operation of an underlying public works infrastructure. Paradoxically, while the absence of adequate infrastructure is often among the first impressions when Americans visit "third world" nations or view various media presentations, the presence of this infrastructure and its impact on America's economic prosperity and quality of life is often less understood and appreciated. Citizens travel on highways and streets, water is consumed and waste is disposed of as if such activities are an innate part of human existence. Until a major disruption or disaster, natural or man-made, brings the public face to face with the sometimes fragile underpinnings of our public works, this infrastructure is too often a hidden and ignored national asset. Moreover, in the U.S. it is an asset that is primarily in the hands of thousands of local and state jurisdictions, with widely varying demographic, cultural, geographic and climatic conditions. Yet, when examined as an integrated network, our infrastructure is the "fabric" that enables America to travel, conduct commerce, participate in recreational activities and enjoy the quality of life that is unique to the U.S.

The importance of the Nation's infrastructure cannot be overstated; yet, in these waning days of the 20th century, the condition and operation of America's public works infrastructure is a matter of growing concern. In many jurisdictions, especially older urban areas, aging infrastructure components, coupled with limited ability to maintain, let alone operate, is the norm. Even in more affluent suburban areas, the operation and maintenance of infrastructure as well as the high cost of capital improvements must compete with the growing demand for social services. Moreover, it is increasingly apparent that the emerging global economy of the 21st century will favor those nations whose public works infrastructure enables and enhances the most efficient production and distribution of goods and services.

How should the U.S. react to these challenges? A three year program known as the Federal Infrastructure Strategy (FIS) Program was established to address the policy aspects of such issues. The FIS was overseen by the U.S. Army Corps of Engineers (USACE), with detailed management through its Institute for Water Resources (IWR). This program was designed to determine if more coherent and integrated Federal policies are needed and/or, indeed, capable of resolving the nation's most pressing infrastructure problems and needs. Program goals included:

- Clarification of the roles of all levels of government;
- Improved performance and efficiency of existing facilities;
- Rational budgeting processes at all levels of government;
- Stronger incentives to insure adequate maintenance;
- Accelerated adoption of new technologies; and
- Greater use of low capital techniques.

The USACE has used independent third parties, such as the Civil Engineering Research Foundation (CERF), to address these goals through facilitating and organizing various workshops and research on identified issues.

OBJECTIVE

CERF's component of the FIS program addressed the goal of "accelerated adoption of new technologies," as well as illuminating some of the other program goals in the process. This increased attention on developing more rapid technology adoption processes emerged from the National Council on Public Works Improvement's analysis of the state of the Nation's infrastructure. Among the Council's important conclusions was the recognition that a significant gap exists between recent advances in infrastructure technologies and their implementation by state and local public works agencies. Moreover, subsequent work by the Congressional Office of Technology Assessment (OTA) confirmed this gap, identifying one of the major barriers to the adoption of innovations in the public works sector as the lack of demonstration projects and the failure to establish a track record for new products and systems.

TECHNOLOGY TRANSFER PROCESS

In view of these findings, IWR engaged CERF to investigate the process and, particularly, procedures that will improve the transfer of infrastructure-related technology created in Federal research and development (R&D) programs into practice within the public works community. As an important corollary, CERF was asked to note the impediments that hinder the transfer of technology. CERF has performed this investigation using a technology transfer model that offers a venue for success. The model includes the following five steps:

- ❒ Determine the most urgent state and local public works needs;
- ❒ Identify potential technology solutions from the Federal laboratory system;
- ❒ Determine the market potential of these technologies;
- ❒ Identify industry/Federal laboratory/public works agency partnerships for potential demonstrations; and
- ❒ Recommend the most promising technologies with partnerships for actual demonstrations.

This process is graphically represented in Figure 2. Discussion of the process, major findings and lessons learned for each of these five tasks is presented in the following five chapters. Detailed efforts, results, and conclusions for each of these five tasks are documented in the complete report on this study, published as a companion document (IWR Report 95-FIS-22).

The study's objectives have been met over the past two years. Beyond this, however, valuable insights about public works operations, perceptions and expectations have been captured; some of the most significant are shared in this *Executive Summary Report.* Finally, it should be noted that this study is likely to be more important for what it says about the potential for improving the current technology transfer process and addressing associated institutional factors, as well as for what it notes as necessary national actions, than for the individual technologies and partnership recommendations that have emerged.

> ...valuable insights about the technology transfer process and public works operations have been captured.

TASK 1: PROBLEM IDENTIFICATION, CLASSIFICATION AND PRIORITIZATION. Conducted a needs assessment, by means of a nationwide survey, of infrastructure problems experienced by state and local public works directors.

TASK 2: TECHNOLOGY IDENTIFICATION. Sought and identified Federal technologies with the potential to mitigate high priority infrastructure problems and needs identified in Task 1.

TASK 3: MARKET POTENTIAL EVALUATION. Conducted a market potential evaluation of promising Federal technologies, identified in Task 2, to determine their demand and opportunity within the public works community.

TASK 4: DEMONSTRATION PARTNER IDENTIFICATION. Sought demonstration partners willing to consider demonstrating and/or commercializing Federal technologies determined in Task 3 to have market potential.

TASK 5: DEMONSTRATION RECOMMENDATIONS. Recommended Federal technologies for demonstration implementation, where partnerships were established in Task 4.

Figure 2 - Technology Transfer Process

TASK 1: PROBLEM IDENTIFICATION, CLASSIFICATION AND PRIORITIZATION: MAJOR FINDINGS

THE TASK

To begin to transfer infrastructure technology, real and tangible needs within the public works community had to be identified whose solutions require the infusion of new technology. The best means for assessing these needs on a national level was a survey of public works directors (in general, this term refers to officials and personnel with public works-related responsibilities) across the country.

This survey was preceded by literature searches and mini-surveys that aided in its development. The survey that resulted was six-pages in length and sought to disclose what public works directors perceived as the most critical and frequent problems/needs for seven infrastructure systems: buildings, transportation, solid waste, hazardous waste, power & energy, wastewater, and water resources. The survey also sought to gain insights on the infrastructure condition of the public works director's municipality and factors affecting it, and on the environment for adoption of new technologies.

This survey was sent to the public works directors of 2500 municipalities in the fall of 1993. These municipalities were randomly-selected and were stratified to represent all major geographical regions, population groups, metro status (i.e., central cities, suburbs, and rural areas), and hydrological conditions of the United States. To broaden the scope of the findings, a shorter version of the survey was also sent to the chief appointed official (e.g., a city manager) and the chief elected official (e.g., a mayor) for 500 of the 2500 municipalities. It addition, surveys were also sent to randomly-selected state and regional infrastructure-related agencies' representatives.

Approximately 800 recipients responded to the survey and 345 of these were public works directors. All geographical regions and population groups of the country were well-represented by the respondents. Their responses to survey questions are given in the following section.

THE FINDINGS: *A PERSPECTIVE OF THE U.S. PUBLIC WORKS COMMUNITY*

The survey results were analyzed and prioritized, revealing critical and frequent problems and needs of public works directors nationwide. These have been compiled into a matrix of the eight highest priority problems and needs for each of the seven infrastructure systems. This matrix is shown in Figure 3. In the process of identifying these priority public works problems and needs, a broader perspective of

America's public works community also emerged. The picture that results provides important insights regarding the environment in which the nation's public works infrastructure is operated and managed.

Some of the more important results are summarized here include:

- Perceptions regarding public works infrastructure condition,
- The priority accorded public works infrastructure,
- Adequacy of funding, and prospects for future funding.

MATRIX OF THE HIGHEST PRIORITY PUBLIC WORKS PROBLEMS AND NEEDS

(Listed per infrastructure system in order of priority)

BUILDINGS ISSUES

B1	ADA Compliance
B2	Maintenance of Building Systems
B3	Construction/Demolition Worksite Safety
B4	Excavation Safety
B5	Flood Protection
B6	Lighting Efficiency
B7	Construction/Demo Scheduling & Estimating
B8	HVAC & Plumbing Efficiency

TRANSPORTATION ISSUES

T1	Maintenance and Repair of Pavements
T2	Drainage of Highways and Roadways
T3	Asphalt Performance for Pavements
T4	Inspection and Management of Pavements
T5	Maintenance and Repair of Bridges
T6	Roadway Markings and Signs
T7	Roadway Snow Removal and De-icing
T8	Road Crew Safety

SOLID WASTE ISSUES

S1	Management of Residential Collection
S2	Source Reduction by Composting
S3	Separation Tech. in Materials Recovery
S4	Separation of Waste in Residential Collection
S5	Source Reduction of Litter
S6	Equip. Maintenance for Residential Collection
S7	Materials Recovery by Paper Recycling
S8	Waste Management for RCRA Compliance

HAZARDOUS WASTE ISSUES

H1	Recycling and Reuse of Hazardous Waste
H2	Worker Safety in Materials Handling
H3	Alternatives to Landfill Disposal
H4	Management and Regulations
H5	Residential Hazardous Waste
H6	Spills/Site Clean-Up Technologies
H7	Groundwater Pollution Monitor'g/Containment
H8	Hazard Identification of Materials

POWER AND ENERGY ISSUES

P1	Leak Detection for USTs
P2	Leak Treatment for USTs
P3	Leak Detection for Utility Pipelines
P4	Above-ground Storage Alternatives to USTs
P5	Repair of Utility Pipelines
P6	Clean Air Act Compliance
P7	Efficiency of Small Generators
P8	Waste Separation in Waste-to-Energy Plants

WASTEWATER ISSUES

W1	Repair & Rehab of Collection Systems
W2	Leak Detection in Collection Systems
W3	Standards & Regulations for Treatment Sys.
W4	Management of Worker Health and Safety
W5	Maintenance and Repair of Treatment Sys.
W6	Land Applications for Sludge Disposal
W7	Composting/Recycling of Sludge
W8	Monitoring of Treatment Systems

WATER RESOURCES ISSUES

R1	NPDES Compliance for Stormwater
R2	Leak Detect. & Repair of Transmission Lines
R3	SDWA Compliance for Potable Water
R4	Stormwater Flood Management
R5	Stormwater Runoff Quality
R6	Flood Control for Waterways
R7	Groundwater Monitoring and Detection
R8	Groundwater Well Drilling and Maintenance

Figure 3 - Matrix of Highest Priority Public Works Problems and Needs

A majority of both public works directors (PWD) and chief appointed/elected officials (CAO/CEO) consider their own public works infrastructure to be in average or better condition, as indicated in Figure 4. This finding is perhaps surprising, given the typically dire perceptions regarding the nation's infrastructure. It is, in fact, probably an accurate assessment. Many cities and most suburban communities/counties have the advantage of at least an average infrastructure condition. This, however, does not lessen the fact that at least 20 percent of the respondents gave their public works infrastructure below average or poor ratings. The enormity of the problem posed by this percentage should not be underestimated given the estimated $3-4 trillion valuation placed on the nation's public works capital assets. While broad agreement regarding condition exists between public works directors and their appointed/elected officials, public works directors, perhaps understandably, appear to view their infrastructure condition somewhat more favorably.

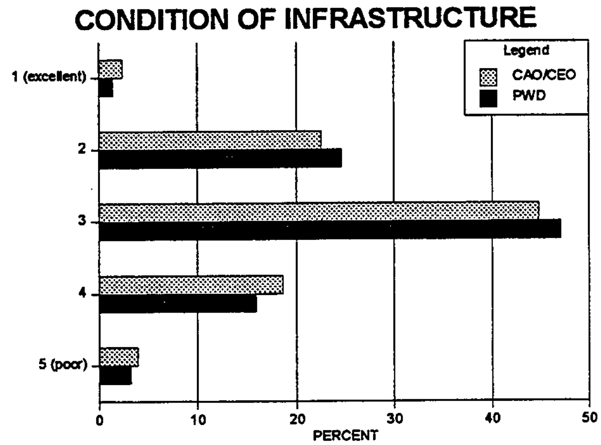

Figure 4 - Condition of Infrastructure

In the intense competition for scarce resources, how do public works issues fare compared to social and fiscal issues? In responding to this question, the divergence between public works directors and the appointed/elected officials is more apparent, as indicated in Figure 5. An appreciably higher percentage of appointed/elected officials indicate that public works is a high priority. Conversely, almost 25 percent of public works directors believe that they receive below average or little priority. In general, however, the perceptions from both groups suggests that our public works infrastructure has average or higher priority and, in a small number of communities and counties, actually enjoys a high priority.

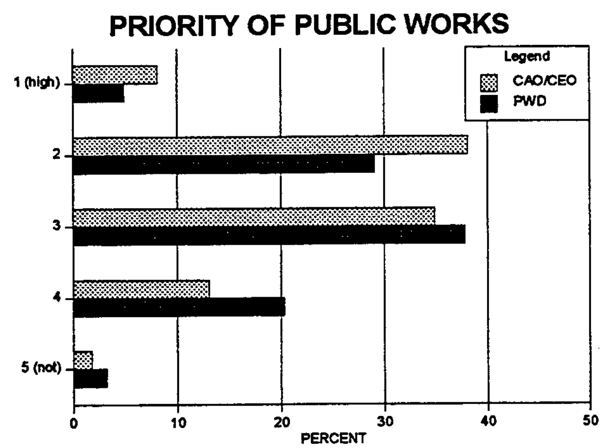

Figure 5 - Priority of Public Works

The most direct influence upon condition of the public works infrastructure is likely to be available funding. What percentage of the local government's budget is typically allocated to public works? In responding to this question, almost perfect consistency between public works directors and appointed/elected officials emerged. The mean of their response was that somewhere between 23-24 percent of the local government's budget is applied to public works, as indicated in Figure 6.

Is this percentage adequate? Apparently not, in the view of both public works directors and the appointed/elected officials. As Figure 7 portrays, almost 70 percent of public works directors and an almost similar percentage of appointed/elected officials believe that this level of investment is inadequate. For at least one quarter of the nation's public works agencies, however, the funding situation appears to be satisfactory.

Will resourcing improve over time? The response to this question provided greater divergence. The majority of public works directors are pessimistic regarding any funding increases, although about 55 percent saw no threat of decreasing resources. For the remaining forty-plus percent, funding will change with a slightly larger number of the public works directors in this group anticipating funding increases rather than decreases, as indicated in Figure 8. Appointed/elected officials are again, as a group, more optimistic regarding future funding of public works.

How do public works directors and appointed/elected officials view some of the fundamental aspects of public works operations? On the survey instrument, they were asked to indicate the priority of problems they face for the five general public works issues listed below. The problems they indicated as being their highest priority for each of these five issues are graphically represented and discussed in the paragraphs that follow.

- ❑ Materials maintenance,
- ❑ Environmental issues,
- ❑ Regulation compliance,

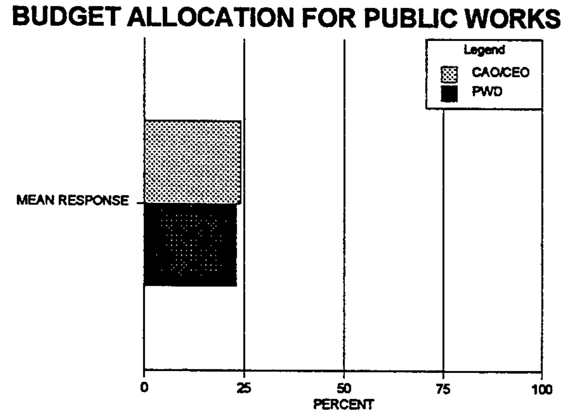

Figure 6 - Budget Allocation for Public Works

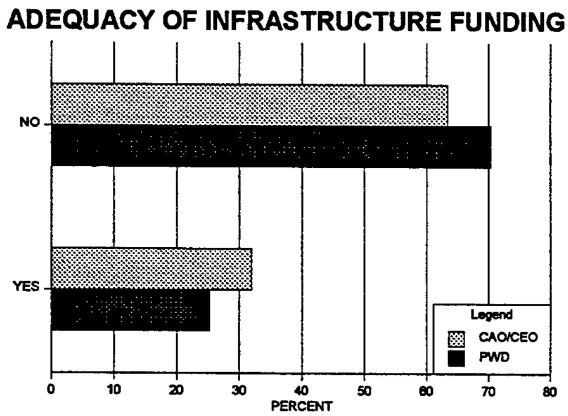

Figure 7 - Adequacy of Infrastructure Funding

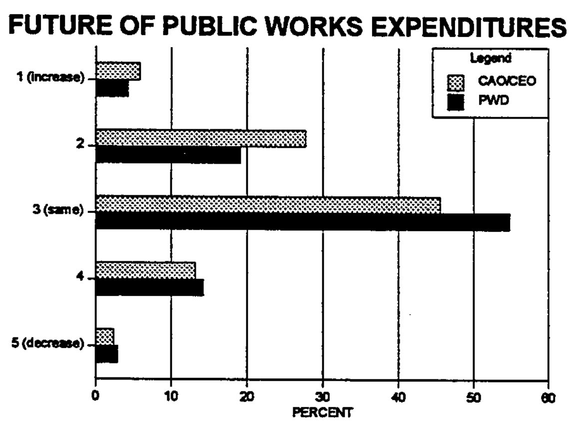

Figure 8 - Future of Public Works Expenditures

- Management tasks, and,
- Safety concerns.

Construction materials of various types comprise our public works infrastructure. Which of these materials poses the greatest maintenance challenges for public works? As Figure 9 indicates, the answers from both public works directors and appointed/elected officials are remarkably consistent, reflecting, perhaps, that asphalt and concrete are used in more active environments, in contrast to the other construction materials, which typically are more passively employed.

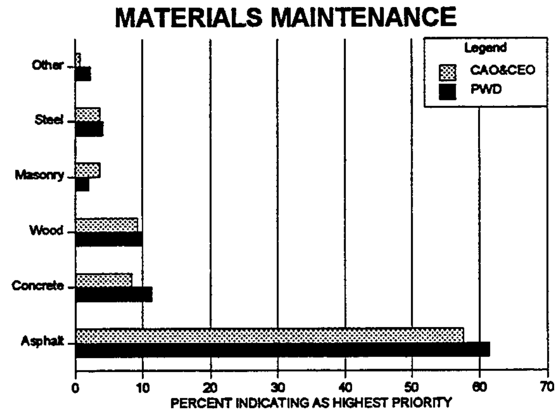

Figure 9 - Materials Maintenance

Responses to environmental issues provided relatively diverse viewpoints. In general, the survey responses (see Figure 10) suggest that public works directors see environmental impacts as larger operational problems than the appointed/elected officials do. Both groups, though, are challenged by groundwater problems, sludge disposal, and litter collection. Attention to the first two of these problems may be prompted by regulatory provisions of the Clean Water Act.

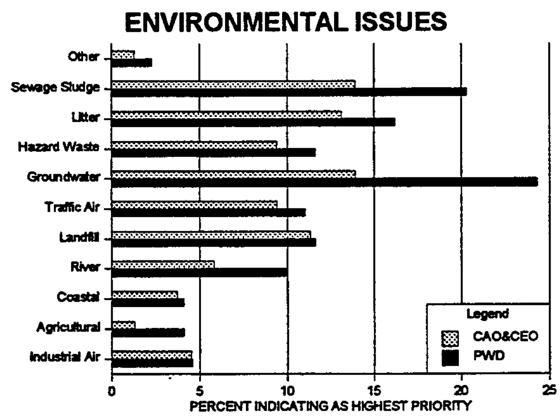

Figure 10 - Environmental Issues

A myriad of regulations, both Federal and state, require compliance and enforcement by local governments. Here the relative priorities of public works directors and appointed/elected officials appear quite consistent with their respective responsibilities, as indicated in Figure 11. Those regulations that impact public works operations and administration are viewed as the more significant challenges by public works directors. Those problems which also have impact beyond public works operations (e.g., legal implications) are viewed by the appointed/elected officials to be of a greater concern. All have great concern for the far reaching impact of the Americans with Disabilities Act and the Clean Water Act.

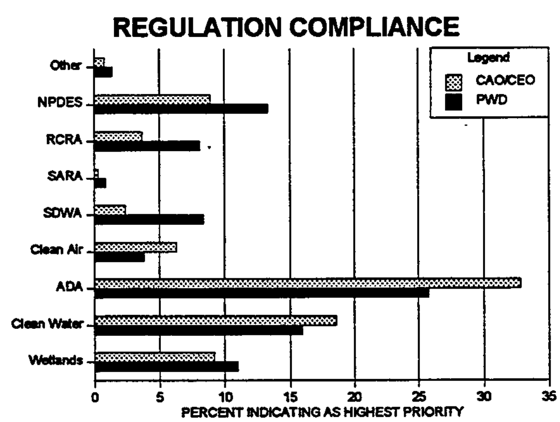

Figure 11 - Regulation Compliance

In the general area of management tasks, agreement between public works directors and appointed/elected officials varies, as indicated in Figure 12. The three obvious problematic management tasks are financial management, public relations, and complaints handling (public relations management being the promotion of a favorable relationship with the public and complaints handling being the management of unfavorable relationships with the public). Public works directors are noticeably more concerned about financial management, while appointed/elected officials consider complaints handling to be of the highest concern. Aside from variance of opinion on the three most problematic tasks, appointed/elected officials consider project planning, resource management, and training to be more challenging than do the public works directors.

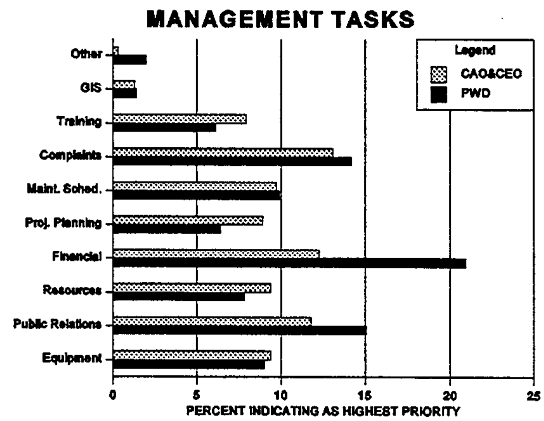

Figure 12 - Management Tasks

The safety concerns that were considered to be high priority present similar patterns of divergence of opinion between the public works directors and the appointed/elected officials. While all safety aspects appear important to both public works directors and appointed/elected officials, public works directors, as a group, are more focused on their public works operations while appointed/ elected officials, as can be expected, show somewhat greater concern for their broad constituency. These differences are depicted in Figure 13.

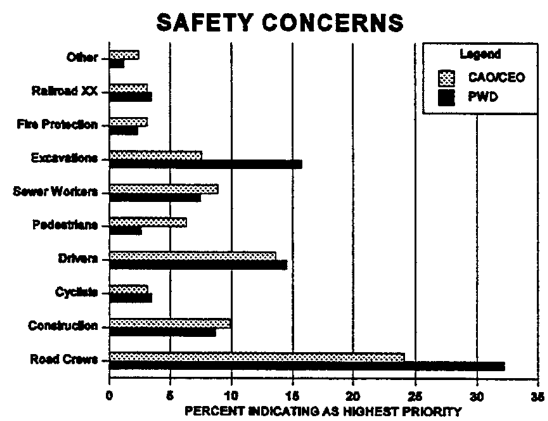

Figure 13 - Safety Concerns

The conclusions from these survey component suggest that the nation's public works directors and the appointed/elected officials of their municipalities have broadly shared views and perceptions on the condition and "environment" of public works and varying viewpoints on priority of problems and challenges within public works operations.

Finally, the survey also asked the respondents, particularly the public works directors, about the environment for the adoption of new technologies. When the public works directors were asked about the adoption of new technologies, only 42 percent felt they had a process in place to facilitate the adoption of new innovations. Only 26 percent indicated that their department was experimenting or testing a new technology that could address one their high priority problems or needs. Even so, over 53 percent of the public works directors thought more than "likely" that their department would attempt to introduce more new technologies in the next five years than they had in the previous five years. They noted their most important sources of information on new innovations was (listed in order of importance) workshops/seminars, professional journals, and personal contacts. Finally, the public works directors were asked about the importance of various factors in the failure of new technologies, they noted the following four factors as being the most important (listed in order of importance):

- Cost
- Inadequate training of personnel
- Poor reliability/performance
- Lack of information about the new technology

THE LESSONS LEARNED

✓ The infrastructure technology needs of the public works community are significant. Even so, these needs are, at present, not periodically assessed, synthesized and evaluated. There are exceptions to this for certain specific aspects of the infrastructure such as the Environmental Protection Agency's (EPA's) biennial wastewater treatment needs survey, Federal Highway Administration's (FHWA's) periodic needs assessments, the National Council on Public Works Improvement's (NCPWI) studies of the late 80's, and needs assessments of specific infrastructure components or sub-components by trade and professional associations.

Aside from the one-time efforts of the NCPWI study and the current FIS work, no coordinated, integrated effort has focused on periodically identifying priority infrastructure issues that should be addressed by our Federal, academic, and industry laboratories. Thus, it is difficult for Federal technology developers to ascertain which public works problems are the most urgent and need to be addressed by their laboratories. In effect, a formalized process for assessing infrastructure needs does not exist and a resultant R&D needs agenda is lacking.

✓ The public works community is diverse and fragmented. Disseminating information within it is a challenge. There are over 83,000 local governments—counties, municipalities, townships, school districts, and special districts. These differ vastly in population size, geographical conditions, socio-economic circumstances, management, and public works responsibility. Moreover, infrastructure-related state agencies number over 150 and each state implements environmental, transportation and other infrastructure-related issues in accordance with their own state's perspective and sovereignty.

✓ For this diverse public works community, there does not appear to be a totally effective conduit for exchange of information between the technology developer and the public works community, though it is well-served by the American Public Works Association (APWA) and other groups representing specific infrastructure systems. While presentations and demonstrations at APWA's national (Congress) and regional meetings and their publication, the *APWA Reporter*, are good venues for reaching the public works community; improving existing conduits is necessary in order to more effectively transfer information about Federal infrastructure technologies.

TASK 2: TECHNOLOGY IDENTIFICATION: MAJOR FINDINGS

THE TASK

This task involved the search for technologies developed in Federal R&D programs that have the potential to mitigate the high priority public works problems and needs identified in Task 1. These technologies were sought by asking Federal sector "experts" in each of the seven infrastructure systems (and in all facets of these systems) to identify technologies they deemed as being potential matches for one of the problems or needs. The experts were chiefly from the 32 laboratories noted in a previous Federal Infrastructure Strategy report as having significant public works infrastructure research and development (PWI R&D) activity.[3] The experts included technology developers, scientists, engineers, technology transfer agents, laboratory directors, and others knowledgeable of infrastructure related R&D efforts in their laboratories. In total, these experts cited 268 Federal infrastructure technologies for further consideration.

...experts cited 268 Federal infrastructure technologies for further consideration.

They provided the name and a brief description of each technology, as well as a point-of-contact (POC), sometimes themselves, or a researcher or other laboratory personnel who could provide more information on the technology. The additional information requested of these POCs included: a detailed description of the innovation, its advantages, costs, stage of development, probability of success, and commercial readiness. This information was necessary to properly evaluate and prioritize the technologies for further consideration in the market potential and demonstration partner identification tasks that followed. While CERF made individual calls to each of the POCs, adequate information was received for only about half (in specific, 133) of the Federal infrastructure technologies initially identified.

These 133 technologies, where sufficient information was provided, were evaluated and prioritized on key criteria such as:

- Positive advantage or impact of the technology on public work operations.
- Urgency or frequency (determined in Task 1) of the problem met by the technology.
- Wide application or usage of the technology in public works operations.
- Ease of adoption.
- Stage of development, i.e., prototype demonstrated in field or beyond.
- Probability of success of the technology.

[3] Civil Engineering Research Foundation, *Federal Public Works Infrastructure R&D: A New Perspective*, Report #93-EF1003, Washington, DC, 1993.

Based on this evaluation, a "short list" of 32 prime candidates emerged for further consideration of market potential. This short list is provided as Exhibit 1 at the conclusion of this Chapter.

THE FINDINGS

It is significant that, through this exercise alone, 268 Federal technologies were identified as having the potential to meet the priority infrastructure problems of public works directors across the country (determined in Task 1). This gives some indication that Federal laboratories are clearly conducting R&D that has infrastructure application. A matrix of these technologies has been developed and is shown in Figure 14, broken out by laboratory and infrastructure system (those technologies which appear to apply to problems in a number of systems are denoted under the heading of "cross-cutting").

Most of the 32 Federal laboratories previously found as having significant PWI R&D activity are represented in the matrix. The U.S. Army Corps of Engineers' (USACE) Construction Engineering Research Laboratories (CERL) and the Department of Energy's Argonne National Laboratory (Argonne) identified and submitted the most technologies, followed by USACE's Cold Regions Research Engineering Laboratory (CRREL) and Waterways Experiment Station (WES).

MATRIX OF PARTICIPATING LABORATORIES AND TECHNOLOGIES SUBMITTED PER INFRASTRUCTURE SYSTEM

LABORATORY	BUILD-INGS	TRANS-PORT.	SOLID WASTE	HAZ. WASTE	POWER& ENERGY	WASTE-WATER	WATER RESRCS.	CROSS-CUTTING
ACE-CERL	17	5	2	2	10	4	4	5
ACE-CRREL	6	6		4		3	2	1
ACE-HEC							2	
ACE-WES		7		5	1		2	
AF-Engng.& Services Ctr.	3	4		1	1			
DOC-NIST-BFRL	3	4						1
DOC-NOAA		3					1	
DOE-Argonne Natl. Lab		3	6	21	13		2	
DOE-Brookhaven Lab		2		1	2			1
DOE-Idaho Lab			2	1	1		1	
DOE-Lawrence Berkeley Lab	3			2				
DOE-Oak Ridge Lab	1			1	1		1	
DOE-Office of Tech Transfer	3							
DOE-Pacific NW Lab	2			4		1		
DOE-Renewable Energy Lab	1			1				
DOE-Sandia Natl. Lab			1	7	1			
DOI-BOM-Albany Ctr.	1	4	2	2			1	1
DOI-BOM-Pittsburgh Ctr.	6	1			1			
DOI-BOM-Twin Cities Ctr.	2							1
DOI-Bur. of Reclamation		1			1		3	2
DOT-FAA		2						
DOT-FHWA		4						
EPA-Air & Energy Engng. Lab					4			
EPA-Athens Envir. Lab								2
EPA-Risk Reduction Lab			3	1			4	
Fed.Emergency Mgmt.Agency	1							
Naval Civil Eng. Lab		2						
Naval Surface Warfare Ctr.						1		1
NASA-Langley Research Ctr.					2			
USDA-ARS-No./High Plains						2	1	
USDA-FS Forest Product Lab		3	3	2				
USDA-Natural Resource CS							1	
USDA-Water Conserv. Lab							2	
VA Medical Center-Palo Alto	3							

Figure 14 - Matrix of Participating Laboratories and Technologies

As previously noted, adequate additional information was submitted for 133 of these technologies, which were evaluated and prioritized on key criteria, resulting in a "short list" of 32 prime candidate technologies (Exhibit 1). Overall, while many of the 268 technologies submitted may potentially solve pressing public works problems and needs and could benefit from the exposure of a well-publicized demonstration, the 32 technologies selected appear to have obvious positive impact on public works operations, wide application, ease of adoption, and are developed to the stage where they can be demonstrated in a public works environment.

As evidenced in the short list of the 32 technologies (Exhibit 1), they come from a multiplicity of laboratories including those of the Army Corps of Engineers, Air Force, Department of Commerce, Department of Energy, Department of Interior, Department of Transportation, Environmental Protection Agency, Department of Agriculture, and Department of Veteran's Affairs. Each infrastructure system is represented by at least two technologies, with several of the technologies having cross-cutting applications. The number of technologies short listed from the transportation infrastructure system, particularly technologies related to pavements, exceeds the other systems. This reflects Task 1 survey results where pavement maintenance and repair was demonstrated to be the most problematic to public works directors.

USACE's CERL technologies are the best represented on the short list, but this is not surprising given the number of technologies submitted by CERL and the congruity of its mission to that of municipal public works operations. A few of the Exhibit 1 short listed technologies have applications that are being studied by more than one Federal laboratory, such as Ground Penetrating Radar, Environmental Compliance Self-Assessment, or Resin Modified Pavement. While DOE's Argonne National Laboratory was very responsive in submitting technologies for consideration, its technologies do not appear on the short list because most apply directly to hazardous waste sites (more often a Federal problem than a local problem) or Clean Air Act compliance (more applicable to private industry than local public works), and do not have wide public works application.

THE LESSONS LEARNED

- ✓ Within the Federal laboratory system (and outside it as well in industry and academia) there is no central national infrastructure research agenda, little apparent inter-agency coordination and interaction on matters pertaining to infrastructure R&D, and no identifiable advocacy or coordinating body to define, coordinate and facilitate infrastructure issues and promote Federal infrastructure R&D.

- ✓ A consequence of this lack of inter-agency coordination and interaction is that no central clearinghouse, publication, or database exists for easily accessing information on Federal infrastructure R&D. This inadequacy in coordinating and cataloging can lead to R&D gaps as well as duplication of effort. The fragmented information that is available is often not presented in a user-friendly, market-oriented format to peak the interest and inquiries of private sector organizations that might commercialize the technology or the public works community that might demand the technology's capabilities, and thereby increase the opportunity its commercialization.

EXHIBIT 1

SHORT LIST OF CANDIDATE TECHNOLOGIES FOR MARKET POTENTIAL EVALUATION

01. LAND APPLICATION OF ANAEROBICALLY DIGESTED SEWAGE SLUDGE. A system to spread dewatered municipal sludge on suitable farm fields located within an economically feasible radius of the source. Requires periodic testing to balance nutrients for profitable crop production without runoff of excess nutrients. Requires sludge at 20-25% solids for manure spreaders.

Advantage: Inexpensive sludge disposal/recycling method, improves crop production

Cost: $7/ton for disposal within 15 mile radius

Laboratory: USDA-ARS Northern Plains Area

02. EXTERNAL COMPOSITE REINFORCEMENT FOR CONCRETE STRUCTURAL MEMBERS. This bridge repair system epoxy-bonds carbon composite materials to deteriorated concrete beams to increase load carrying capacity two to five times. Restores weakened structural bridge members by easy exterior application method without major reconstruction.

Advantage: Allows quick repair and continued use of deteriorated bridges and other highway structures

Cost: $5/SF materials and $6/SF labor

Laboratory: Tyndall Air Force Civil Engineer Support Center

03. SLUDGE TO OIL REACTOR SYSTEM WITH NITROGEN REMOVAL. By means of an aqueous alkaline process and high pressure sludge organics are dissolved and converted into oil. This process takes place in a very small area, destroys toxic organics, precipitates and removes metals, doubles nitrogen removal effectiveness, and produces clean water and saleable #4 heating oil. Example: STORS/NITREM

Advantage: Greatly minimizes sludge disposal problems; low operating costs; minimal land requirements

Cost: < $150,000/unit; treatment for population of 15,000

Laboratory: DOE Pacific Northwest Laboratory (Battelle)

04. DENSIFICATION OF WASTE PAPER FOR USE AS FUEL IN STEAM PLANT. Densifies clean waste paper and corrugated cardboard into pellets for use as fuel in solid fuel steam and electric plants. No paper sorting is required. Densification by pelletizing and cubing reduces landfill disposal up to 40%, yields low cost solid fuels, and eases handling and transporting.

Advantage: Reduces waste paper disposal in landfills and the associated costs; source of fuel

Cost: < $150,000 for equipment to treat 5 tons/hr

Laboratory: DOE-Idaho National Engineering Laboratory (Lockheed Company)

05. VOLATILE ORGANIC COMPOUND SENSOR. Portable sensor that eliminates need for laboratory analysis to detect and characterize volatile organic compounds at job sites, in water, and in soils. Instrument detects and rapidly evaluates presence of organic pollutants, such as those from underground storage tanks. Gives initial site characterization, and provides post-spill monitoring. Example: Portable Acoustic Wave Sensor (PAWS)

Advantage: Inexpensive, accurate, rapid measurement for detecting and monitoring leaks, spills and contamination

Cost: < $3,000 per unit

Laboratory: DOE-Sandia National Laboratories

06. CATHODIC PROTECTION (CP) DIAGNOSTIC FOR UNDERGROUND STORAGE TANKS, PIPING, AND ELEVATED STORAGE TANKS. This diagnostic computer program assists in evaluating, troubleshooting, and maintaining data on CP systems for structures requiring this protection. Also assists in determining causes and remedies. Can be used in conjunction with a portable pen-based computer system.

Advantage: Maximizes cathodic protection effectiveness; assists in regulatory compliance

Cost: ~$350, software costs

Laboratory: Army Construction Engineering Research Laboratories

07. WEIGHT-BASED COLLECTION OF SOLID WASTE: This method uses a vehicle-mounted scale, and an identification and reporting system to automatically weigh household refuse at the truck and bill customers in proportion to weight. Scale, on-board computer, and container identification system link with accounting process automatically. Correlates refuse expenses to consumer choices.

Advantage: Encourages customers to limit solid waste generation; saves landfill space; provides equitable billing

Cost: ~$50,000-$150,000, plus vehicle

Laboratory: EPA-Risk Reduction Engineering Laboratory

EXHIBIT 1 - SHORT LIST OF CANDIDATE TECHNOLOGIES (Continued)

08. ENVIRONMENTAL COMPLIANCE SELF-ASSESSMENT PUBLICATION. This single source outlines requirements to help municipalities achieve and maintain accurate standards of compliance to Federal environmental mandates. Clear, direct guidance allows managers to identify problem areas and prioritize operations. Example: The Environmental Assessment Manual (TEAM)

Advantage: Complete, reliable, single source for environmental compliance guidance

Cost: $35-50 per copy

Laboratory: Army Construction Engineering Research Laboratories

09. LANDFILL AS A BIOREACTOR. Pumps, piping, vertical wells, and controls are used to recirculate landfill leachate liquid. This leachate liquid helps decompose organic elements, and it is partially or fully treated by recovering, oxygenating, and recirculating. Reduces volume of refuse 30%, and lowers leachate treatment costs.

Advantage: Accelerates decomposition; reduces landfill volume, environmental risk, and leachate treatment costs

Cost: ~$250,000-350,000 for modifying new landfill

Laboratory: EPA-Office of Research and Development

10. ENGINEERED MANAGEMENT SYSTEM FOR ROOFING. This practical decision-making software helps identify cost-effective strategies for repair and replacement of low-slope roofs. It includes procedures for collecting inventory and inspection information, evaluating roof condition, identifying repair/replacement strategies, prioritizing projects and developing work plans. Example: ROOFER

Advantage: Objective condition evaluation procedures for prioritizing of projects and optimal budget allocating

Cost: ~$350, software costs, plus inspections

Laboratory: Army Construction Engineering Research Laboratories

11. IMPROVED DESIGN PROCEDURES FOR PAVEMENTS IN FREEZE/THAW REGIONS. This computerized mechanistic model allows for more accurate design of pavements for regions subject to a freeze/thaw cycle. A frost heave model allows for effective design of subgrade, subbase, and base course to reduce frost heaving, provide adequate subgrade support during thawing and permit acceptance of a variety of materials at a lower cost. Calculates seasonal load limits for roads.

Advantage: Assesses degree of expected thaw weakening

Cost: < $1,000, software costs

Laboratory: Army Cold Regions Research and Engineering Laboratory

12. ROOF BLISTER VENT. This miniature, hand inserted, pressure relief valve releases gases and moisture without allowing air or water to reenter. Air pockets in built-up roofs can result in rapid breakdown and leaks, leading to early replacement. Thumb-sized plastic vents deflate air blisters, prevent blister recurrence, eliminate more expensive cut-and-patch repair or reroofing and extend roof life. Minimal training for installation.

Advantage: Alleviates major cause of early roof failure

Cost: $8-12 per vent, plus $4 in-house labor

Laboratory: Army Cold Regions Research and Engineering Laboratory

13. MANAGEMENT SYSTEM FOR BRIDGES. This computerized bridge engineered management system assists in the management of bridge maintenance. The system includes a standardized procedure for collecting inventory and inspection information, and a condition ratings tied to current practices and acceptable rating requirements. Maintenance alternatives and costs can be compared with potential improvements in bridge condition and load carrying capability. Example: BRIDGER

Advantage: Makes effective use of bridge maintenance resources; better understanding of a bridge's condition

Cost: < $1,000, software costs, plus inspections

Laboratory: Army Construction Engineering Research Laboratories

EXHIBIT 1 - SHORT LIST OF CANDIDATE TECHNOLOGIES (Continued)

14. DIRECTIONS BY PHONE. Telephone-based, interactive voice response system gives spoken route directions/descriptions to visually-impaired visitors seeking destinations in defined and structured environments, such as large public facilities. System is accessed through touch-tone telephone keypad whether at home or at facility. Also helpful for non-impaired visitors needing directions.

Advantage: Helps meet certain ADA requirements; greatly eases access for everyone

Cost: < $30,000 per facility covered

Laboratory: VA-Rehabilitation R&D Center

15. IMPROVED SLUDGE DEWATERING TECHNOLOGY. Sand drying beds are retrofitted with planted reed beds to provide more effective dewatering and treatment of sewage sludge using the natural capabilities of the plants and soil. Plant capabilities allow more rapid and complete dewatering, storage, and composting of domestic sewage sludge. Ideal for smaller wastewater treatment plants; works effectively in northern climates.

Advantage: Environmentally-friendly; Dries sludge faster

Cost: <$50,000, plus land

Laboratory: Army Construction Engineering Research Laboratories

16. DEVICE FOR SORTING PLASTICS. A near-infrared reflectance sensing machine differentiates among the six most common types of recyclable, post-consumer plastics regardless of shape and color. Identifies plastics by resin type and signals machine to sort them. Most effective in conjunction with sorting machines that remove aluminum, etc. in a separating line.

Advantage: Eliminates costly hand sorting of plastics in recycling operations; recyclables save landfill space

Cost: < $50,000

Laboratory: DOE-Sandia National Laboratories

17. MANAGEMENT SYSTEM FOR WATER PIPES. This computerized engineering management system assists in making cost-effective maintenance and repair decisions for underground water distribution systems. System includes inventory, hydraulic modeling capabilities, quantitative condition index, condition prediction, prioritization, and economic analysis. It can predict flow reduction, corrosion and leaks, and degradation of non-metallic pipelines. Example: W-PIPER.

Advantage: Reduces life cycle costs through better allocation of funds for maintenance and repair

Costs: < $1,000, software costs, plus inspections

Laboratory: Army Construction Engineering Research Laboratories

18. PRESTRESSED PAVEMENTS: PAVEMENT SUBSTITUTE FOR REDUCED MAINTENANCE. Roadway segments are built in prestressed, long unjointed sections. Segments are matched to terrain and prestressed over maximum distance. Prestressed segments reduce the number of joints and cracks, the main cause of pavement failure. Life-cycle costs are reduced for high-volume roads due to lower maintenance.

Advantage: Reduced maintenance and life-cycle costs

Cost: Approximately equal to traditional concrete paving methods per mile

Laboratory: DOT-FHWA Turner-Fairbank Highway Research Center

19. PAVEMENT MANAGEMENT SYSTEM. This computerized pavement management system optimizes the use of repair funds and allocation of resources. Accomplished through the use of a Pavement Condition Index for roads, parking lots and airfield pavements. The approach behind the system entails inventory documentation, inspection, condition assessment, condition prediction (through analysis modeling) and work planning. Example: Micro-PAVER

Advantage: Objective pavement assessment for maximizing available funds

Cost: ~$300 for annual subscription, includes updates

Laboratory: Army Construction Engineering Research Laboratories

EXHIBIT 1 - SHORT LIST OF CANDIDATE TECHNOLOGIES (Continued)

20. MOBILE PAVEMENT MARKING MEASUREMENT SYSTEM. A van, retroreflectometer, and computer combine to measure, characterize, and record condition of horizontal pavement markings at speeds up to 55 mph. System speed and accuracy allow highway and road departments to inventory and code horizontal pavement markings quickly and inexpensively, using only two technicians. Example: Laserlux

Advantage: Provides a quick, accurate assessment of markings with minimal labor

Cost: ~$100,000, depending on van

Laboratory: DOT-Federal Highway Administration

21. MICROWELLS. A special electro-vibratory hammer drill rig, mounted on an all-wheel drive truck, rapidly drives small diameter monitoring wells with minimum soil disturbance and low cost. Microwells allow rapid characterization of critical groundwater sites. Can be used to measure landfill leachate, monitor groundwater, or detect pollutant migration.

Advantage: A quick and simple monitoring system

Cost: $500-$1000 per microwell; $100,000-$150,000 for specialized drill rig (can be contractor owned)

Laboratory: Army Cold Regions Research and Engineering Laboratory

22. MANAGEMENT SYSTEM FOR BUILDINGS. This computerized engineered management system uses engineering technology and expert opinion to manage facilities. This decision support tool for maintaining buildings and their key components includes a condition index and condition prediction modeling. Example: BUILDER

Advantage: Assists in making maintenance and repair decisions; keeps buildings in optimum condition for lower costs

Cost: < $1,000, software costs, plus inspections

Laboratory: Army Construction Engineering Research Laboratories

23. LUMINESCENCE SPOT TEST FOR POLYCHLORINATED BIPHENYLS (PCBs). This hand-held device with test strips provides a simple, rapid, spot test to detect PCBs in the part-per-billion range. Consists of a hand held UV light to activate sensor strips and photo-metric reader to give instant results on site. Provides rapid characterization (12 samples/15 minutes) of suspected PCBs in or around soil, water, oil, transformers, buildings, etc.

Advantage: Quick, low-cost, accurate and convenient

Cost: $800 for equipment, $5 per test strip

Laboratory: DOE-Oak Ridge National Laboratory

24. RUT RESISTANT ASPHALT MIXTURES. This pavement mix and installation method yields asphaltic concrete of great density and strength. The system uses a reduced amount of binder material and special compaction techniques to construct rut resistant pavements for heavy truck traffic. Designed for military runways, the mix is stable and strong when contractor follows compaction schedule and specifications closely.

Advantage: Durability resulting in reduced maintenance

Cost: Comparable to standard asphaltic concrete

Laboratory: Tyndall Air Force Civil Engineer Support Center

25. LOW HEAT, HIGH PERFORMANCE CONCRETE. Portland cement concrete is optimized for low heat production during setting. The low heat characteristic allows rapid construction with greater strength and less cracking. It is formulated for rapid set for caissons, water diversion, or other structures where speedy work reduces risk of structural collapse, or for natural events such as storms or floods.

Advantage: Quick-set concrete allows rapid construction

Cost: Less than standard Portland cement concretes

Laboratory: DOI-Bureau of Reclamation

EXHIBIT 1 - SHORT LIST OF CANDIDATE TECHNOLOGIES (Continued)

26. RESIN MODIFIED PAVEMENT. This special pavement material and method consists of open-graded asphalt and resin-cement slurry grout. An open-graded asphalt course is put down, then resin-cement slurry is applied to bind and seal the asphalt and aggregate. This tough and durable paving material combines the flexible characteristics of an asphalt concrete material with fuel, abrasion and wear resistance of portland cement concrete.

Advantage: Provides a pavement surface equal to portland cement concrete at a lower cost

Cost: $8-12/SY of pavement

Laboratory: Army Engineer Waterways Experiment Station

27. NUTRIENT-SEDIMENT CONTROL SYSTEM. Constructed wetlands are used to remove agricultural chemicals from runoff water. This method matches wetland design to expected nutrient load. Can also be used in suburban areas where lawn chemicals enter the groundwater. Provides a low maintenance wetland habitat with a park-like setting.

Advantage: Low-cost, natural, attractive wildlife habitat that supports compliance with water quality standards

Cost: < $50,000 to construct, excluding land

Laboratory: USDA-Natural Resources Conservation Service

28. ELECTRICAL SIGNATURE ANALYSIS. A meter is used to establish normal motor electronic signature. With each motor having a unique signature, the meter and a separate laboratory analysis system are used to detect changes that could mean impending failure. This non-intrusive method provides preventive monitoring of the condition and performance of motor driven electrical equipment.

Advantage: Reduces maintenance costs and downtime

Cost: < $15,000 for equipment, analysis additional

Laboratory: DOE-Oak Ridge National Laboratory

29. MANAGEMENT SYSTEM FOR UNDER-GROUND STORAGE TANKS (USTs). This computerized system simplifies management of USTs by making information access and updates more efficient and accurate. System features a Leak Potential Index (based on soil, age, capacity, etc.), plus extensive tracking and reporting capabilities and management of testing, regulatory, and project information. System provides a simple means of prioritizing USTs for monitoring, testing, maintaining, upgrading or removal. Example: TANKMAN

Advantage: Manages each UST, aids regulation compliance

Cost: < $1,000, software costs

Laboratory: Army Construction Engineering Research Laboratories

30. GROUND PENETRATING RADAR. This portable radar finds and evaluates buried objects and conditions without digging. Requires operator expertise and data processing support. Defines the extent of subsurface leaks, excavations, and hazards. Examines layers of highway pavement without drop-testing.

Advantage: Accurate underground inspection and evaluation without digging

Cost: < $50,000 for purchase or can be rented from distributors

Laboratory: Army Cold Regions Research and Engineering Laboratory

31. POLYPHOSPHATE RETARDER FOR CONTROLLED SETTING OF SLAG CEMENTS. Recycled, alkali-activated slag is used in cements to produce a rapid strength patching material for pavements. A polyphosphate retarder additive balances the hardening rate to achieve a manageable mixture for permanent patching of roads without cracking. Safely recycles metallurgical slag. Can also be used similar to portland cement in hazardous waste management.

Advantage: Recycled material yields inexpensive and effective pothole repair

Cost: Less than standard portland cements

Laboratory: Army Engineer Waterways Experiment Station

32. EXPERT SYSTEM FOR HIGHWAY-RELATED DECISION MAKING. This computer management software assesses multiple factors to assist road and highway departments in diagnosing problems and selecting materials for repair and rehabilitation of concrete structures. It aids in the understanding of material problems and design (material selection) of highway structures. Example: HWYCON

Advantage: Assists in choosing best repair method

Cost: $150 per copy, software costs

Laboratory: DOC-NIST Building and Fire Research Laboratory

TASK 3: MARKET POTENTIAL EVALUATION: MAJOR FINDINGS

THE TASK

In Task 3, the market potential of the 32 short listed candidate technologies was evaluated by means of a survey. Market potential was determined by asking the public works directors, who had responded to the Task 1 needs assessment, to consider the potential of each of the short listed technologies to meet their specific needs or the needs of the overall public works community. Accompanying the survey was a description of each of the technologies, including its advantages and cost. On the survey, the public works directors were asked to indicate the problem or need the technology addressed, the current solution being employed, competing technologies, reasonableness of the predicted costs, and the likely procurement options for obtaining or utilizing the technology. In addition, they were asked to indicate their willingness to participate in a technology demonstration. The market potential survey provided good insights regarding the potential demand and, hence, the opportunity for each technology to attract the necessary private industry investment. Moreover, the results can also be understood as further validation of those problem areas deemed by the public works directors as most urgent in terms of technology needs.

> ...the results can be understood as further validation of those problems areas deemed...as most urgent...

THE FINDINGS

Figure 15, on the following page, presents the quantitative results of the market potential survey for each of the 32 short listed technologies; these results are based on the responses of 120 public works directors/officials (9 from states, remaining local). The survey instrument asked the public works directors to select the four technologies which they believed to have the greatest market potential. Technologies selected were to be listed in order of desirability. As shown in Figure 15, **FREQ.** (frequency) represents the number of times a technology was selected, where each selection is given a value of 1; **INDEX** (index of desirability) represents a summation of the values assigned to the order the technology was listed on the survey, where the first selection = 4, second selection = 3, third selection = 2, and fourth selection = 1; and **TOTAL** represents the sum of the **FREQ.** (frequency) and the **INDEX** (index of desirability) and is used to rank order the technologies. **HOSTS** represents the number of municipalities indicating an interest in hosting a technology demonstration.

MARKET POTENTIAL SURVEY: QUANTITATIVE RESULTS

TECHNOLOGY (ID number & name)	TOTAL	FREQ.	INDEX	HOSTS
19 Pavement Management System	180	49	131	10
17 Management System for Water Pipes	113	31	82	7
11 Improved Design Procedures for Pavements in Cold Regions	107	28	79	4
24 Rut Resistant Asphalt Mixtures	103	31	72	11
08 Environmental Compliance Self-Assessment Publication	93	25	68	3
07 Weight-Based Collection of Solid Waste	92	23	69	5
26 Resin Modified Pavement	86	24	62	4
30 Ground Penetrating Radar	85	23	62	8
13 Management System for Bridges	85	22	63	2
22 Management System for Buildings	69	19	50	5
01 Land Application of Anaerobically Digested Sewage Sludge	67	15	52	4
27 Nutrient-Sediment Control System	56	16	40	3
02 External Composite Reinforcement for Concrete Structural. Members	47	12	35	4
32 Expert System for Highway-Related Decision Making	39	14	25	4
06 Cathodic Protection Diagnostic for Underground Storage Tanks, Gas Pipes, and Elevated Water Tanks	39	11	28	1
29 Management System for Underground Storage Tanks	31	10	21	1
16 Device for Sorting Plastics	30	12	18	1
09 Landfill as a Bioreactor	29	7	22	1
10 Engineered Management System for Roofing	24	7	17	2
18 Prestressed Pavements: Pavement Sub. for Reduced Maintenance	22	7	15	1
05 Volatile Organic Compound Sensor	22	6	16	2
15 Improved Sludge Dewatering Technology	20	5	15	0
03 Sludge to Oil Reactor System with Nitrogen Removal	18	5	13	3
25 Low Heat, High Performance Concrete	14	4	10	1
28 Electrical Signature Analysis	12	4	8	0
14 Directions by Phone	11	3	8	1
21 Microwells	10	3	7	1
23 Luminescence Spot Test for Polychlorinated Biphenyls	8	2	6	0
12 Roof Blister Vent	7	2	5	0
31 Polyphosphate Retarder for Controlled Setting of Slag Cements	5	1	4	1
20 Mobile Pavement Marking System	0	0	0	0
04 Densification of Waste Paper for Use in Steam Plants	0	0	0	0

Figure 15 - Market Potential Survey: Quantitative Results

Several conclusions can be drawn from the results of this market potential evaluation. Management technologies cut across all infrastructure systems and tended to dominate the top choices of the public works directors. The reasons for this include: the fact that they appear to offer great benefit at low costs and that, in the Task 1 needs assessment survey, better management tools were seen by public works directors as a key factor in improving productivity. Also, the results of the market potential survey represent some timely needs, especially with the technology that emerged as the most desired by the public works directors—a computerized pavement management system. Legislation (in particular the and a growing awareness of the benefits of computerized management are prompting the demand for this technology and for the other computerized management technologies.

While the survey revealed the desire for computerized management systems, it also revealed a strong market potential for technologies that provide a specific solution to a highly visible problem. Examples of this include: "rut resistant asphalt mixtures" and "resin modified pavement" to address highly visible pavement needs; "weight-based collection of solid waste" to meet the demand for a variable rate system; "ground penetrating radar" to assist in detecting unseen infrastructure; and "land application of anaerobically digested sewage sludge," "nutrient-sediment control system," and "sludge to oil reactor system with nitrogen removal" to address the pressing need for management and alternative processing methods for wastewater and sludge.

THE LESSONS LEARNED

- ✔ The market potential of Federal infrastructure technologies under development is not routinely considered. This may, however, result from the fact that much research is driven by agency mission requirements and the broader market potential of a new technology is not a primary consideration.

- ✔ The earlier in the development of a Federal technology that total market potential is considered and that industry and user input and participation is sought, the greater the likelihood of transferring the technology into commercial application. Potential commercializers and users who play a role in the development of a technology are very likely to "pull" it, since they have made an investment of time or money, perceive tangible advantages from the R&D, or see it as meeting a pressing need.

TASK 4: PARTNER IDENTIFICATION: MAJOR FINDINGS

THE TASK

The objective of Task 4 was to identify those private sector organizations willing to consider participating in a demonstration of a technology and willing to consider investing in its commercialization. The technologies under consideration were the 32 short listed candidates presented in Exhibit 1 that had received a market potential evaluation in Task 3. The process used to identify the private sector participants or partners was twofold. First, potential partners were sent a survey, similar to the Task 3 survey to public works directors, that asked them to evaluate the market potential of the technologies, and to express interest in commercializing and participating in a demonstration of a technology. These survey recipients were also asked to indicate if any of the technologies were non-viable. The results of this survey helped to validate the findings from the Task 3 public works directors' market potential evaluation. The second means of identifying private sector partners were phone interviews conducted with the technology laboratory point-of-contact (POC), private sector organizations known to have been involved in the technology's development or suggested by the POC, and with those respondents to the survey who had expressed interest in participating in a demonstration. The technologies that had demonstrated market potential in Task 3 and for which a demonstration team could be identified in Task 4 would be recommended for demonstration in Task 5. Demonstration teams would be comprised of a municipal public works host, the Federal laboratory developer, and a private sector partner.

THE FINDINGS

In all, over 800 corporate and manufacturing members of APWA and CERF were sent the survey and given the opportunity to express interest in transferring a Federal infrastructure technology. Eleven private sector organizations expressed interest in this manner. This low response rate was perhaps due to: though it was short, the time and effort needed to complete a survey; the fact that commercialization opportunities were presented to them instead of their seeking such opportunities; and, though expressions of interest were not binding, their reluctance to participate in anything that might eventually lead to commitment of resources.

Phone interviews yielded much better results than the survey. The Federal technology's point-of-contact (POC) was telephoned and asked about the status of the technology, possibilities for transferring it into use, and recommendations for private sector partners. As a result, private sector partners who had participated in the development of the technology, others recommended by the POC, or those expressing interest on the survey were contacted. Some were very eager to participate in technology transfer efforts, while others expressed reserved interest (they would wait and see what the particulars of a demonstration would be and, if the technology was a viable product or process).

"Driving forces" are needed for the transfer of most Federal infrastructure technologies.

THE LESSONS LEARNED

✔ "Driving forces" are needed for the transfer of most Federal infrastructure technologies. These forces might include the technology meeting a critical need, having a private sector champion, or having a Federal laboratory "push." They are amplified below:

- A "driving force" might be an unmet, critical or frequent, public works need. The best opportunity for transfer of technology is when these needs are periodically assessed and the laboratory works closely with the public works community to understand and mitigate a need in a timely way (recognizing that, in most instances, a Federal laboratory has mission specific, non-infrastructure focus and accountability).

- Another "driving force" might be a private sector organization that has already partnered with the Federal laboratory in developing a technology. In this case, they have a stake in seeing it commercialized, especially if they hold the rights or patent to it.

- Additionally a technology might be transferred by means of a Federal laboratory "push". For example, where a Federal laboratory has developed a technology with a clear infrastructure application, or one that meets an infrastructure need that it is uniquely qualified to do, then the laboratory should have a commitment to transferring the technology. This commitment can come in the form of testing, demonstrating, and verifying that a technology is market ready, and in announcing its availability to the private and public sector players in the public works community.

TASK 5: DEMONSTRATION RECOMMENDATIONS: MAJOR FINDINGS

THE TASK

The purpose of Task 5 was to recommend demonstration projects for the Federal infrastructure technologies with apparent market potential and with an identified demonstration team. In total, recommendations were made for 16 of the technologies. The demonstration recommendations for each of these technologies included: a description of the technology, the Federal laboratory point-of-contact, a discussion of status of the technology, suggestions for technology transfer efforts, listings of private and public sector demonstration partners, and funding options.

> They [the demonstration recommendations] provide a basic road map for transferring these technologies into state and local public works agencies.

The demonstration recommendations provide a basic road map for transferring these technologies into state and local public works agencies. While every effort was made to solicit interest in demonstrating and commercializing these technologies, for many, as previously noted, technology transfer is unlikely to occur without a driving force or "champion" in the public or private sector.

THE FINDINGS

All of the 32 candidate technologies that resulted from Tasks 2 and 3 appear to have the potential to positively impact public works operations. All would benefit from the increased exposure that well-publicized demonstrations would bring to them, but some technologies were not recommended for the reasons that follow. A few of the technologies were not recognized by the surveyed public works directors as having market potential, though they may be suitable for specific applications or geographic regions. One technology had been put "on hold" by its laboratory. A few were found to be in an earlier stage of development than previously suspected; hence, a demonstration would be premature. Private sector organizations noted a few of the technologies as non-viable, which was also taken into consideration in whether or not to recommend a technology for demonstration.

Overall, the biggest factor in determining which technologies were recommended for demonstration was the ability to identify a private sector partner willing to consider participating in a demonstration of the technology and in marketing it. The technologies recommended for demonstration also had to have at least one public works director interested in hosting a demonstration of it in their municipality (based upon responses of the public directors on the Task 3 market potential survey). Additionally, effort was expended in seeking private sector partners relative to the market potential survey results and relative to assuring at least one technology was recommended from each of the seven infrastructure systems (buildings, transportation, solid waste, hazardous waste, power & energy, wastewater, and water resources). These criteria outweighed the consideration of which Federal laboratory was the source of the technology.

Based upon the considerations given above, sixteen Federal infrastructure technologies were recommended for demonstration and they are listed in Exhibit 2 on the following page.

THE LESSONS LEARNED

- ✔ The technologies recommended need demonstrations for verification, validation and/or publicity. Their successful technology transfer should be given priority, since each can positively impact public works.

- ✔ Federal infrastructure technologies need to be publicized, in all stages of development, beyond the boundaries of the laboratory. In some cases, this may be the technology's greatest technology transfer need. For those Federal infrastructure technologies "sitting on the shelf," many may never receive private sector commercialization or public sector involvement unless their availability and capabilities are aggressively publicized, in a market-oriented form, by the Federal laboratory, or a consortium of laboratories focused on this objective.

EXHIBIT 2- TECHNOLOGY DEMONSTRATION RECOMMENDATIONS

TRANSPORTATION & BUILDING-RELATED:

- **PAVEMENT DESIGN FOR SEASONAL FROST CONDITIONS.** This computerized mechanistic model, developed by U.S. Army Cold Regions Research and Engineering Laboratory, allows for more accurate design of sub-grade, subbase, and base course of pavements for regions subject to a freeze/thaw cycle.

- **RUT RESISTANT ASPHALT MIXTURES.** This pavement mix and installation method, facilitated by the Tyndall Air Force Civil Engineer Support Center to offset excessive rutting of asphaltic pavements, yields asphaltic concrete of great density and strength by means of unusually low binder content and special compaction techniques.

- **RESIN MODIFIED PAVEMENT.** This special pavement material and method, which has been evaluated and facilitated by the U.S. Army Engineer Waterways Experiment Station and additionally by the U.S. Air Force and Federal Aviation Administration, consists of open-graded asphalt and resin-cement slurry grout, and combines the flexible characteristics of an asphalt concrete material with fuel, abrasion and wear resistance of portland cement concrete.

- **GROUND PENETRATING RADAR.** This portable radar, also known as "subsurface interface radar," is being researched by the U.S. Army Engineer Waterways Experiment Station for applications related to surveying of pavement thickness, voids below a roadbed and the wear of an asphalt surface. Also listed under environmental-related.

- **EXTERNAL COMPOSITE REINFORCEMENT FOR CONCRETE STRUCTURAL MEMBERS.** This bridge repair system epoxy-bonds carbon fiber reinforced plastics (CFRP) strips applied to both, reinforced and non-reinforced deteriorated concrete beams, in the tensile and shear areas of the beam to increase the load carrying capacity. It is being explored by Tyndall Air Force Civil Engineer Support Center.

ENVIRONMENTAL-RELATED:

- **ENVIRONMENTAL COMPLIANCE ASSESSMENT AND MANAGEMENT PROGRAM.** This complete, reliable, single source manual, developed by U.S. Army Construction Engineering Research Laboratories, outlines requirements to help municipalities achieve and maintain standards of compliance to Federal environmental mandates.

- **WEIGHT-BASED COLLECTION OF SOLID WASTE** This collection method, developed by the U.S. Environmental Protection Agency's National Risk Management Research Laboratory, uses a vehicle-mounted scale, and an identification and reporting system to automatically weigh household refuse at the truck and bill customers in proportion to weight.

- **GROUND PENETRATING RADAR.** (Previously listed above) This portable radar, also known as "subsurface interface radar," is being researched by the U.S. Cold Regions Research and Engineering Laboratory for applications related to finding and evaluating buried objects and investigating subsurface features, thus providing a nondestructive testing alternative to boring holes or excavating.

- **NUTRIENT SEDIMENT CONTROL SYSTEM.** This prototype system, developed by the U.S. Department of Agricultures's Natural Resources Conservation Service, is an advanced design of a constructed wetland and is devised to intercept and treat runoff water that carries pollutants to sensitive aquatic ecosystems.

- **DEVICE FOR SORTING PLASTICS.** A near-infrared reflectance sensing machine, developed as part of a cooperative agreement at the U.S. Department of Energy's Sandia National Laboratories, differentiates among the six most common types of recyclable, post-consumer plastics, regardless of shape and color.

- **LANDFILL AS A BIOREACTOR.** Pumps, piping, vertical wells, and controls are used to recirculate landfill leachate liquid and rapidly decompose landfill contents through this wet-cell operational method. This system was developed by the U.S. Environmental Protection Agency's National Risk Management Research Laboratory.

- **SLUDGE TO OIL REACTOR SYSTEM WITH NITROGEN REMOVAL (*STORS/NITREM*).** By means of an aqueous alkaline process and high pressure, sludge organics are dissolved and converted into oil. This takes place in a very small area. The system was developed by the U.S. Department of Energy's Pacific Northwest Laboratory (Battelle) and the U.S. Environmental Protection Agency.

COMPUTERIZED MANAGEMENT TOOLS:

These management tools were developed by the U.S. Army Construction Engineering Research Laboratories for use on personal computers to optimize the use of limited repair and maintenance funds. All incorporate condition prediction using a family-grouped analysis modeling technique.

- **PAVEMENT MANAGEMENT SYSTEM (*Micro PAVER*).** A pavement management system optimizes the use of pavement repair funds and allocation of resources.

- **MANAGEMENT SYSTEM FOR WATER PIPES (*W-PIPER*).** A management tool that assists in making maintenance and repair decisions for underground water distribution systems.

- **MANAGEMENT SYSTEM FOR BUILDINGS (*BUILDER*).** An engineered management tool that uses engineering technology and expert opinion to manage facilities.

- **CATHODIC PROTECTION (CP) DIAGNOSTIC FOR UNDERGROUND AND ELEVATED STORAGE TANKS, AND FOR PIPING (*CP Diagnostic*).** A software management program that assists in evaluating, troubleshooting, and maintaining data on CP systems for structures requiring this protection.

- **MANAGEMENT SYSTEM FOR UNDER-GROUND STORAGE TANKS (USTs) (*Tankman*).** This computerized system simplifies management of USTs by making information access and updates more efficient and accurate and assesses the likelihood of tank leakage.

CONCLUSIONS AND RECOMMENDATIONS

FINDINGS & CONCLUSIONS

- Each technology and the circumstances surrounding its development, progress and eventual commercialization is unique. Some general findings and conclusions can be drawn and recommendations made, but each technology can have a positive impact on public works operations and each merits special attention.

- A catalyst or driving force must be in place for most of these Federally-developed infrastructure technologies to be commercialized and utilized. The driving force may be:

    - **A critical or frequent unmet public works need**. In this case the best chance for technology transfer is when public works needs are periodically assessed and when the laboratory is able to work closely with the public works community to understand and meet the needs in a timely way (recognizing that, in most instances, a Federal laboratory has mission specific, non-infrastructure focus and accountability);

    - **A private sector organization** who has partnered with the Federal laboratory in developing the technology, and has a stake in seeing it commercialized, especially if they hold the rights or patent to it; or

    - **A Federal laboratory** developing a technology with a dual infrastructure application, or trying to meet infrastructure needs that it is uniquely qualified to do. In this case, the laboratory should have a commitment to ensuring the transfer of its technology. This commitment can come in the form of testing, demonstrating, and verifying that a technology is market ready, and in announcing its availability to the private and public sector players in the public works community.

- For Federal technologies "sitting on the shelf," most will never receive private sector commercialization or public sector involvement unless their availability and capabilities are aggressively publicized, in a market-oriented form, by the Federal laboratory.

- Many of the technologies being recommended for demonstration implementation fall into two groups: management software and pavement-related technologies. The reasons for this are:

technologies in these two groups ranked the highest in the market potential evaluation by state and local public works officials, and these technologies are more likely to have the public and private sector partners associated with them. The software management tools are generally low risk, low cost technologies to demonstrate and transfer to the public works community. Pavement issues are very visible and pervasive, so much attention and resources have been invested in meeting them. This makes it much more likely that technologies are being developed and that private sector partners are involved with the technologies, and eager to demonstrate and market them.

- In addition to the management software and pavement-related technologies being recommended, there are some environmentally-related technologies, that if demonstrated and proven to be successful, could have a truly positive effect on public works operations. They often do not receive as much attention as other technologies, but their impact could be significant. These include the Weight-Based Collection of Solid Waste, Nutrient-Sediment Control System, Landfill as a Bioreactor, and Sludge to Oil Reactor System with Nitrogen Removal.

RECOMMENDATIONS

✓ As concluded in other reports in this project and reemphasized by this study, the ***infrastructure problems and needs of the public works community should be periodically assessed***. In this way, infrastructure research and development can be focused on solving the most critical and frequent public works problems and needs. Similarly, ***Federal infrastructure research and development should be periodically cataloged*** to detect gaps and overlaps, dual-use technologies that can benefit the public works community, and technologies "sitting on the shelf" that could be applied.

✓ The infrastructure technologies being recommended in this report will have major beneficial impact on public works operations if successfully implemented. ***All need some form of demonstration***. Some need a demonstration(s) to verify and validate results; to prove the technology and reduce the risk surrounding it. Others need a well-publicized demonstration(s) to expose the technology's availability and capability to the public works community.

✓ ***All the technologies recommended***, whether in the hands of the laboratory or a private sector partner, ***need publicity and marketing*** to either, make the private sector aware of the opportunity for commercialization, or to make the public works community aware of the potential solutions to some of their pressing problems.

✓ ***The technologies identified herein must not remain buried in this report***. Funding/ partnership mechanisms should be a priority effort in order to ensure that these technologies fulfill their potential contributions to solving public works problems.

THOUGHTS ABOUT NEXT STEPS

Concern for the future of Nation's public works infrastructure has been expressed in many venues over the past several decades. As recently as 1991, the National Symposium on Infrastructure urged a comprehensive national program involving "all levels of government, professional organizations and the private sector." The Federal Infrastructure Strategy (FIS) is itself anchored in the 1988 analysis by the National Council on Public Works Improvement (NCPWI). A principal component of the Strategy is the adoption of appropriate new technologies. This study echoes the concerns voiced in these earlier for a while focusing on one critical aspect of an effective infrastructure strategy: the effective transfer of innovative technologies, especially from the Federal laboratory system, into wide-spread practice.

Improving the linkages for demonstration/validation of innovative technologies is especially important in this context. Evaluation, validation and demonstration are essential for effective commercialization. Unfortunately, these components of the R&D process are often the weak link. Unless this phase is adequately planned, funded, properly executed and given adequate publicity, even the most promising technologies may have difficulty. Providing the opportunity for effective interaction between Federal laboratories, interested public works agencies and potential manufacturers as early in the R&D process as possible and, particularly, during this phase will enhance the probability of successful commercialization of worthy technologies. The results of this study suggest that this phase of the technology transfer process is the most challenging, constituting, in effect, a virtual "valley of death" for many technologies. This technology transfer (T^2)"valley" is depicted in Figure 16 for Federal laboratories and the potential public works "user" community.

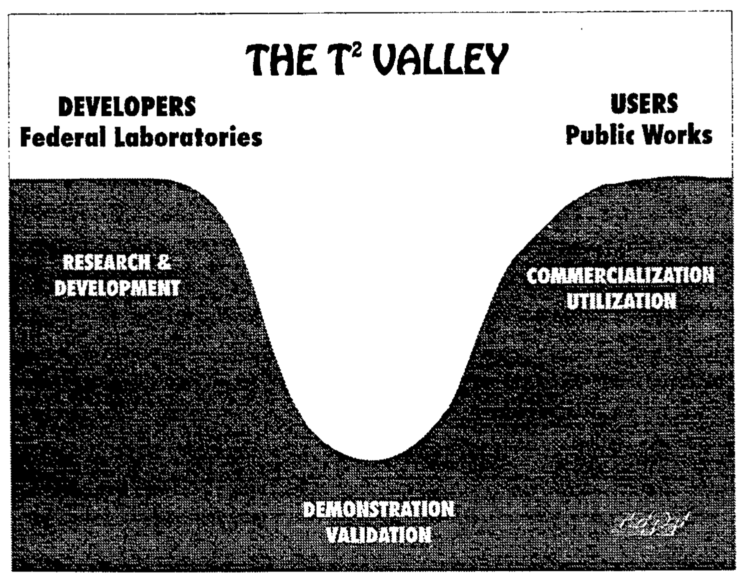

Figure 16 - The T^2 Valley

As documented by others[4], while impetus and capital are often available for research and development, both often wane as the technology is ready for prototyping, testing, evaluation, validation, and demonstration. This is the formidable trough in the technology transfer valley. Only when a technology has been successfully demonstrated, or a private sector partner sees the value and potential, develops a firm commitment and raises the necessary capital to enable commercialization, is the technology capable of emerging out of the valley and into eventual utilization by the nation's public works agencies. For some Federal infrastructure technologies, it appears to be very difficult to keep the evaluation/validation/demonstration phase from being the valley into which neither the developer nor the commercializer/user wants to venture.

QUESTIONS FOR THE FUTURE

This is the general conundrum of technology transfer. However public works technology differs in some respects from other technologies. There are innumerable actors in the public works field across all levels of government. The circumstances in which potential technologies can be implemented are diverse, ranging from small towns in cold climates to large cities in warm ones. Budgets for experimentation and implementation are often extremely tight. And there are often great differences between the technical interest and capacity of the technology developer and the potential user, in most cases a local public works department.

This study has yielded findings, conclusions and recommendations about infrastructure technology transfer and how it might be facilitated. Some specific demonstration candidates have been identified which might be pursued where mutual interest between developer and user may exist. However the study has also suggested some questions which can be the subject of further contemplation by policy makers and further research by policy analysts.

One set of questions revolves around the technology transfer process.

- ❏ Does one technology transfer process fit all situations? Public works providers are very different than, say, defense technology providers suggesting that there may be no one model applicable to all types of technology.

- ❏ Is the specific 5-step technology process used in this study the appropriate model for future technology transfer in the infrastructure field? Given the fragmentation of infrastructure providers and their often limited capacity to experiment, a low-effort and low-cost process may be recommended.

- ❏ Who should drive the technology transfer process? The process used in this study was driven largely by the research community, especially CERF. This is understandable in a prototype development. But a more self-directed process which builds off the prototype may not necessarily be best driven by researchers.

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[4]William M. Haney, "Technology Development via Corporate Partnering," *Conference Proceedings-Entrepreneurial Technology Transfer: The Commercialization Success Factors for Intra- and Entrepreneurs*, MIT Enterprise Forum, Baltimore, MD, December 2-5, 1992, slide-"Capital Availability Evolves."

- ❑ Should different infrastructure modes have different technology transfer processes? The modes themselves are quite different. Surface transportation has a more well-developed and centralized information exchange mechanism (through the Transportation Research Board for example) than hazardous waste management, and there are fewer actors in, say, highways, (mainly State highway departments) than in the water supply arena. To take an example of a different sort of institutional nuance, railroad operators are almost entirely private (save AMTRAK) while the primary waterway operator is the Corps of Engineers. All of these differences suggest that different tech-transfer mechanisms may be used depending on the circumstance.

The other set of questions revolves around policy, specifically formulation of future infrastructure policies.

- ❑ How much of current infrastructure problems due to R & D insufficiencies and how much is due to other factors such as lack of funds or inefficient program management? This study has focused on R & D, but it should be kept in mind that there are many influences on infrastructure provision and management and these may be more important in terms of service delivery outcomes.

- ❑ What is the best market-test for technology transfer demonstrations? This study has identified a number of potential technology pilots, and has also suggested a leading role for Federal laboratories in coordinating those pilots. However there is always a risk that a pilot will be chosen for political rather than economic or good policy reasons. Leaving matters entirely to the private market may yield too little R & D (after all, the uncertainty surrounding new technology and the difficulty that private actors may have in capturing all the benefits of a technology once it is developed is one of the primary justifications for public sector involvement in the area). But there can be too much coordination as well. How can the balance be struck and what incentives are necessary to keep it there?

These are not easy questions, but they must be considered carefully, both in implementing the demonstrations developed and in carrying out some of the policy options recommended here.

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Carl Magnell and Lisa Diehl
Civil Engineering Research Foundation
1015 15th Street, NW, Suite 600
Washington, D.C. 20005

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

USACE, Water Resources Support Center
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This report provides an executive summary of an interagency study, facilitated by the U.S. Army Corps of Engineers and conducted under the auspices of the Construction Engineering Research Foundation (CERF), of a five-stage technology transfer process which identified promising public works technologies in Federal laboratories and matched them with public works needs in the private sector. The Program began with a survey of public works needs, followed up with a canvass of existing Federal technologies which might meet those needs. The process concluded by matching needs and technologies to identify potentially high-payoff commercialization prospects.

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