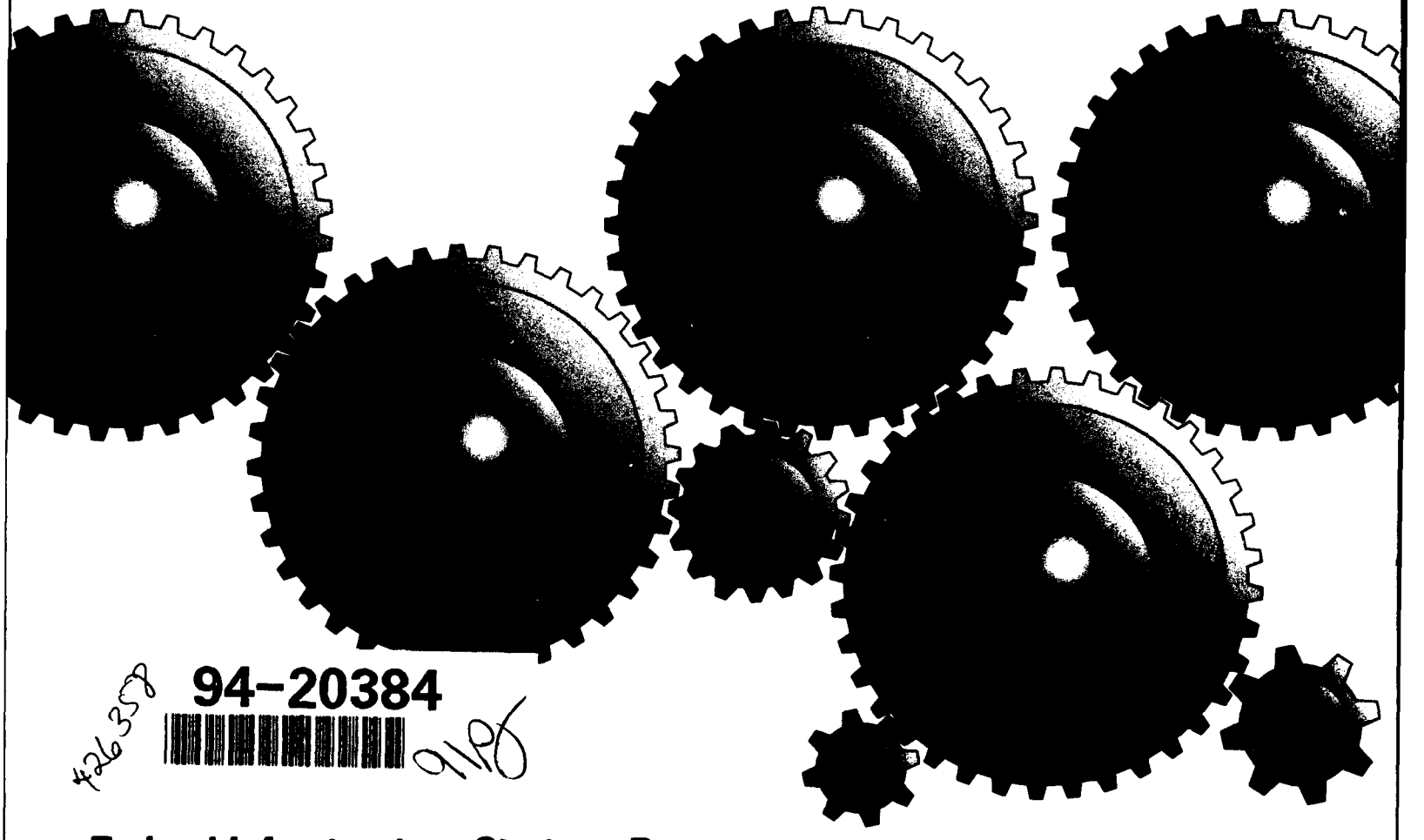
U.S. Army Corps of Engineers
Water Resources Support Center
Institute for Water Resources

Federal Public Works Infrastructure R&D: A New Perspective



Federal Infrastructure Strategy Program

July 1993

94 7 5 051

IWR Report 93-FIS-5

Federal Infrastructure Strategy Reports

This is the fifth in a series of interim reports prepared to support the Federal Infrastructure Strategy Initiative, a 3-year program to explore the development of an integrated multi-agency Federal infrastructure strategy.

The Federal Infrastructure Strategy is a dynamic program involving many Government departments and agencies. The series of reports which chronicle the strategy's development reflect the desire to publish interim documentation as results become available. Theses documents will be used to facilitate the dialogue within the Federal and non-Federal infrastructure communities as policy deliberations continue.

The program will culminate with a final report to be published at the end of 1993. The interim documentation contained herein is not intended to foreclose or preclude the program's final conclusions and recommendations. Within this context, comments are welcome on any of these reports.

This report documents the results of an in-depth study and workshop which developed methods which could be applied to overcome barriers to innovation and the use of innovative technology within the nation's public works infrastructure.

The first report published as part of the Federal Infrastructure Strategy Program was:

> The Federal Infrastructure Strategy Program: Framing the Dialogue - Strategies, Issues and Opportunities (IWR Report 93-FIS-1).

The next three reports planned for publication as part of the program are:

> Challenges and Opportunities for Innovation in the Public Works Infrastructure, Volume I and Volume II (IWR Report 93-FIS-2 and IWR Report 93-FIS-3), and
>
> Infrastructure in the 21st Century Economy: A Review of the Issues and Outline of a Study of the Impacts of Federal Infrastructure Investments (IWR Report 93-FIS-4).

For further information on the Federal Infrastructure Strategy, please contact Robert A. Pietrowsky, Program Manager at:

Institute for Water Resources
Casey Building
7701 Telegraph Road
Fort Belvoir, VA 22060-5586
Telephone: (703)-355-3073

The Federal Infrastructure Strategy study team includes Cameron E. Gordon, Economic Studies Manager and James F. Thompson, Jr., Engineering Studies Manager. The program is overseen by Dr. Eugene Z. Stakhiv, Chief, Policy and Special Studies Division, and Kyle Schilling, Director of the Institute.

Reports may be ordered by writing (above address) or calling Arlene Nurthen, IWR Publications, at (703) 355-3042.

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, WATER RESOURCES SUPPORT CENTER
INSTITUTE FOR WATER RESOURCES
7701 TELEGRAPH ROAD
ALEXANDRIA, VA 22315-3868

REPLY TO ATTENTION OF

June 24, 1994

CEWRC-IWR

MEMORANDUM FOR COMMANDER, Defense Technical Information Center, Cameron Station, Alexandria, VA 22314

SUBJECT: Transmittal of IWR Report 93-FIS-5

1. Reference AR 70-31.

2. Two copies of IWR Report 93-FIS-5, "Federal Public Works Infrastructure R&D: A New Perspective", has hereby been submitted.

3. Initial distribution of this report has been made to appropriate Corps of Engineers agencies. It is recommended that copies of this report be forwarded to the National Technical Information Center.

4. Request for the DTIC Form 50 (Incl 2) be completed and returned to WRSC-IWR.

FOR THE DIRECTOR:

Enclosure

Kyle E. Schilling
Director

THE FEDERAL INFRASTRUCTURE STRATEGY PROGRAM

FEDERAL PUBLIC WORKS INFRASTRUCTURE R&D:

A NEW PERSPECTIVE

Prepared by

Carl O. Magnell

Civil Engineering Research Foundation
1015 15th Street N.W.
Washington, D.C. 20005

for

Water Resources Support Center
Institute for Water Resources
Casey Building
Fort Belvoir, VA 22060-5586

July 1993

IWR Report 93-FIS-5

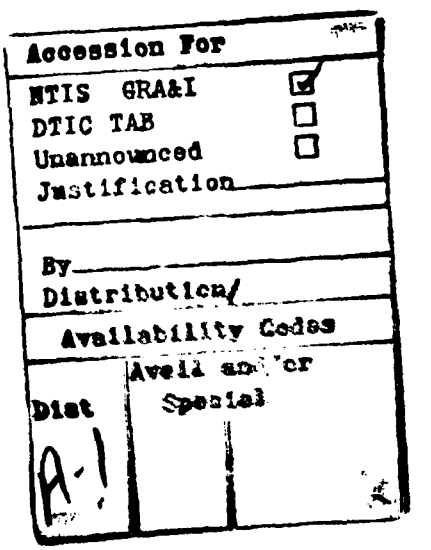
PREFACE

This report documents one of a series of analyses undertaken by the U.S. Army Corps of Engineers' Institute for Water Resources under a broad Congressional directive aimed at development of a federal infrastructure strategy.

This non-statistically based report on the federal role in public works infrastructure R&D was prepared by the Civil Engineering Research Foundation (CERF), the research affiliate of the American Society of Civil Engineers (ASCE), in conjunction with the University of Illinois.

Neither CERF nor any person acting on behalf of CERF:

- Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report.
- Assumes any liability with respect to the use of, or for damages resulting from the use of, any information disclosed in this report.
- Makes any endorsement, recommendation, or preference regarding the information contained in this report.



ACKNOWLEDGEMENTS

This report reflects the insight and the expertise of many infrastructure experts. As appropriate, these individuals or their studies are cited or quoted. In addition, the Civil Engineering Research Foundation (CERF) wishes to acknowledge the special contributions of individuals whose efforts and suggestions have significantly influenced this report. The author of this report is Carl O. Magnell, CERF's Director of Research. Professor Joseph Murtha of the University of Illinois provided initial suggestions and insights regarding scope, invaluable help in the compilation of data and graphic formats, and critical review of the report. The superb assistance of other University of Illinois personnel, including Ms. Helen Mardis in developing informational tables and Mr. Terry Wall in creating graphics, is likewise appreciated. The support and insight obtained from the Federal Laboratory Consortium was especially useful in formulating a strategy for determining Federal laboratory public works infrastructure R&D; the assistance of Dr. Andrew Cowan, the Federal Laboratory Consortium Locator Manager, is particularly acknowledged.

CERF also acknowledges the critical review, supervision, and suggestions provided by CERF management staff. Finally, the assistance of Ms. Lisa Diehl, CERF Research Project Coordinator, in formatting, editing, and reviewing this report was invaluable and is deeply appreciated.

Harvey M. Bernstein, President
Civil Engineering Research Foundation

TABLE OF CONTENTS

	Page
Preface	iii
Acknowledgements	v
List of Figures	ix
Executive Summary	xi
1.0 Objective and Background	1
1.1 Objective	1
1.2 Background	2
1.3 Defining Public Works Infrastructure	5
2.0 Federal Infrastructure R&D Role: An Agency Perspective	7
3.0 Federal Public Works Infrastructure R&D	13
3.1 Overview	13
3.2 Funding	14
3.3 Primary Federal PWI Laboratories	23
3.4 PWI Systems/Principal Laboratories	25
3.5 Funding by Application Area	31
3.6 Location of Research	32
3.7 Types of Research	32
3.8 Technology Transfer	32
4.0 Foreign Infrastructure Research and Development	35
4.1 Organizational Structure for PWI R&D	35
4.2 The Role of Industry	36
4.3 Funding for PWI R&D	37
5.0 Conclusions and Recommendations	41
Endnotes	43
References	47
Appendices	49
A FLC: List of Federal Laboratories	A-1
B Sample: Federal Infrastructure R&D Analysis Questionnaire with Cover Letter	B-1
C Tables	C-1
D List of Acronyms	D-1

LIST OF FIGURES

Figure		Page
1.1	Cross-Country Comparison of Productivity Growth and Public Investment to GDP Ratio (1973-1985)	3
2.1	FHWA Program Development	10
3.1	Federal R&D Funding Range for FY 1992 Public Works Infrastructure Systems	15
3.2	Federal R&D Funding for FY 1992 Public Works Infrastructure Systems	16
3.3	Federal R&D Funding Range for Transportation	17
3.4	Federal R&D Funding Range for Water Resources	18
3.5	Federal R&D Funding Range for Energy Source/Delivery	19
3.6	Federal R&D Funding Range for Building/Structures	20
3.7	Federal R&D Funding Range for Waste	21
3.8	Federal R&D Funding Range for Other	22
3.9	Approximate Distribution of Effort for Transportation for FY 1992	25
3.10	Approximate Distribution of Effort for Water Resources for FY 1992	26
3.11	Approximate Distribution of Effort for Energy Source/Delivery for FY 1997	27
3.12	Approximate Distribution of Effort for Building/Structures for FY 1992	28
3.13	Approximate Distribution of Effort for Waste for FY 1992	29
3.14	Higher Percent Budget Allocations	31
3.15	Most Preferred Technology Transfer Methods	33

EXECUTIVE SUMMARY

This report was prepared for the Federal Infrastructure Strategy Initiative, a 3-year program to explore the development of an integrated federal infrastructure strategy. The program was initiated as one of the President's Budget items for Fiscal Year (FY) 1991 and approved by Congress for execution by the U.S. Army Corps of Engineers (USACE) Directorate of Civil Works. The Corps' Institute for Water Resources (IWR) has detailed management responsibility under the direction of Dr. Eugene Z. Stakhiv, Chief, Policy and Special Studies Division and Mr. Robert A. Pietrowsky, Program Manager. As an initial effort of this program, IWR tasked the U.S. Army Construction Engineering Research Laboratories (USACERL) to conduct an analysis of the federal role in public works infrastructure research and development. The analysis and the final report were accomplished in conjunction with the University of Illinois by the Civil Engineering Research Foundation (CERF).

The objective of this report is to provide the Federal Infrastructure Initiative with a "snap-shot" in time of federal resources committed to infrastructure research and development (R&D). Resources are defined as levels of funding and the number of federal laboratories engaged in infrastructure related R&D.

In performing this analysis, the Civil Engineering Research Foundation (CERF) contacted more than a dozen federal agencies and coordinated with the Federal Laboratory Consortium (FLC) to obtain data from 257 of the federal laboratories.

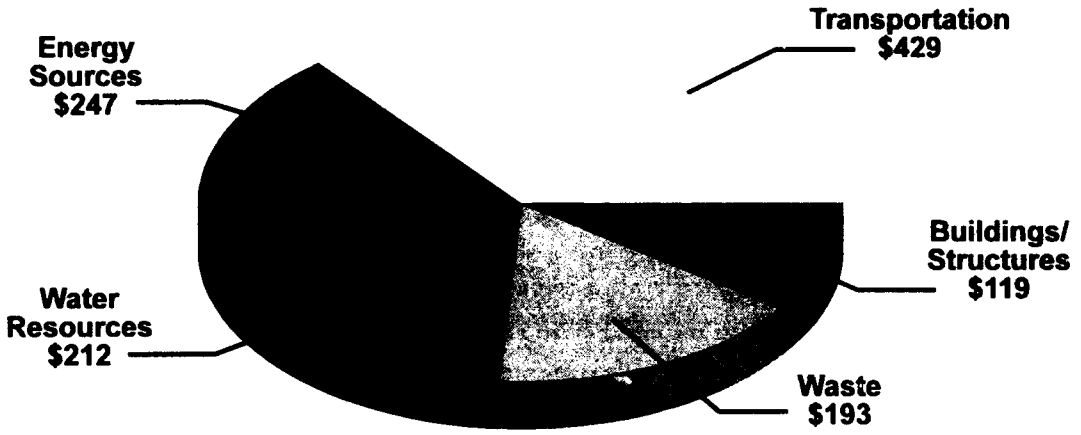
Research and development for the purposes of this report was taken to be the context in which this term is used in the federal laboratory system, that is, as basic, applied, or demonstrations. Federal laboratories were asked to categorize their efforts in this format (see, for example, Table 3.11); as noted in this Table, several laboratories indicated that portions of their research and development efforts fall outside of these three categories.

Data from the federal laboratories indicate that public works infrastructure research and development activity ranges between $1.026 and $1.386 billion for FY 1992. The upper and lower range values, when averaged, suggest that federal expenditures for public works infrastructure research and development was on the order of $1.2 billion for FY 1992, or approximately 1.6 percent of total federal expenditures for research and development.

Federal funds were distributed among five primary public works infrastructure systems as indicated below:

Federal R&D Funding for FY 1992
Public Works Infrastructure Systems

(Budget in Millions of Dollars)



Total Expenditures = $1.2 Billion

There is no consensus national definition of public works infrastructure; this poses a fundamental difficulty in assessing the federal role. **Such a definition is needed and action to achieve this is recommended.** As defined for this study, the federal role in public works infrastructure research and development, while small in relation to total federal R&D expenditures, is more extensive than documented in previous studies. The actual levels of expenditure may be even higher than determined in this analysis inasmuch as the concept of public works infrastructure is not deeply embedded in many of the laboratories or agencies; laboratories may therefore have understated actual involvement.

Public works infrastructure R&D lacks the guidance of a comprehensive, coordinated and integrated national policy. In its absence, the various agencies and laboratories are focused on executing agency missions related to their respective components of the infrastructure. No federal agency has been assigned (or has taken) a lead role. The lack of an integrated national policy may likewise contribute to relatively weak inter-agency coordination on infrastructure issues, including research and development. **This analysis therefore recommends the cooperative development of a national public works research agenda by the federal government, state and local entities, and the private sector.**

The following broad conclusions were drawn from agency level interviews:

- √ **Federal agencies have widely differing perspectives regarding PWI R&D.**
- √ **Strong, focused PWI R&D programs exist in several agencies.**
- √ **Inter-agency coordination/cooperation is modest, but may be increasing.**
- √ **No cohesive federal strategy exists for PWI R&D; therefore, there is no discernible national focus or thrust.**

With respect to infrastructure, it has been suggested that infrastructure alone, of major national activities, lacks an institutional means to effect coordination and policy formulation. **This analysis concurs, concluding that no federal agency has a clear leadership role nor a mandate to coordinate actions and policy related to public works infrastructure**. Furthermore, the terminology, or indeed, concept of infrastructure or more precisely, public works infrastructure, is not clearly embedded in some of the agencies.

Public works infrastructure research and development is concentrated in a small number of federal laboratories, primarily laboratories in the Department of Transportation, the Department of Defense, the Department of Energy, and the Environmental Protection Agency. Specifically, 32 of the 257 laboratories identified through the Federal Laboratory Consortium are engaged in public works infrastructure research. Significant basic research is undertaken by the National Science Foundation. Technology is transferred through a number of methods, including both traditional means (such as publications and presentations) and new methods made possible by enabling legislation, such as licenses and cooperative research and development agreements (CRDAs). **The significant use of licenses and CRDAs is encouraging and suggests the growing importance and effectiveness of legislation enacted in the last decade**.

Data on foreign government expenditures for public works related infrastructure research and development is inadequate. **More emphasis on obtaining such data is recommended**. A notable contrast in both Europe and Japan is the significant participation of the construction industry in funding and executing infrastructure related research and development; while exact comparisons were beyond the scope of this study, foreign construction firms appear to have forged closer relationships with government and academia and in many instances provide the majority of funds. Moreover, **the effectiveness of technical transfer mechanisms and management techniques for research and development resources in these countries deserve added consideration**.

Does federal PWI R&D meet national public works infrastructure needs? Meeting such needs requires at least two components, performance of relevant R&D and the effective transfer of R&D results into practice. This analysis does not answer this fundamental question; indeed, it cannot be answered until national needs are better defined and prioritized, and specific federal research and development matched to those needs. Much, if not all, of the on-going federal research and development is clearly focused on real needs, but it is not currently guided by a national infrastructure research agenda. **How well the technology transferred matches actual national infrastructure needs is therefore unclear; determining this is recommended as a priority action**.

CHAPTER 1

OBJECTIVE AND BACKGROUND

This report was prepared for the U.S. Army Corps of Engineers Institute for Water Resources (IWR) as part of a 3-year program to explore the development of an integrated federal infrastructure strategy. This program, The Federal Infrastructure Strategy, was initiated as one of the President's budget items for Fiscal Year (FY) 1991 and approved by Congress. The U.S. Army Corps of Engineers (USACE) was selected to act as program facilitator; other government departments and agencies are also participating. Program oversight is accomplished by the USACE Directorate of Civil Works; the Institute for Water Resources (IWR) has detailed management responsibility.

1.1 OBJECTIVE

The objective of this study is to establish baseline information regarding the federal government's role in public works infrastructure research and development (for convenience referred to at times, hereafter, as PWI R&D). That the federal government has been and continues to be a principal participant and funder of PWI R&D is well established. **What, where, and how PWI R&D is accomplished by the federal government is the focus of this analysis.**

The most recent estimates place the level of annual federal expenditures for R&D at approximately $76 billion. It is estimated that $23 billion of this total is allocated to fund federal laboratories.[1] How much of this total funding is further allocated towards PWI R&D is more difficult to estimate, but is a primary objective of this analysis. It is therefore anticipated that the results of this analysis may serve to better define and understand the federal role in PWI R&D and may help influence and potentially improve the allocation of federal resources towards PWI R&D. The scope of this analysis includes these primary objectives:

- Identify federal agencies directly or indirectly involved in infrastructure R&D, areas of research emphasis, and the funding dedicated to these efforts.
- Explore how federal agencies execute their responsibilities and the priority given to infrastructure R&D.
- Develop trend data by agency on the financial resources devoted to public works infrastructure R&D.
- Compare the role of the U.S. government in public works infrastructure R&D with selected European countries and Japan, including resources committed and institutional arrangements.

1.2 BACKGROUND

A nation's infrastructure determines, in fundamental ways, what and how critical societal functions and events are accomplished. In the broadest interpretation, infrastructure may be defined as those natural and constructed facilities essential for the proper functioning of a society. In this sense, the infrastructure can differ markedly, depending upon the stage of development and needs of a society. The public works infrastructure may likewise differ within a nation, depending upon the demographics, the geography, the degree of urbanization, and the differing economies in various regions. In the United States, the infrastructure in the fifty states and the major regions differ markedly for these reasons. Perhaps as a result of these factors, the infrastructure of the United States has been described as basically a local/regional matter, but with strategic national consequences.[2]

Infrastructure is a major national investment, comprising approximately 20 percent of the nation's stock of physical capital.[3] Latest estimates places the value of the nation's public works infrastructure at $2.7 trillion.[4] The bulk of public works infrastructure, $1.9 trillion, is in state and local hands.[5] Spending associated with the nation's public capital stock is a large component of the nations' total construction activity, estimated to be between 25 and 30 percent of the current annual expenditure of approximately $450 billion.[6]

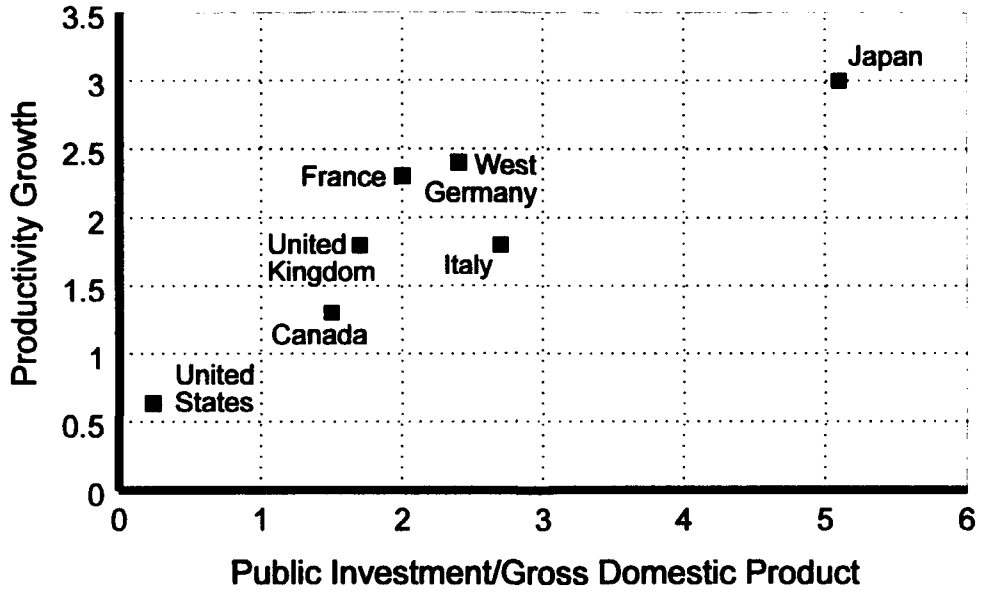
The emergence of the United States as a leader within the world community is a reflection of the historical excellence and extent of our infrastructure. Today, however, the excellence and indeed, the adequacy of that infrastructure is increasingly questioned. Many of the nation's public works systems are now aging and exhibit various stages of decay and sometimes, failure. Several examples are illustrative. Recent reports indicate that over 25 percent of the interstate highway system is in poor shape and that 23 percent of the 575,000 bridges in the United States are structurally deficient while another 19 percent are functionally obsolete.[7] Water distribution systems are estimated to require between $14-$40 billion over the next twenty years, in addition to $1.4 billion per annum for new construction.[8] To provide its citizens with efficient public services and remain internationally competitive, the United States is estimated to require $800 billion to create the infrastructure required for the 21st Century.[9]

The National Council on Public Works Improvement (NCPWI), in a 1987 study, examined major issues affecting the U.S. public works infrastructure, including research and development. The council report, *Fragile Foundations: A Report on the Nation's Public Works*, encompassed air and land transportation, water and waste water systems and the disposal of wastes. Among the disturbing trends identified by the NCPWI was the steady relative decline in public spending on infrastructure, from 3.6 percent of gross national product (GNP) in 1960 to 2.6 percent in 1985. More recent data paints an even bleaker picture. By 1990, federal infrastructure spending had fallen to 2.5 percent of all federal outlays, adding state and local outlays, infrastructure accounted for a mere 0.5 percent of gross domestic product (GDP). This figure contrasts sharply with

infrastructure to GDP expenditure ratios in other countries; by this measure, the United States is vastly out-spent by its principal economic rivals as shown in *Figure 1.1*.

Figure 1.1

Cross-Country Comparison of Productivity Growth and Public Investment to GDP Ratio (1973-1985)



Source: Public Investment and Private Sector Growth, *published by the Economic Policy Institute*

With respect to R&D, the NCPWI concluded that the level of effort and resources applied to infrastructure research and development in the United States falls far short of current, as well as future, requirements. The NCPWI also noted that federal spending on infrastructure R&D had fallen steadily in recent years.[10]

Since 1987, several public and private organizations have also identified the importance of improving and upgrading our nation's infrastructure system. Notable among recent analyses is the 1991 report by the U.S. Congress, Office of Technology Assessment (OTA), entitled *Delivering the Goods; Public Works Technologies, Management, and Financing*. This study was undertaken at the request of the Senate Committee on Environment and Public Works and the House Committee on Public Works and Transportation. Among the important conclusions emerging from this study

was OTA's assessment that changes in federal programs management, investment policies, **and R&D** were needed. More specifically, the study suggested that it was essential to:

> " ...collect information that will enable the government to refocus support for short-term R&D to target applied technologies that will improve the condition, extend the life, and increase the capacity of existing public infrastructure; then, using the data as a base, develop and implement long-term systems R&D programs to address future needs."[11]

In another 1991 report, the Civil Engineering Research Foundation explored the research needs of the civil engineering profession and the design/construction industry. This report, *Setting A National Research Agenda for the Civil Engineering Profession*, was the result of a national needs forum in which more than 25 engineering and scientific organizations and 300 of the nation's foremost civil engineering leaders from industry, academe, and government participated. They identified five major research thrust areas, the first of which was revitalization of the nation's infrastructure. The infrastructure research thrust area was further developed into ten priority research initiatives, as follows:

1. Developing Tools to Make Smart Management Decisions
2. Finding New Ways to Finance Infrastructure Investment
3. Extending the Useful Life of the Infrastructure
4. Protecting Bridges from Natural Hazards
5. Identifying Structural Problems Through Diagnosis
6. Removing Institutional Barriers to Innovation
7. Economic Benefits from Public Works Investments
8. Improving Water-Resource Systems Data through New Technology
9. Mitigating Coastal Damage from Natural Hazards
10. Protecting Dams Against Earthquakes and Floods

Each study of the nation's infrastructure shares one conclusion— the infrastructure system is a national asset and must be both maintained and enhanced for our nation to function effectively and compete in an increasingly complex international economy. Several economists have identified a strong correlation between investments in the infrastructure, productivity, and economic growth; David A. Aschauer, for example, estimates that private sector growth would have been 50 percent higher had infrastructure investment between 1970 and the present equaled the levels (relative to GNP) of the period 1950 to 1970.[12] Alicia Munnell concurs with Aschauer, but calculates a smaller increase of 0.34 percent in private sector output/productivity from a one percent increase in the stock of public capital.[13]

1.3 DEFINING PUBLIC WORKS INFRASTRUCTURE

Determining the federal role in public works infrastructure requires defining what constitutes the public works infrastructure. There is, however, no single or simple answer to help determine this. The National Council on Public Works Improvement in their 1987 analysis, as noted earlier, considered three principal components (air and land transportation, water and waste water systems, and disposal of wastes). The Office of Technology Assessment defined public works as consisting of roads and bridges, mass transportation, ports and airports, waterways and water supply, wastewater treatment and solid waste disposal.[14] The Portland Cement Association, in its recent publication, *Investing in Our Future*, considers infrastructure to consist of "highways, roads, bridges, airports, mass transit systems, water supply systems, wastewater treatment plants, sewer systems".[15] The National Science Foundation (NSF) and others, view public works infrastructure in a broader context, especially in view of the changing global environment. This more expansive view includes the traditional components and incorporates the communication "highways" that are already emerging. It is clear that the definition of public works infrastructure should not be an arbitrary decision; **one conclusion of this analysis is that a consensus national definition of public works infrastructure would be helpful and is needed.**

For this analysis, public works infrastructure is defined to encompass:

Transportation	Roads, bridges/tunnels, rail systems, mass transit, ports and harbors, airports and air control facilities, water transportation, etc.
Water Resources	All components, including dams, reservoirs, water supply (treatment and distribution), sewers and sewerage treatment, irrigation and land drainage, waterways.
Energy Sources/Delivery	Stations and sub-stations, distribution and transmission networks, monitoring centers, etc. related to hydro, fossil fuel, nuclear, solar and other power and energy sources.
Building/Structures	This category includes all types of federal facilities, for example, defense installations, administrative and judicial facilities, research facilities, etc., as well as general building and structure research.
Waste	All forms of solid waste and solid waste treatment, including landfills, incineration, bio-degradation, etc.

CHAPTER 2

THE FEDERAL INFRASTRUCTURE R&D ROLE: AN AGENCY PERSPECTIVE

The federal government holds a substantial, but minority, stake in the nation's infrastructure. As noted earlier, most of the nation's public works infrastructure belongs to states and local communities. Even so, the assets controlled by the federal government are very substantial:

- 230,000 miles of highway (six percent of total)
- 2800 miles of railway
- 417,000 buildings
- 68,000 leased locations
- Over 10,000 miles of inland waterways
- Over 3000 dams

In addition to outright ownership, federal aid funds portions of 600,000 miles of highway (16 percent of total) and supports 270,000 bridges (47 percent of total)[16].

Among the important objectives in this study are to clarify how the various federal agencies define their public works infrastructure roles and how the agencies actually formulate and execute PWI R&D. In accomplishing this task CERF contacted the following federal departments and agencies:

- The Department of Defense
- The Department of Energy
- Department of Commerce
  - National Institute of Standards and Technology
- Department of Transportation
  - Federal Highway Administration
  - Federal Aviation Agency
- Department of the Interior
- Department of Housing and Urban Development
- National Aeronautics and Space Administration
- Environmental Protection Agency
- General Services Administration
- Federal Emergency Management Agency
- National Science Foundation

Valuable information was provided by knowledgeable personnel in each agency contacted. CERF interviewed senior career personnel in each agency; their corporate knowledge provided useful insights into long term trends and issues within the infrastructure arena.

Agency interviews were formulated around the following set of questions:

- ✓ What is your agency's R&D strategy/focus?
- ✓ What is your total R&D funding?
- ✓ How does your agency define Public Works Infrastructure (PWI)?
- ✓ From your agency's perspective, is there a **national infrastructure** strategy?
- ✓ Is PWI Infrastructure important to your agency's mission?
- ✓ Is PWI Infrastructure an explicit variable in your agency's planning? Strategy?
  If yes, what is the strategy/focus for PWI Infrastructure R&D?
- ✓ What is your PWI Infrastructure R&D funding level?
- ✓ Is your PWI Infrastructure R&D program developed "bottom up" or "top down"?
- ✓ Will the scope/focus of your PWI Infrastructure R&D effort change next year?
  Over the next five years? Is this part of a defined strategy?
- ✓ Does your agency coordinate PWI Infrastructure R&D with other federal agencies?
  With other governmental organizations (state/local/etc.)?
  With other nations?

Based upon responses to these questions, the following broad conclusions were drawn from agency interviews:

- √ **Federal agencies have widely differing perspectives regarding PWI R&D.**
- √ **Strong, focused PWI R&D programs exist in several agencies.**
- √ **Inter-agency coordination/cooperation is modest, but may be increasing.**
- √ **No cohesive federal strategy exists for PWI R&D; therefore, there is no discernible national focus or thrust.**

With respect to infrastructure, it has been suggested that no other large national activity lacks an institutional means to effect such coordination and policy formulation.[17] It is therefore appropriate to consider the last conclusion, cited above, first. All federal agency personnel interviewed acknowledged that a clear and comprehensive federal strategy does not exist for public works infrastructure, R&D included. Perhaps as a result, **this analysis concludes that no federal agency has a clear leadership role nor a mandate to coordinate actions and policy related to public works infrastructure**. Furthermore, the terminology, or indeed, concept of infrastructure or more precisely, public works infrastructure, is not clearly embedded in some of the agencies.

The question must be asked— does federal PWI R&D meet national public works infrastructure needs? Meeting such needs requires at least two components, performance of relevant research and the effective transfer of research results into practice. This analysis does not answer this fundamental question; indeed, it cannot be answered until national needs are better defined and

prioritized, and specific federal research matched to those needs. Much, if not all, of the on-going federal research is clearly focused on real needs, but it is not currently guided by a national infrastructure research agenda. **This analysis concludes that the development of a national public works infrastructure research agenda should be a priority**.

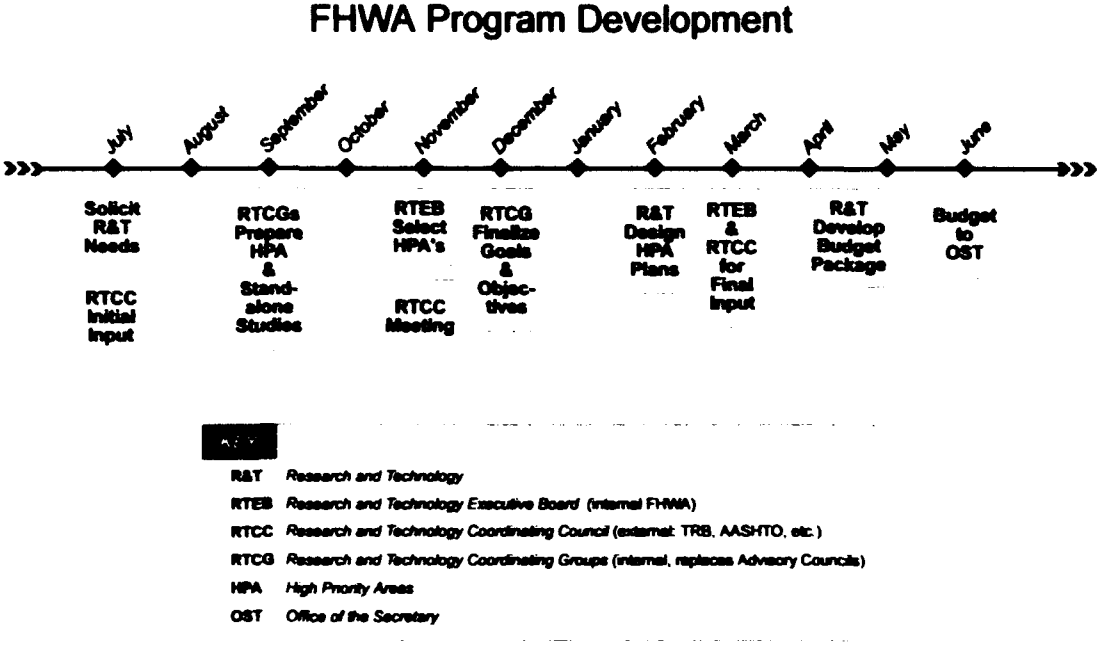
In the absence of an agenda, the typical agency R&D focus is on agency mission related components of the infrastructure. In this respect, several federal agencies, such as the Federal Highway Administration (FHWA), the U.S. Army Corps of Engineers, the Department of Energy, the Environmental Protection Agency (EPA) and others have strong and focused efforts. Other agencies acknowledge having little or no involvement in R&D and that PWI R&D does not seem to be an important agency mission. The General Services Administration (GSA), the Federal Emergency Management Agency (FEMA), and the Department of Housing and Urban Development (HUD) are agencies in this category.

In general, agency R&D programs do not appear to be developed "top down", that is, with research and development personnel directed to perform specific research. Likewise, programs do not appear to be left primarily to the discretion of laboratory researchers (a "bottom up" approach). Instead, a synthesis of the two appears to be the norm within most agencies; a process in which programs are developed by agency laboratories, based upon broad agency guidance, and submitted through specified agency channels. These programs are then evaluated by senior agency officials and approved or modified, as appropriate. In several cases, agency constituents (non-federal entities, including states, local governments, and the private sector) play important roles through their recommendations. The procedure used by the Federal Highway Administration (FHWA) is an illustrative example.

Program development within the FHWA benefits from an interactive process that incorporates user input. This process enables formulation of the FHWA R&D program in accordance with Department of Transportation strategic policy through the Research and Technology Executive Board (RTEB) and provides for final input and coordination by both the RTEB and the Research and Technology Coordinating Council (RTCC). Internal-external coordination occurs at several levels. High Priority Areas (HPA's) are defined through interaction between FHWA Research and Technology Coordinating Groups (RTCG's) and state, university, and industry working groups; this interaction allows the Research and Technology Executive Board (RTEB) to select HPA's. Goals and objectives can now be defined by the RTCG's; after this, external advice from the RTCC assists senior FHWA policymakers on the RTEB in final program decisions. What is apparently not embedded in this process is also noteworthy: there is no explicit indication of any inter-agency coordination in development of the FHWA R&D program. However, some informal inter-agency input, which is not explicitly recognized in agency decision process, is obtained through the Committee on Materials (COMAT), Federal Coordinating Council on Science, Engineering and Technology (FCCSET).

The FHWA process is depicted below, in *Figure 2.1*.

Figure 2.1



Agencies with significant nation-wide responsibilities for infrastructure components appear to have the most robust and most focused PWI R&D programs. Agencies with strong R&D programs are focused on well-defined and developed strategies and missions. Two examples are the U.S. Department of Transportation's *National Transportation Policy* and the Department of Defense's *Defense Science and Technology Strategy*. The Federal Highway Administration, the U.S. Army Corps of Engineers, and the Department of Energy provide the most visible examples, the Corps with respect to both its large civil works function and its responsibilities for the infrastructure associated with large military installations.

In view of the internal focus of most agencies, it is not surprising that inter-agency coordination/ cooperation appears to be modest in scope and was acknowledged by many agency officials to be so (***as noted below, inter-agency coordination was viewed as weak by all non-federal agency persons contacted during this analysis***). However, several agencies, including the Department of Defense and the National Institute for Standards and Technology, see themselves as routinely interacting with other agencies. The Federal Construction Council (FCC) was cited by one agency as an important vehicle for coordination. The FHWA noted its focus on coordination with the

states and other DOT agencies. Agencies with minor infrastructure R&D programs, or no R&D program at all, indicated little or no interaction or coordination.

Initiatives have been started, or are programmed to start, that may lead to more awareness and increased cooperation among the federal agencies. The Federal Construction Council is one example of federal agency interaction, in this case for the specific purpose of advancing building science and technology. The FCC's recent sponsorship of a symposium on infrastructure problems on federal installations is an encouraging example of federal agency interaction. Symposium participants identified steps that agencies should undertake to help solve infrastructure problems; these are worth noting as is the symposium summation which identified a framework for federal agency action. The symposium suggested taking the following steps:

- √ discussions between agency technical managers and government policymakers in both the executive and legislative branches to ensure mutual understanding of the complexities of infrastructure problems and the corrective actions that must be taken;

- √ educational programs for agency and contractor technical personnel to promote understanding of available technologies that can improve the serviceability of infrastructure systems;

- √ developing better methods of collecting, recording, analyzing, and retrieving data about infrastructure deficiencies and repair methods in order to improve the accuracy and credibility of infrastructure repair, maintenance, and replacement programs and budgets; and

- √ developing strategic plans for addressing the financial, political, administrative, and technical issues.

The symposium framework for action recognized that sustained action by top agency management and the Congress is required, and it called for renewed commitment within the agencies, Congress, and industry to work together to solve infrastructure problems.[18]

The need for this type of federal agency interaction is also recognized in the Corps of Engineers' sponsored Infrastructure Strategy Initiative report by the U.S. Advisory Commission on Intergovernmental Relations (ACIR) which recommends that:

> " ...the nation's state and local governments, and the several federal infrastructure agencies, **work more closely together**, to take advantage of opportunities to make the nation's infrastructure more efficient, better coordinated, and more highly productive."[19]

Among the programs recommended is a national cooperative infrastructure research program, including a strong technology transfer component.[20]

In addition to this initiative, the National Science Foundation (NSF) has embarked on a self-study of its infrastructure role. This study envisions a multi-year research initiative, **anchored in strong interaction between federal agencies and the private sector**.[21]

A major infrastructure related R&D effort, estimated to require federal funding of approximately $2 billion dollars, involves the private sector with fourteen federal agencies. The agencies are cooperating through the Committee on Materials (COMAT) of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET). These agencies, almost all of whom have public works infrastructure responsibilities, are linked together with the private sector in a multi-year program to develop high performance construction materials; this program, coordinated by the Civil Engineering Research Foundation, is tentatively named *High Performance Construction Materials: An Essential National Program for America and its Infrastructure*. The program is designed to foster the close cooperation of federal agencies, academe, and the private sector in developing the construction materials and systems necessary for providing the nation with a durable and flexible infrastructure—an infrastructure that will be required in the increasingly complex and competitive environment of the 21st Century.

Finally, the technology policy of the Clinton administration recognizes the need for infrastructure development and has proposed development of a 21st century infrastructure program that would stimulate new national R&D efforts. One potential program would advance infrastructure R&D through the Office of Science and Technology Policy (OSTP) and the Federal Coordination Council on Science and Engineering and Technology (FCCSET). OSTP and FCCSET would coordinate and enhance cooperation between the public and private sectors to develop infrastructure research needs.[22]

In order to obtain an enhanced perspective of the federal role in PWI R&D, CERF extended this analysis by conducting interviews with selected infrastructure experts outside of the federal agencies. These experts included representatives from the National Research Council, the National Science Foundation (NSF), the Advisory Commission on Intergovernmental Relations (ACIR), and the private sector. The results of these interviews confirm the results of agency interviews, including the absence of an explicit federal infrastructure strategy, the variance in quality, emphasis, and scope of PWI R&D among the agencies, and the relative lack of inter-agency coordination. In addition, important insights were provided to explain the current federal approach to public works infrastructure, including PWI R&D. Among suggested significant factors underlying the present situation are: a Jeffersonian view of the nation, i.e., a distrust of central government authority; the sheer size of the United States and its varied topography and climatology; and the relatively recent urbanization of the nation (now 70-75 percent of the populace). The perceived "distrust" may also give rise to a greater dependence by the federal government on quasi-public (such as the National Institute of Building Sciences and the Building Research Board) and private entities, such as Rebuild America, ASCE/CERF and others, to assist in resolving public works infrastructure issues.

CHAPTER 3

FEDERAL PUBLIC WORKS INFRASTRUCTURE R&D

This chapter seeks to quantify the federal role in public works infrastructure R&D. The components of this quantification include estimates of federal funding for PWI R&D, where such R&D is accomplished, the types of R&D performed, and technical transfer mechanisms. Funding trends for the various infrastructure components is also an objective of this study. Data from both agencies and agency laboratories form the basis for this quantification.

The federal laboratory system is large, encompassing hundreds of laboratories ranging in size from world renowned mega facilities to small specialized facilities with a handful of researchers. Nestled between these extremes are the federal laboratories identified in this analysis as focused on research and development that is public works infrastructure related. In order to determine the scope and size of federal laboratory involvement, CERF worked in close coordination with the Federal Laboratory Consortium (FLC), in particular the FLC Locator Manager. The FLC listing of federal laboratories, attached as Appendix A, was used to contact the various laboratories and request data on their public works infrastructure related research and development efforts. To accomplish this, a questionnaire and cover letter was sent to each laboratory requesting data regarding their PWI R&D efforts (Appendix B). Coordination with the FLC also enabled the large number of laboratories (257) to be further categorized into three tiers: laboratories with a high likelihood of PWI R&D (41), laboratories with potential for such research (54), and laboratories with little or no likelihood of PWI research (162).

3.1 OVERVIEW

Principal conclusions regarding federal PWI R&D are summarized as follows:

- **Significant funds are allocated by the federal laboratories towards PWI related research.**
- **The bulk of federal public works infrastructure research and development is accomplished by a small number of laboratories.**
- **All PWI systems have significant research and development programs.**
- **Environment, materials, equipment, automation (software), natural hazards, and non-destructive evaluation (NDE) are principal areas of application.**
- **Both traditional and new technology transfer methods are in use.**

- **Within the federal laboratories there is growing recognition of the importance and need for PWI R&D.**

3.2 FUNDING

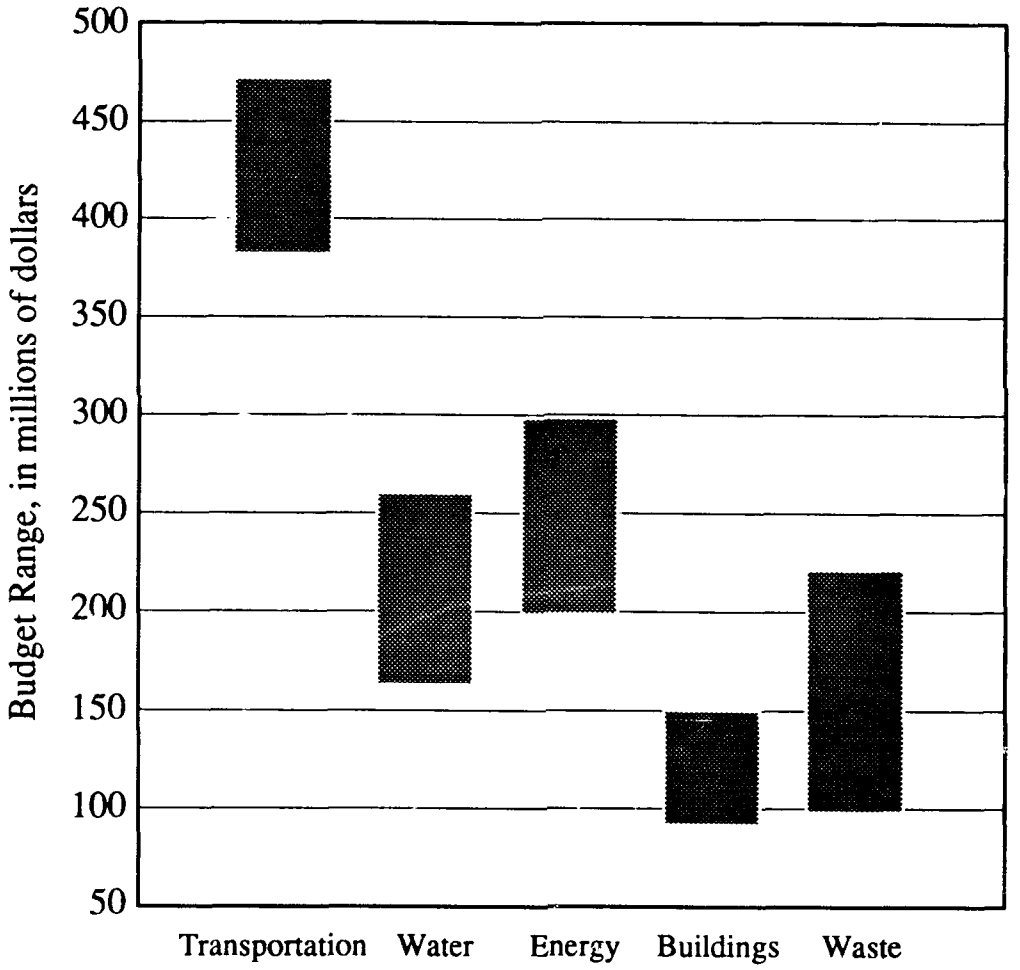
Federal funding for public works infrastructure related research has been estimated several times in recent years. These estimates have varied significantly. For example, the National Council on Public Works Improvement in their 1988 report *Fragile Foundations: A Report on America's Public Works* estimated that approximately $103 million or one-third of one percent of the total federal R&D budget for Fiscal Year 1985 was allocated towards PWI R&D. However, in the more recent report, *Delivering the Goods*, (April 1991) the U.S. Congress, Office of Technology Assessment reports significantly higher federal PWI R&D funding of over $1 billion for fiscal year 1990. This clearly sizable funding level remains a relatively small 1.6 percent of the total federal investment of $60 billion in research and development for fiscal year 1990. The latest estimates of federal R&D funding is even higher at $76 billion but no comparable estimate is available for PWI R&D.

The laboratories were asked to provide funding data in accordance with the funding ranges established in question 4 of the questionnaire, Appendix B. Laboratory responses confirm that PWI R&D funding remains a relatively low percentage of total federal research and development expenditures. On the other hand, this analysis has produced results that suggest that explicitly identified federal funding for PWI R&D is moderately higher than previously thought, and that such funding is projected to increase for fiscal years 1993 and 1994. **Moreover, the funding data obtained from the laboratories may be lower than actual on-going PWI related R&D for several reasons.** First, the terminology and concept of PWI R&D is not embedded in the federal laboratory system and may have led to negative responses from laboratories that in fact have ongoing research that impacts on public works infrastructure. Several laboratories identified in this analysis as conducting PWI R&D responded initially that they did not perform PWI R&D; only after follow-up was CERF able to establish that such research was in fact being accomplished. Second, many federal laboratories may be involved in cross-cutting technologies that have PWI application but do not have a perspective that makes them aware of this potential. This possibility was identified earlier in *Federal Research: Opportunities for the Design and Construction Industry*, a CERF sponsored report by the Research Triangle Institute.[23] On the other hand, data received from the laboratories indicates that federal laboratories transfer a limited amount of their research to other federal laboratories, a procedure that appears to take advantage of optimal facilities or expertise. The level of such activity (Table 3.10), while as much as 30 percent of total PWI R&D for several laboratories, is, in toto, modest in both frequency and funding levels.

Based on these findings, federal PWI R&D funding for fiscal year 1992 is estimated to be between $1.026 billion and $1.386 billion. Corresponding figures for fiscal year 1993 range between $1.104 and $1.465 billion, while for fiscal year 1994 the projected expenditures lie between $1.163 and

$1.521 billion. Also included in the figures presented above, is the estimated PWI R&D funding of the General Services Administration (between $100,000-$500,000 per year) and the Department of Housing and Urban Development ($320,000 for FY 1992). The overall funding for FY 1992 is further distributed among the five PWI systems as shown in *Figure 3.1*.

Figure 3.1
Federal R&D Funding Range for FY 1992
Public Works Infrastructure Systems



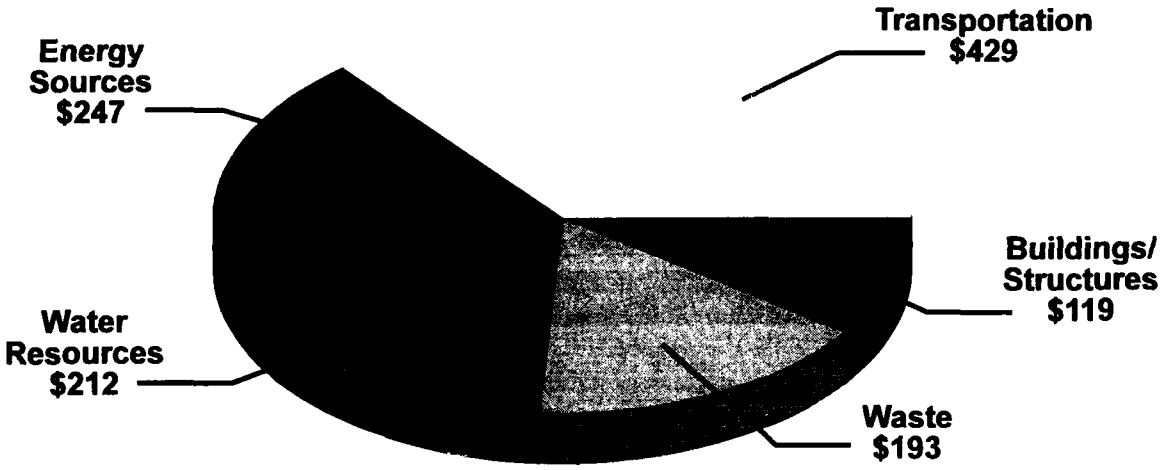
While *Transportation* receives proportionately more funds than other PWI systems, it should be noted that both water resources and energy systems benefit from substantial private sector research, through organizations such as the Gas Research Institute, the Electric Power Research Institute, The American Water Works Association, the Water Environment Federation, and the National Water Research Institute.

A second, simpler perspective also depicts the approximate distribution of federal funding for each PWI system, see *Figure 3.2* below. In developing this pie chart the upper and lower range total of the data for fiscal year (FY) 1992 was averaged to determine values for each system (the same procedure was used in creating all pie charts depicted in this study). The category "Others" is not included in this representation.

Figure 3.2

Federal R&D Funding for FY 1992
Public Works Infrastructure Systems

(Budget in Millions of Dollars)



Total Expenditures = $1.2 Billion

The laboratories were also asked to estimate expenditure data for fiscal years 1990-1992 and projected expenditures by PWI system for fiscal years 1993-1994. The results are tabulated in Appendix C, Tables 3.1 through 3.7. The estimated range of expenditures are shown for each PWI system in the following series of Figures.

Figure 3.3
Federal R&D Funding Range for *Transportation*

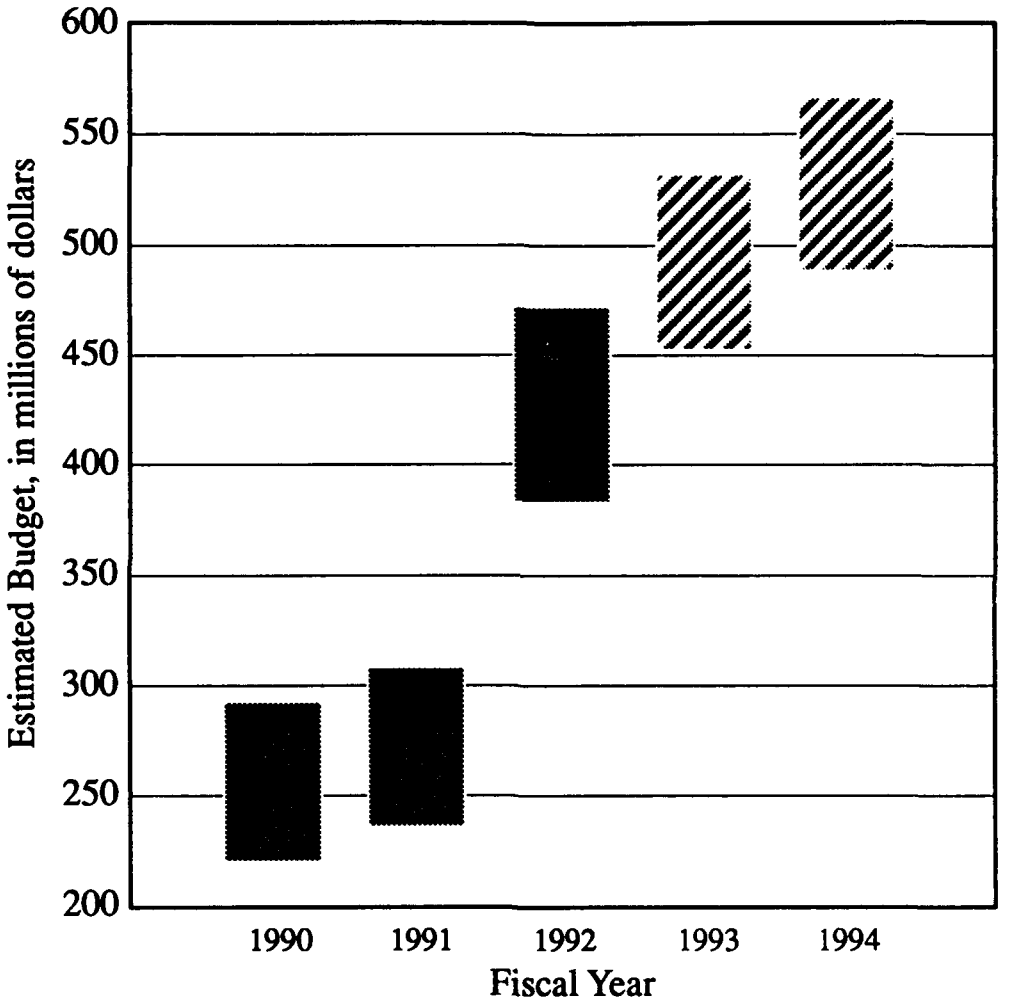


Figure 3.4
Federal R&D Funding Range for *Water Resources*

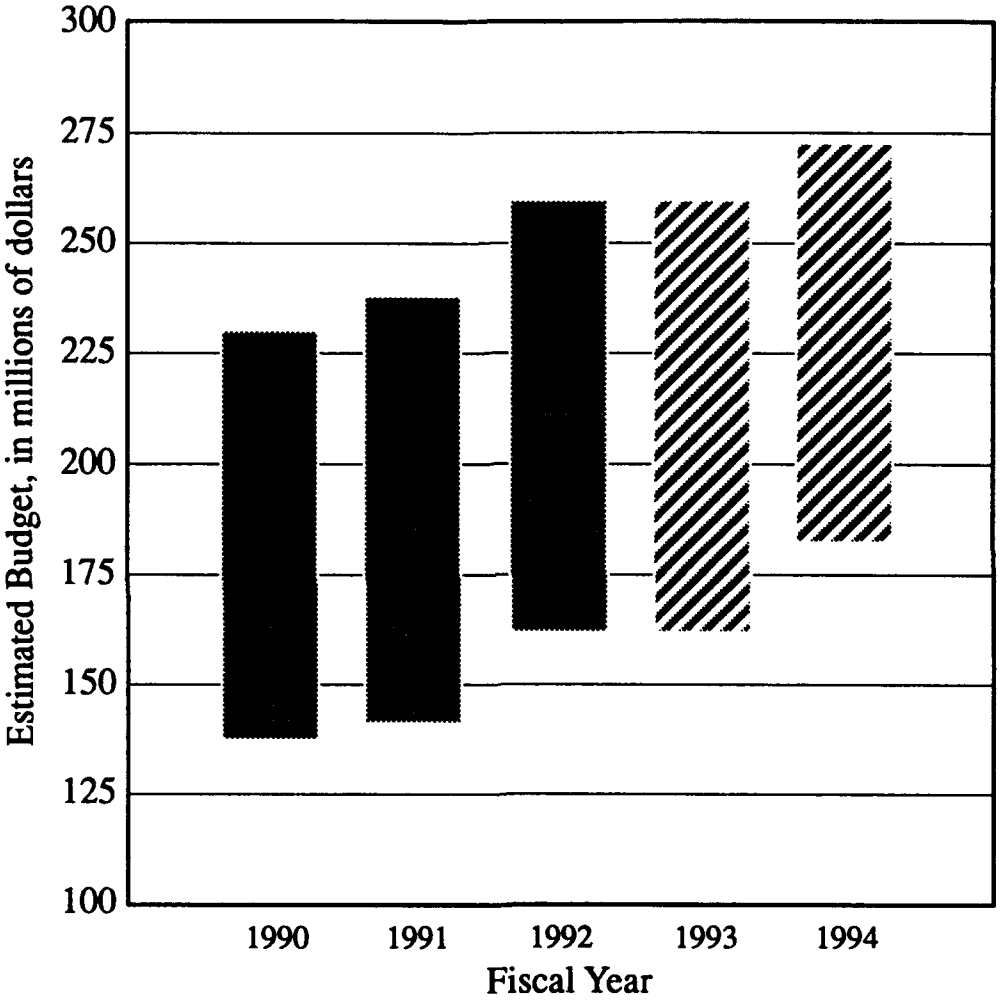


Figure 3.5
Federal R&D Funding Range for *Energy Source/Delivery*

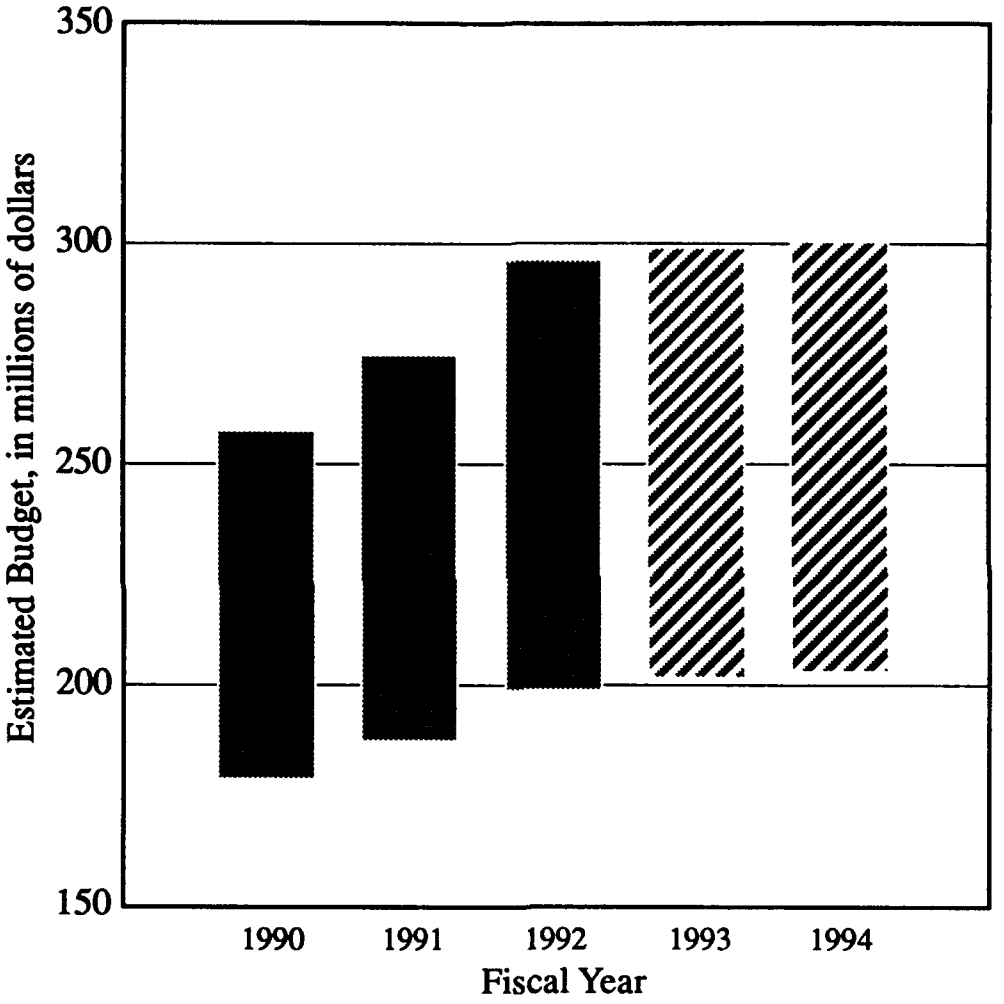


Figure 3.6
Federal R&D Funding Range for *Building/Structures*

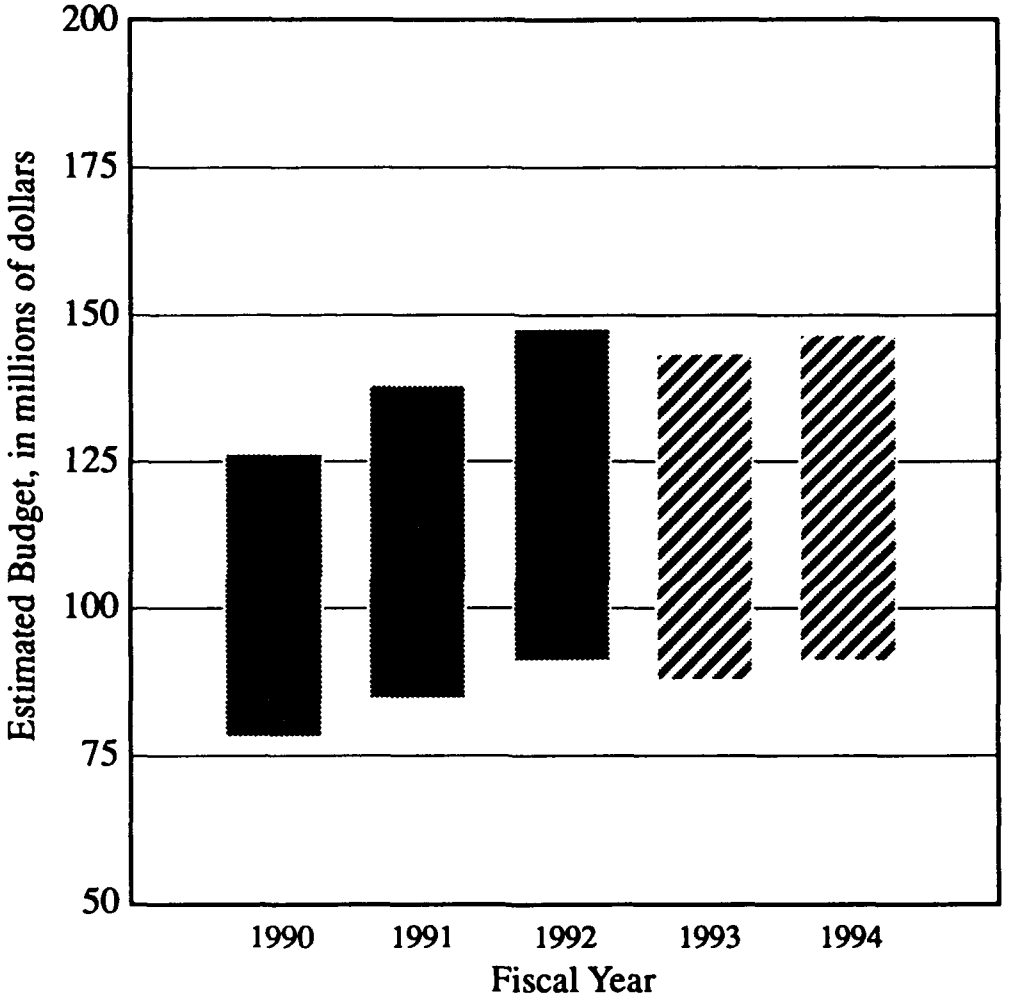


Figure 3.7
Federal R&D Funding Range for *Waste*

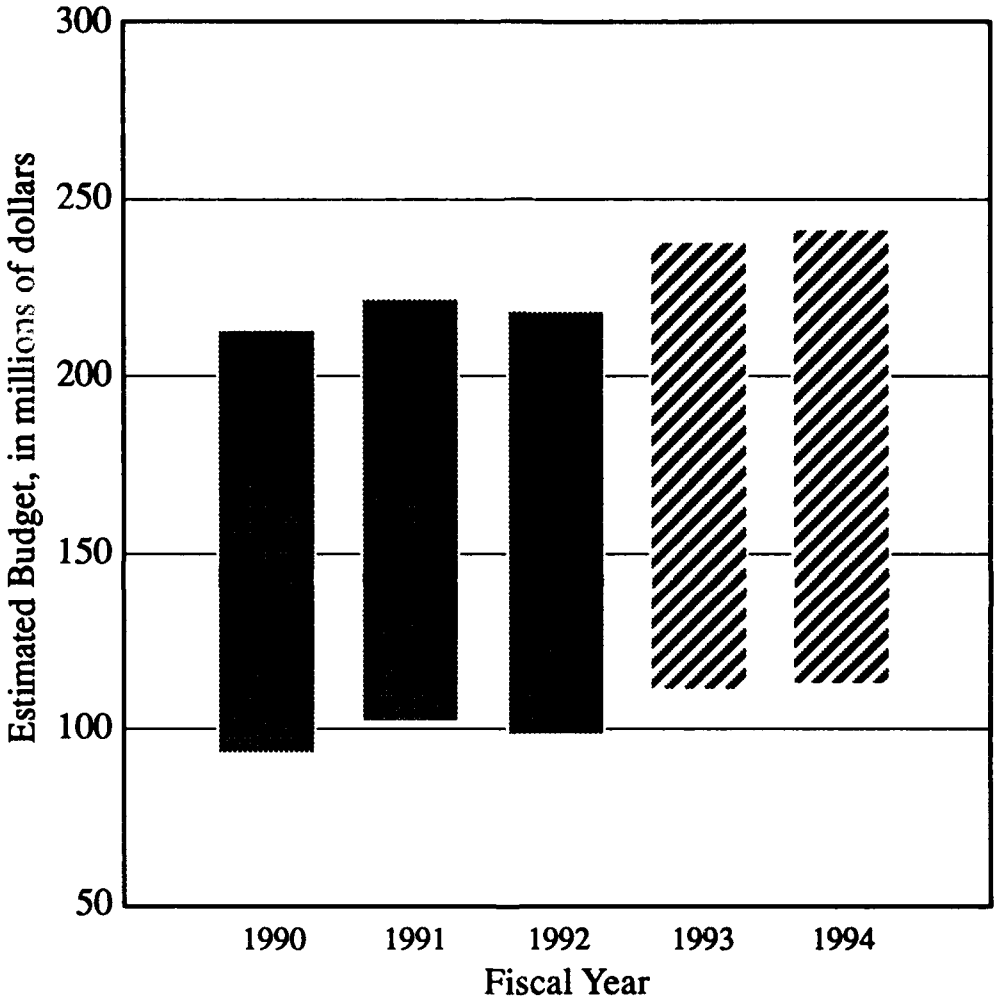
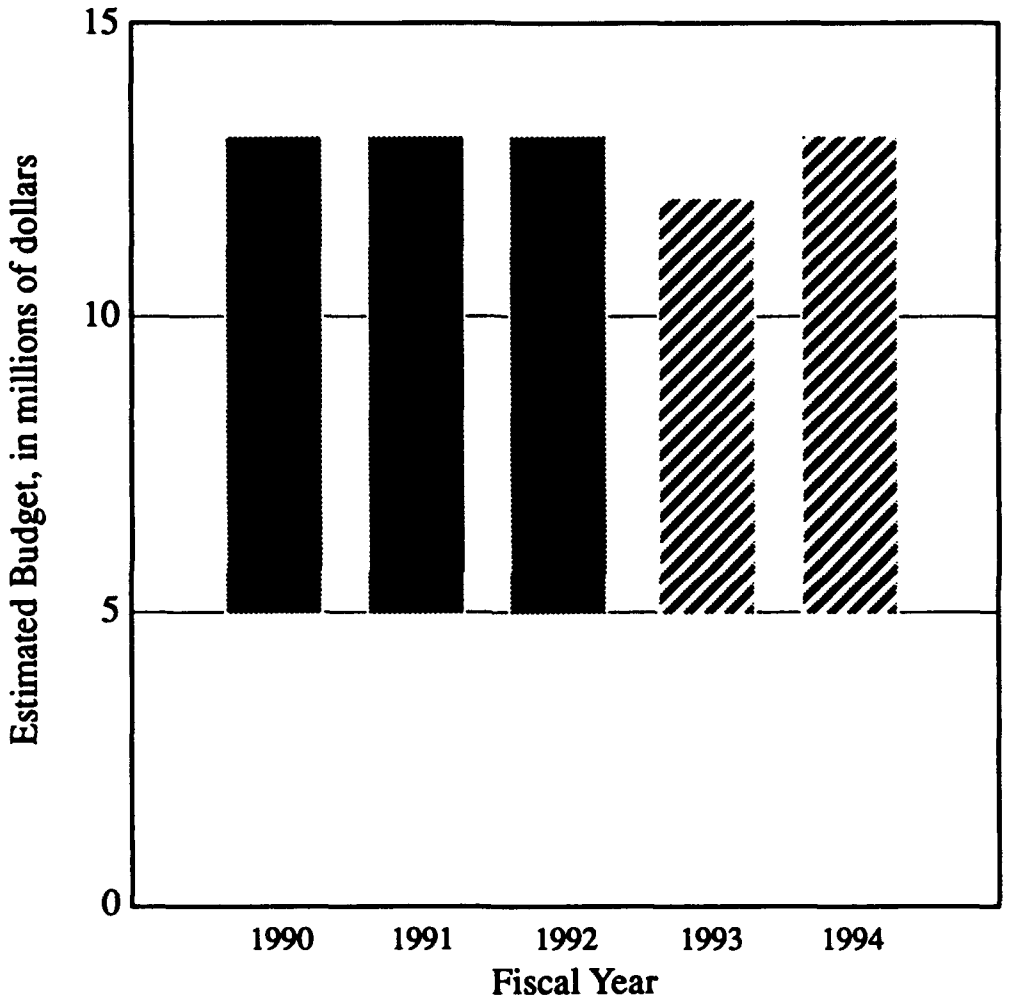


Figure 3.8
Federal R&D Funding Range for *Other*



3.3 PRIMARY FEDERAL PWI LABORATORIES

As noted earlier, coordination with the Federal Laboratory Consortium led to identification of 257 federal laboratories and the grouping of these laboratories into three tiers, based upon laboratory research and development focus. Specifically, laboratories were categorized as likely to perform PWI research, having potential for such research, or having little or no likelihood of doing so. Laboratory responses generally confirmed this FLC assessment. The number of laboratories considered as likely to perform PWI research that responded in the affirmative was 23 of the 41. Laboratories considered as potentially conducting PWI research that indicated such a role was 5 of the 54. Finally, 4 of the 162 federal laboratories considered by the FLC as unlikely to conduct PWI R&D responded affirmatively. Most laboratories provided comprehensive responses; in some cases, however, laboratories indicated that they did not maintain specific data or were reluctant to provide estimates.

The number of federal laboratories who acknowledged a role in PWI is small, numbering only 32, or 12.5 percent of the population. Moreover, only 12 of these 32 laboratories (or approximately 5 percent of the total) indicated that PWI is the primary activity. These laboratories are:

Bureau of Reclamation

DOE-Argonne National Laboratory

DOE-Idaho National Engineering Laboratory

DOT/FHWA Turner Fairbank Highway Research Center

EPA Engineering Laboratories (Cincinnati, OH and Research Triangle Park, NC)

NIST, Building & Fire Research Laboratory

U.S. Army Construction Engineering Research Laboratories

U.S. Army Institute for Water Resources

U.S. Army Waterways Experiment Station

USDA/FS Timber Bridge Information Resource Center

Veterans Administration R&D Center

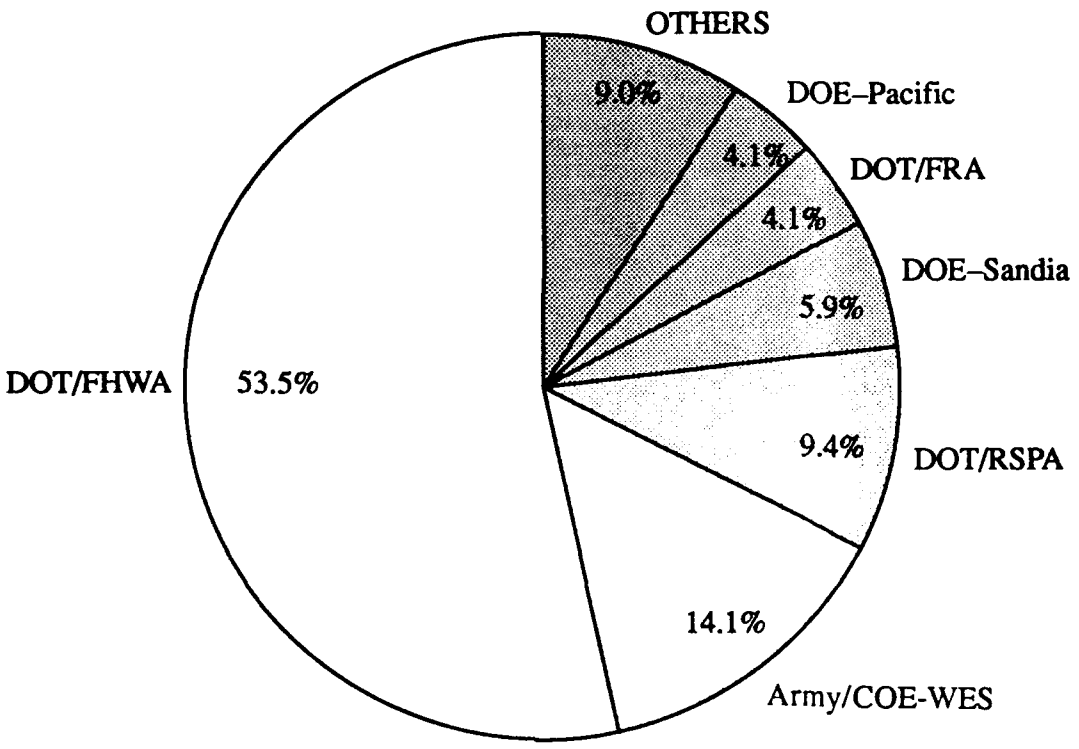
Only one of the very large federal laboratories listed PWI as the primary research activity. Two laboratories in this category, however, Pacific Northwest and Brookhaven, have very significant PWI efforts—efforts that appear to exceed the programs of all twelve laboratories identified as primary PWI R&D centers, except for the DOE-Idaho National Engineering Laboratory. Three of the twelve laboratories have small overall programs (less than $10 million), while the other nine range in funding from $10 million to approximately $200 million.

3.4 PWI SYSTEMS/PRINCIPAL LABORATORIES

Federal laboratories are engaged in a wide range of PWI R&D. In this section principal laboratories for each PWI system are identified. In developing the approximate distribution of effort among the laboratories, the procedure used is as noted in Section 3.2.

Department of Transportation (DOT) laboratories, as might be expected, have major responsibilities in *Transportation* related research and development. Three of the top six laboratories for this PWI system are DOT laboratories (FHWA Turner Fairbank Highway Research Center, the RSPA Transportation Systems Center, and the FRA Transportation Center). Among the largest Transportation programs, however, is that of the U.S. Army Waterways Experiment Station, or WES. Two Department of Energy laboratories, Pacific Northwest and Sandia, also have significant Transportation related research. These six laboratories (a total of 23 laboratories have Transportation related R&D) account for approximately 91 percent of Transportation related R&D. Complete Transportation R&D funding data is provided in Table 3.2, Appendix C. The distribution of Transportation related R&D is shown in ***Figure 3.9 below***:

Figure 3.9
Approximate Distribution of Effort for *Transportation* for FY 1992

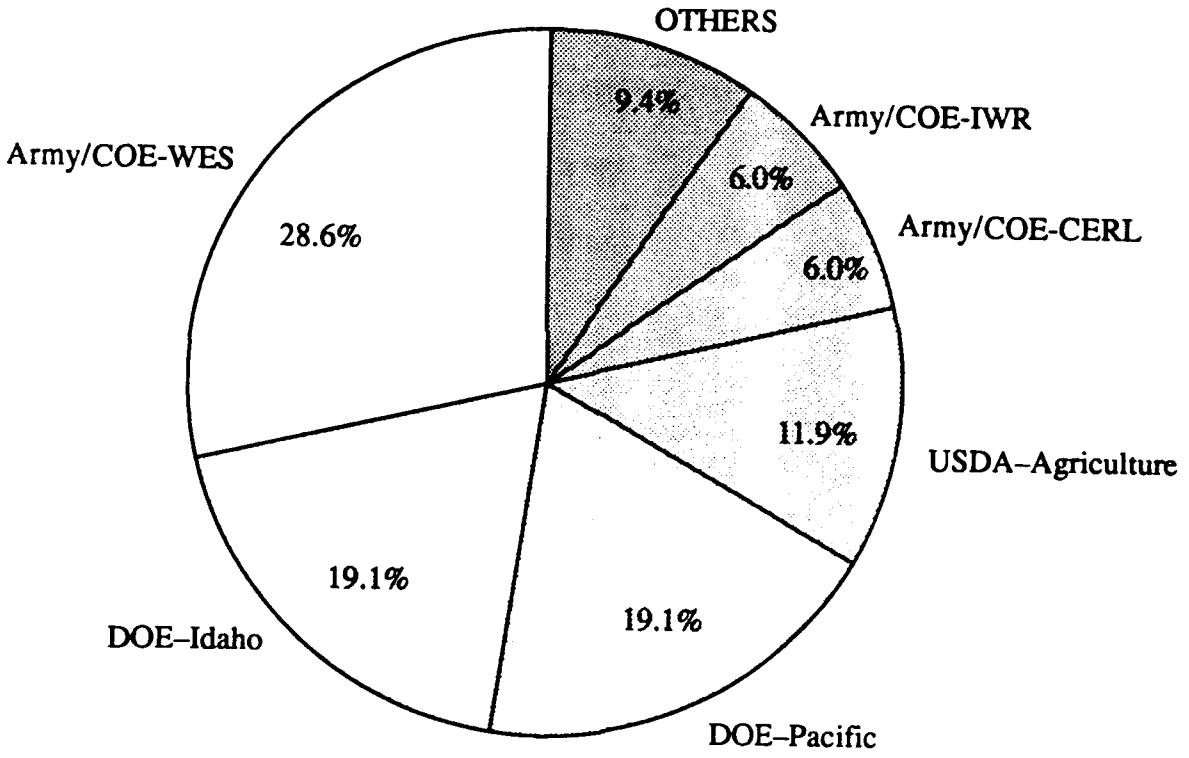


Total *Transportation* Expenditures = $429 Million

Six laboratories dominate the federal effort in *Water Resources* related research and development. Four of the laboratories (the U.S. Army Waterways Experiment Station, DOE- Pacific Northwest Laboratory, DOE-Idaho National Engineering Laboratory, and the USDA-Agricultural Research Service) account for approximately 79 percent of all research. Water resources related research and development is undertaken by 21 laboratories; nine of these laboratories have minor efforts of approximately one million dollars per year or less. Total Water Resources funding is shown in Table 3.3, Appendix C. Distribution of effort is shown in ***Figure 3.10 below***:

Figure 3.10

Approximate Distribution of Effort for *Water Resources* for FY 1992

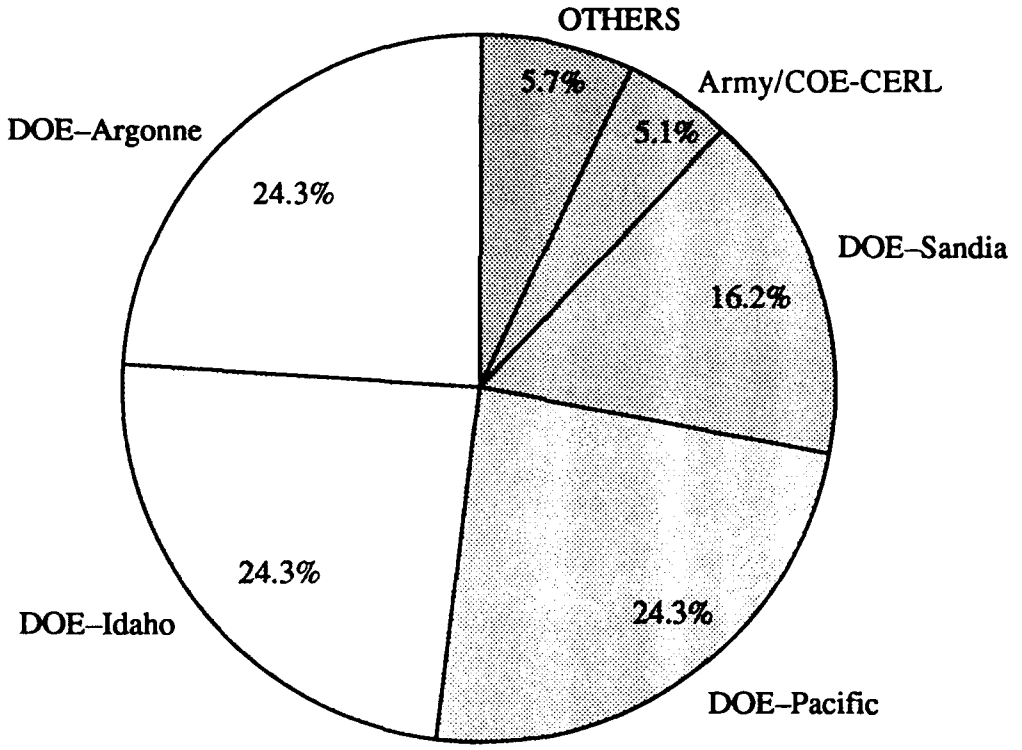


Total *Water Resources* Expenditures = $212 Million

Energy Source/Delivery R&D is primarily accomplished by four Department of Energy laboratories; fourteen other laboratories have PWI energy related programs. In addition to the DOE laboratories, the U.S. Army Construction Engineering Research Laboratories performs significant PWI energy research, with a program of between $10 and $15 million per year. The DOT/RSPA Transportation Systems Center projects a sizeable 200 to 300 percent increase for fiscal years 1993-1994, but this program remains small when compared to DOE programs. Total Energy Source/Delivery R&D funding is presented in Table 3.4, Appendix C. Distribution of effort for Energy Source/Delivery is shown in ***Figure 3.11 below***:

Figure 3.11

Approximate Distribution of Effort for *Energy Source/Delivery* for FY 1992

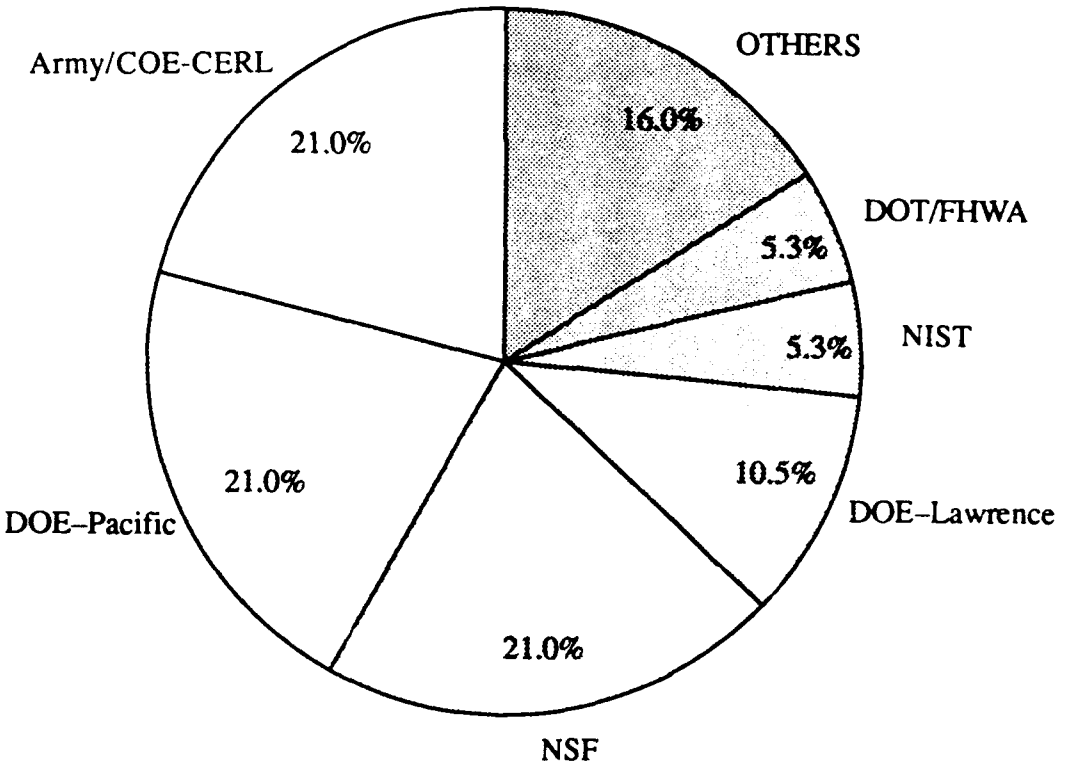


Total *Energy Source/Delivery* Expenditures = $247 Million

Buildings/Structures PWI related research is also dominated by a few federal institutions; in this case five laboratories and the National Science Foundation. Eighteen laboratories play a role in buildings/structures R&D. This PWI system is funded at somewhat lower levels than the preceding systems; furthermore, little or no growth is projected in fiscal years 1993-1994. Two laboratories (the U.S. Army Construction Engineering Laboratories and DOE's Pacific Northwest Laboratory) and the National Science Foundation (NSF) have approximately equal programs (in terms of funding). Smaller programs are on-going at the DOE Lawrence Berkeley Laboratory and the National Institute of Standards and Technology (NIST) Building and Fire Research Laboratory. It is important to note that the General Services Administration (GSA), the largest federal facility "owner", has only minor PWI related R&D. Total federal R&D funding for Buildings/Structures is provided in Table 3.5, Appendix C. The distribution of effort is shown in ***Figure 3.12 below***:

Figure 3.12

Approximate Distribution of Effort for *Building/Structures* for FY 1992

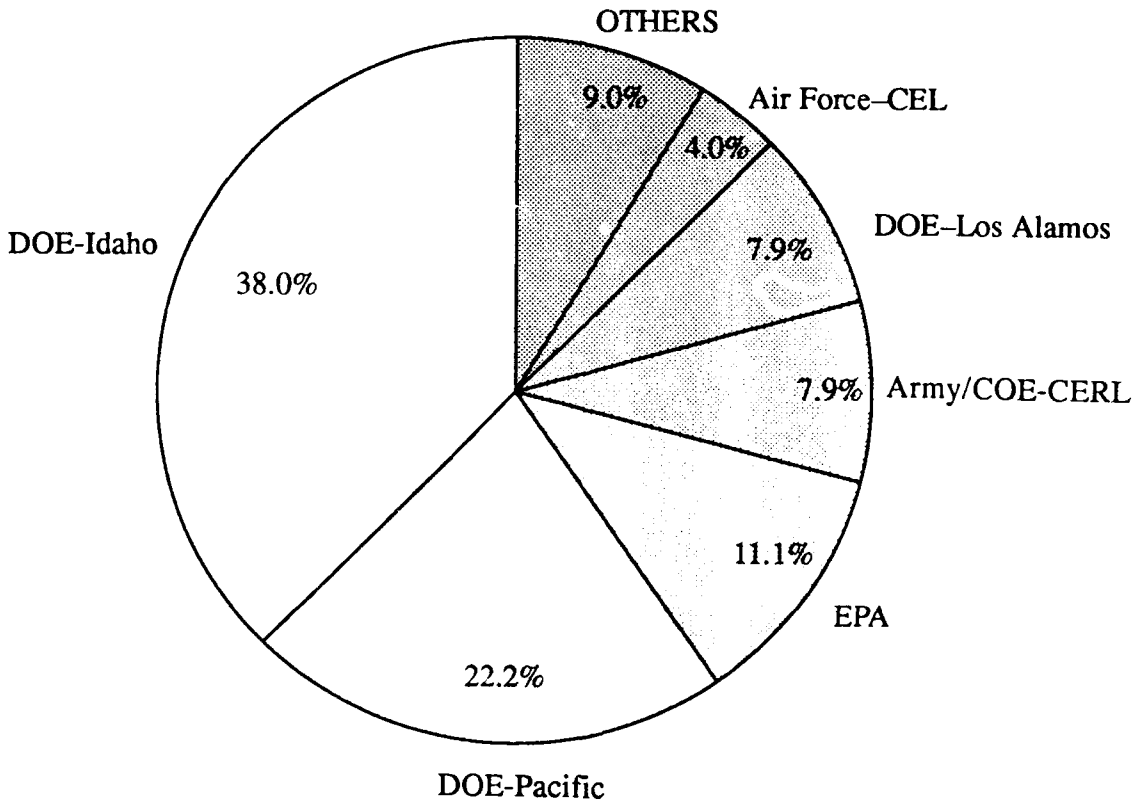


Total *Building/Structures* Expenditures = $119 Million

Waste related PWI research and development is conducted by fifteen of the laboratories. As with the other systems, the bulk of effort is concentrated in a few laboratories. One laboratory, the DOE Pacific Northwest Laboratory, by itself, accounts for approximately 38 percent of the total effort. Another DOE laboratory, the Idaho National Engineering Laboratory, accounts for 22 percent, while the two Environmental Protection Agency laboratories share 11 percent. While not explicitly stated, DOE programs may be heavily focused on nuclear wastes. Smaller programs are in place in three other laboratories, including the U.S. Army Construction Engineering Research Laboratories (CERL), the DOE Los Alamos National Laboratory, and the U.S. Air Force Civil Engineering Laboratory. Program growth is only projected by Los Alamos, but this increase, at 100 percent, is significant. See Table 3.6, Appendix C, for complete federal funding for Waste. Distribution of effort for waste systems is indicated in ***Figure 3.13 below***:

Figure 3.13

Approximate Distribution of Effort for *Waste* for FY 1992



Total *Waste* Expenditures = $193 Million

In addition to the five systems identified, the laboratories were given the opportunity to identify any PWI R&D not classified in the five identified systems. Five laboratories responded, indicating relatively small programs for fiscal years 1990-1994. These results are shown in Appendix C, Table 3.7.

The percent of laboratory research staff allocated to each PWI system is presented in Table 3.8, Appendix C. This data correlates well with the laboratory responses on funding for the various PWI systems, suggesting strong linkage between funding and the allocation of technical staff to perform research. Some apparent discrepancies were fully explained by contacting laboratories; for example, the Turner-Fairbank Highway Research Center reported that only 5-10 percent of its research staff is engaged in transportation research. This is in fact true; most of the staff is engaged in managing research conducted at other facilities. The response also correlates with Turner-Fairbank data showing where research is conducted (Table 3.10). The laboratories were also asked to provide data on funding programmed towards basic research; this data is presented in parentheses for each PWI system in Table 3.8. This data was compared to data in Table 3.11, showing distribution of effort between basic research, applied research, demonstrations, and other forms of research. Due to limited laboratory responses in Table 3.8, correlation is difficult to achieve but those laboratory responses provided show general consistency between these tables.

3.5 FUNDING BY APPLICATION AREA

Common elements exists within the five PWI systems. Materials such as concrete and steel, for example, have application across all of the systems. The laboratories were therefore asked to provide data regarding budget allocation by specific areas of application. This data is presented in Table 3.9, Appendix C and in *Figure 3.14* below, where a relative rank order of funding by area of application is depicted.

Figure 3.14
Higher Percent Budget Allocations

GROUPS	Rank Order in Group			
	1	2	3	4
Highest Rank	Environmental	Materials	Natural Hazards /Software	Equipment
One of Two Highest Ranked	Environmental	Materials	Equipment	Software
One of Three Highest Ranked	Environmental	Materials	Equipment	Non-destructive Evaluation
One of Four Highest Ranked	Environmental	Materials	Natural Hazards	Non-destructive Eval./Software

This added perspective indicates that federal PWI R&D is primarily focused on environmental issues, materials, equipment, natural hazards, automation (software) and non-destructive evaluation (NDE). Some laboratories with very specialized focus show significant funding outside of these primary application areas. Several examples include the FAA Technical Center's air safety program, the Veteran's Administration's responsibility for veterans needs, and the National Science Foundation focus on seismic R&D.

3.6 LOCATION OF RESEARCH

Federally funded research is performed in various ways. For a number of federal laboratories the bulk of research is accomplished in-house; 11 of the laboratories indicated that ninety percent or more of their program is accomplished in this manner. Both academe and industry are significant participants; nine laboratories reported significant industry involvement, that is between 20 and 55 percent of the total program. Academic institutions are used by approximately the same number of laboratories, but at a somewhat lower percent of total effort except for the National Science Foundation with 90 percent of research accomplished on campuses across the nation. The distribution of research by performer is presented in Table 3.10, Appendix C.

3.7 TYPES OF RESEARCH

With several exceptions, the PWI R&D performed by the federal laboratories is primarily a combination of applied research and demonstrations. Significant basic research was reported only by two laboratories and the National Science Foundation. Twenty-seven laboratories reported that at least half of their PWI efforts were applied, with five laboratories indicating that all of their PWI related R&D was applied. The distribution by type of research is presented in Table 3.11, Appendix C.

3.8 TECHNOLOGY TRANSFER

While the federal government is a large stakeholder in infrastructure, the bulk of the nation's infrastructure is non-federal. Transfer of federal PWI technology is therefore a significant issue. **Federal public works infrastructure research is of little value if effective technology transfer mechanisms are absent!** For at least the past decade there has been a growing awareness of the potential importance of federal laboratories for numerous non-federal applications, to include public works infrastructure. Federal legislation, private sector interest, and the rapid emergence of a highly competitive global economy have all become primary motivators for increased transfer of relevant federal technology into practice. A concise history and description of recent federal legislation is presented in *Federal Research: Opportunities for the Design and Construction Industry*, a 1992 CERF publication (# 92-N6003).

Laboratory preferences with respect to technology transfer methods are depicted in Table 3.12, Appendix C; in *Figure 3.15* preferred technology transfer methods are depicted in relative rank order.

Figure 3.15
Most Preferred Technology Transfer Methods

GROUPS	Rank Order in Group			
	1	2	3	4
Highest Rank	Publications	CRDAs	Presentations Demonstrations	Licenses
One of Two Highest Ranked	Publications	Presentations	CRDAs	Workshops Licenses
One of Three Highest Ranked	Publications	Presentations	Workshops CRDAs	Licenses
One of Four Highest Ranked	Publications	Presentations	Workshops	CRDAs

The traditional methods of disseminating research results, publications and presentations, retain their importance in all of the laboratories with consistent high preference rankings. This is also true for the twelve laboratories with primary PWI focus; all of these laboratories cited publications as one of the top five preferred methods while six listed it as the first or second most preferred method. Presentations, likewise, is one of the top five technical transfer preferences, with three of the twelve laboratories ranking it as first or second. **The relatively high ranking of technical transfer methods made possible by recent legislation is significant**. Seven of the twelve primary PWI laboratories cite Cooperative Research and Development Agreements (CRDA's) among the top five methods, while six laboratories place licenses in the same category. Use of CRDA's and licenses appears to be particularly prominent in Department of Energy laboratories.

The frequency of use of technology transfer methods by the laboratories are listed in Table 3.13, Appendix C. This data correlates closely with the expressed preferences indicated in Table 3.12, and suggests that the laboratories are using a wide range of methods to effect technical transfer. In some cases, little used methods are prominent in a single laboratory, for example, the use of support centers by the U.S. Army Construction Engineering Research Laboratories (CERL).

This analysis concludes that federal laboratories are actively transferring research and are using a variety of methods to achieve this. How well the technology transferred correlates with actual national infrastructure research needs was beyond the scope of this study but is recommended for analysis as a priority action.

CHAPTER 4

FOREIGN INFRASTRUCTURE RESEARCH AND DEVELOPMENT

The preceding chapters have developed important new insights regarding federal involvement in U.S. public works infrastructure R&D. Public works infrastructure, however, is common to all nations. **How does the United States compare with some of the other industrially advanced nations**? In order to place federal public works infrastructure R&D into a worldwide perspective, a limited response to this question was sought from several European nations, Canada, and Japan. Data on how these nations accomplish public works infrastructure R&D and the resources they devote to such R&D were sought. Information was obtained through contact with embassies; additional information was obtained from foreign research establishments. Finally, significant data was obtained through literature searches.

From this limited analysis of foreign infrastructure R&D, several conclusions were evident:

- ✓ **Infrastructure R&D is normally handled by more than one government agency.**
- ✓ **Industry support of infrastructure R&D is significant.**
- ✓ **Infrastructure R&D spending is typically higher as a percent of GDP.**

4.1 ORGANIZATIONAL STRUCTURE FOR PWI R&D

It has been suggested that the United States differs from many other countries in that no single U.S. agency has overall responsibility for public works infrastructure. This brief comparison, however, finds that in only one of the countries studied is there a single agency with such responsibility. In some cases, the structure is similar to that found in the United States. With the apparent exception of France, the European countries included in this brief analysis (Germany, France, the United Kingdom, and Sweden) assign responsibility for PWI R&D to multiple ministries or departments. In Canada, public works infrastructure responsibilities are likewise divided between at least two departments. In Japan, land-based infrastructure matters, including R&D, are vested in one ministry, the Ministry of Construction (MOC); non-land based infrastructure, such as ports and harbors, are the responsibility of the Ministry of Transport (MOT). The Japanese approach to public works infrastructure is documented in *Transferring Research into Practice: Lessons from Japan's Construction Industry*, a 1991 report by the Civil Engineering Research Foundation (CERF).

National government level responsibility for infrastructure related R&D in these countries is depicted below:

Country	Government Agencies responsible for PWI R&D
Germany	The Federal Ministry for Research and Technology The Federal Ministry for Transportation The Federal Ministry for Economics The Federal Ministry for Housing
France	Ministry of Research and Technology
United Kingdom	Department of Education and Science Department of Environment Department of Transport Department of Trade and Industry
Sweden	Ministry of Communications Ministry of Environment and Natural Resources Ministry of Industry
Canada	Federal Department of Transport Federal Public Works Department
Japan	Ministry of Construction Ministry of Transport

4.2 THE ROLE OF INDUSTRY

A striking difference between the United States and the other industrialized countries is the significant involvement of industry in construction (infrastructure related) R&D; in the United States investment by industry is low, estimated recently as less than 0.1 percent of annual construction volume.[24] The validity of this estimate is currently being investigated by CERF and the National Science Foundation (NSF) through a national survey of government, industry, states, associations, and academe to determine the current level of investment in civil engineering related R&D by these sectors. European industry participation, however, is often extensive as was noted in the recent National Science Foundation report, *Civil Infrastructure Systems Research*. The level of industry funding varies from country to country and has been estimated to range from 20 to 80 percent of the total.[25] The NSF report also notes that in Europe the construction industry cooperates extensively with universities and research institutes and is a principal source for applied research funding.[26] Funding for research institutions may come from several sources; in some cases a

levy is imposed on construction contracts (France and Sweden). In Germany the twenty Material Testing Institutes (MPA) are funded by both industry and the government.[27] A common focus of research in Europe is high performance concrete. This focus reflects the fact that concrete is the principal construction and structural material in Europe; France, Sweden and Norway have coordinated national programs in place.[28] In terms of thrust or application, transportation (both roads and rail) has primary emphasis.[29] The increasing influence of an integrated Europe has resulted in significant European Community (EC) R&D; however, it is interesting to note that while the construction industry represents 12 percent of member states' GDP, only 3 percent of EC-funded projects are infrastructure related.[30]

The pattern in Japan is somewhat different as noted in CERF's 1991 report; in addition to substantial government funding, the largest construction firms have created large research centers, the ten largest of which each employ more than 100 researchers. The level of expenditure for R&D by Japanese firms is likewise noteworthy; the six largest companies allocate an average of one percent of contracts awarded towards R&D, or about 60 percent of net profit.[31] Improved construction materials and automation of construction equipment are major research thrusts. Furthermore, efficient utilization of space is central to Japan's efforts to improve its infrastructure; intelligent buildings and structures are likewise major objectives in infrastructure related R&D.[32]

4.3 FUNDING FOR PWI R&D

Determining approximate infrastructure R&D expenditures for federal agencies posed significant challenges; doing so for other countries is no less challenging. Difficulties arise for several reasons. In some cases, agencies in other countries are reluctant to provide such data or are unable to because infrastructure specific R&D expenditure data is apparently not available. Second, since no common definition of public works infrastructure exists, interpretation of available data and estimating approximate expenditures is difficult at best and requires significant time and resources. Finally, the data obtained by CERF covers different years, making comparisons potentially less useful. **For these reasons, a truly accurate estimate of foreign government expenditures for public works infrastructure R&D is not possible within the constraints of this study**. Valuable insights were obtained, however, for several of the countries.

GERMANY

At 2.9 percent for 1990, Germany allocated a significant portion of its gross domestic product (GDP) towards R&D; of the total programmed R&D expenditures of approximately $9.3 billion, an estimated $330 million, or approximately 3.5 percent, was devoted towards construction related R&D. The focus of this research was on roads, urban and regional planning and development, and land-bound transport. Additional infrastructure related research is likely to be embedded

in the broad categories of materials research and environment, which were programmed in 1990 at a combined total of $338 million.[33]

SWEDEN

Data for Sweden shows a similarly high percentage of GDP devoted to R&D, at approximately 3 percent; it is further estimated that approximately 37 percent of all R&D is funded by the government.[34] With respect to infrastructure or construction research, universities and government research institutes play a leading role. The primary government organization is the Swedish Council for Building Research (BFR), with an annual budget of approximately $45 million as of this year. The Swedish construction industry also funds research through its development fund, Svenska Byggbranschens Utvecklingsfond (SBUF). SBUF funding is approximately $10 million for 1992.[35] The Council (BFR) has established the following research priorities for 1990-1993:

- Climate in the built environment
- Infrastructure
- Efficient electricity use in the built environment
- Durability and economic life of buildings
- Planning, building, and the management process
- Urban renewal, development, and social change[36]

FRANCE

As already noted, France has a centralized system for R&D, through its Ministry of Research and Technology (MRT). Government research that can be related to infrastructure is relatively small, however, and is estimated to be $101 million for 1990, or 0.11% of the annual French construction turnover of approximately $83 billion.[37] Much of the R&D is accomplished in large research centers such as the Centre Scientifique et Technique du Batiment (CSTB), the Laboratorie Central des Ponts et Chaussees (LCPC), and the Centre Experimental de Recherches et d'Etudes du Batiment et Travaux Publics (CEBTP). Focus of French research was defined by the CSTB in 1989, as follows:

- Improvement in the competitiveness of the French construction industry
- Improvement of comfort, safety, and health in buildings
- Advancement of equipment and services in buildings
- Improvement of communications in the production system of construction
- Improvement in the performance of construction components and the prevention of failure
- Mastering the properties and uses of materials[38]

THE UNITED KINGDOM

Public funding for infrastructure related R&D in the United Kingdom was estimated to be $78 million in 1985; it is also estimated that approximately 40 percent of construction R&D is funded by the government.[39] R&D is generally conducted in the universities and polytechnics; several of these were cited as excellent in the recent National Science Foundation report on Civil Infrastructure Systems Research.[40] Research priorities include transportation, waste disposal, irrigation, urban drainage, flood control, construction materials, in-situ testing methods, quality assurance and worksite safety.[41]

CANADA

Canadian investment in infrastructure R&D, as with other countries, is difficult to estimate. The response provided to CERF noted candidly that "no figures are available which adequately describe the level of activity in Canada". Data was provided for the Institute for Research in Construction; for 1992-1993 funding is projected at $2.3 million for PWI R&D. In addition, Canada has announced a major highway reconstruction program, lasting ten years and valued at $22.2 billion; 0.1 percent of this total is to be set aside for supportive R&D. Finally, the Canadian Strategic Highways Research Program (C-SHRP) has been budgeted at $4.4 million.[42]

JAPAN

For Japan, accurate data was obtained for industry funding of construction R&D. Discussions with both U.S. government and university experts on Japan provided additional insight. Japanese industry funding in 1990 for construction, transport, communication and public utilities R&D totaled approximately $3.91 billion.[43] This significant expenditure level correlates with the information obtained by CERF's Japan International Research Task Force (JTF), as documented in *Transferring Research into Practice: Lessons from Japan's Construction Industry*. The overall ratio of government to industry funding for R&D has been estimated to be 13 percent to 87 percent. If this ratio is valid for construction related R&D, government funding may be on the order of $509 million. The primary focus of Japanese research was noted earlier in this chapter.

Based on the limited information available, the estimated **government funding** for PWI related R&D for each country is as indicated below:

Country	Funding ($ millions)	Year
Germany	$329.5	1990
France	$101.0	1990
United Kingdom	$77.8	1985
Sweden	$45.0	1992
Canada	$6.7	1992
Japan	$509.0	1990

Federal expenditures for PWI R&D in the United States are substantially higher than the figures cited above. When the sizeable investment by private industry in these countries is factored in, however, the total infrastructure related R&D expenditure in each country is significant. Moreover, as a percentage of GDP, the United States is being outspent. Spending aside, one should also consider the apparent fact that both Japan and Europe are more adept at moving research into practice. The effectiveness of technical transfer mechanisms and management of research and development resources in both Europe and Japan may be factors and should be examined.

A better understanding of infrastructure R&D in other industrially advanced countries is needed and appropriate steps to achieve this are recommended to be undertaken. In this regard, a planned CERF coordinated International Task Force trip to Western Europe on Civil Infrastructure Systems, programmed for the Summer of 1993 and comprising leaders from government, industry and academe, may provide valuable insight regarding European countries.

Finally, it should be noted that the pattern of infrastructure investment and infrastructure R&D is changing in Europe as European integration proceeds; existing national initiatives appear destined to become part of a larger, more integrated European infrastructure fabric. This trend is clearly evident in data received from several European nations, and it is reinforced by the recent proposal of the European Commission for $73 billion in coordinated infrastructure spending to stimulate member nation economies.[44]

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Federal agency and laboratory responses have produced useful information and valuable insights about federal involvement in infrastructure research and development and lead to the following conclusions and recommendations:

- There is no consensus national definition of public works infrastructure; this poses a fundamental difficulty in assessing the federal role. **Such a definition is needed and action to achieve this is recommended**. An accepted definition of infrastructure may promote inter-agency coordination and technology transfer since federal laboratories, typically engaged in mission related R&D, will then have a clear basis for relating their efforts to the concept and needs of infrastructure.

- No federal strategy for public works infrastructure has been developed. Absent such an overarching strategy, each infrastructure component appears to be considered in policy, planning, and execution as independent of the other components. **This analysis therefore recommends that the new administration ensure the cooperative development of a national public works research agenda by the federal government, state and local entities, and the private sector**.

- Coordination of PWI R&D between federal agencies is weak, although signs of improvement are evident as cited in this report. **More emphasis on inter-agency planning is needed and is recommended as an administration goal**; such planning should lead to better utilization of scarce resources. **Development of mechanisms that stimulate inter-agency coordination and interaction should be given priority**.

- PWI R&D programs and emphasis vary significantly between agencies. Highly visible components of the PWI, in general, appear to have the most robust R&D; highways and associated structures are a prime example. In agencies with less visible PWI components or less demanding constituencies, the R&D emphasis is correspondingly low.

- Federal funding for PWI R&D is more extensive than previously thought. It is in fact possible that the funding levels calculated and cited in this analysis, on the basis of federal laboratory and agency responses, are themselves lower than what is actually being expended. Determining funding levels with more accuracy will require a better concept within agencies and laboratories of what constitutes public works infrastructure.

- Public works infrastructure research and development is concentrated in a small number of federal laboratories, primarily laboratories in the Department of Transportation, the

Department of Defense, the Department of Energy, and the Environmental Protection Agency. Specifically, 32 of the 237 laboratories identified through the Federal Laboratory Consortium are engaged in public works infrastructure research. Significant basic research is undertaken by the National Science Foundation. Technology is transferred through a number of methods, including both traditional means (such as publications and presentations) and new methods made possible by enabling legislation, such as licenses and cooperative research and development agreements (CRDAs). While traditional technical transfer methods, such as publications, presentations and workshops, remain the preferred modes, the significant use of newer (and potentially more effective) methods such as licenses and CRDA's is encouraging. **How well the technology transferred matches actual national infrastructure needs is unclear however; determining this is recommended as a priority administration action.**

☞ Significant public works infrastructure R&D is taking place in other countries; **this research should be examined in more detail** in order to benefit from research results, research procedures and avoid duplication of effort. A notable factor in both Japan and Europe is the significant participation of the construction industry in funding and executing infrastructure related research and development; closer relationships have been forged with government and academia than is the case in the United States. The effectiveness of technical transfer mechanisms and overall management techniques for research and development in these countries should also be given more attention.

ENDNOTES

1. *Technology: the Engine of Economic Growth, A National Technology Policy for America* (Clinton/Gore National Campaign Headquarters, September 1992), pp 15-16.

2. Andrew C. Lemer, "We Cannot Afford Not to Have a National Infrastructure Policy," *APA Journal*, Summer 1992, p. 362.

3. David Alan Aschauer, *Public Investment and Private Sector Growth: The Economic Benefits of Reducing America's "Third Deficit"* (Economic Policy Institute, 1990), p 8.

4. Alicia H. Munnell, "Policy Watch: Infrastructure Investment and Economic Growth," *Journal of Economic Perspectives*, (Volume 6, Number 4, Fall 1992), p 190.

5. Aschauer, p 8.

6. Civil Engineering Research Foundation, *National Civil Engineering Research Needs Forum: Setting a National Research Agenda for the Civil Engineering Profession*, Report #91-F1003.E (Washington, DC, 1991), p 1; and Federal Construction Council, *Addressing Infrastructure Problems on Government Installations: Summary of a Symposium*, Report No. 119 (Washington, DC: National Academy Press, 1992), p 2.

7. U.S. Department of Transportation, *Moving America: New Directions, New Opportunities* (Washington, DC: GPO, February 1990), p 23.

8. Civil Engineering Research Foundation, pp 1-2.

9. James E. Ellis, "Rebuilding America: The Mind-Numbing Cost," *Business Week/Reinventing America*, (Bonus Issue, 1992), p 195.

10. National Council on Public Works Improvement, *Fragile Foundations: A Report on America's Public Works* (February 1988), p 25.

11. U.S. Congress, Office of Technology Assessment, p 5.

12. Aschauer, p 1.

13. Munnell, p 191.

14. U.S. Congress, Office of Technology Assessment, p 41.

15. Portland Cement Association, *Infrastructure: Investing in our Future* (Skokie, Illinois, 1992), p 1.

16. *COMAT Infrastructure/Construction Initiative*, Briefing by the Federal Highway Administration, 1992.

17. Federal Construction Council, p 45.

18. Federal Construction Council, p 49.

19. Advisory Commission on Intergovernmental Relations, *Towards a Federal Infrastructure Strategy: Issues and Options*, A-120 (Washington, DC: GPO, August 1992) p 25.

20. Advisory Commission on Intergovernmental Relations, p 25.

21. National Science Foundation, *Civil Infrastructure Systems Research*, Report of a Workshop Held by National Science Foundation, April 15, 1992 (Washington, DC, September 1992) pp 4-5.

22. *Technology: the Engine of Economic Growth, A National Technology Policy for America*, p 10.

23. Civil Engineering Research Foundation, *Federal Research: Opportunities for the Design and Construction Industry*, Report #92-N6003 (Washington, DC, 1992), p 16.

24. National Science Foundation, p 44.

25. Masumitsu Ito, Javier Ibanez-Guzman, and Brian Atkin, *Construction R&D In Western Europe* (Tokyo: Institute of Technology/Shimizu Corporation, June 1991).

26. National Science Foundation, p 35.

27. National Science Foundation, p 35.

28. National Science Foundation, p 37.

29. Swiss Bank Corporation: Equities Group, *The European Contractors* (London, June 1990), pp 12-13.

30. Masumitsu Ito, Javier Ibanez-Guzman, and Brian Atkin, p 23.

31. Civil Engineering Research Foundation, *Transferring Research Into Practice: Lessons From Japan's Construction Industry*, Report #91-N5005 (Washington, DC, November 1991), p 18.

32. National Science Foundation, pp 45-46.

33. The Federal Ministry for Research and Technology, *Facts and Figures 1990: Update of the Report of the Federal Government on Research 1988* (Bonn: Federal Ministry for Research and Technology, 1990), pp 45-46.

34. Masumitsu Ito, Javier Ibanez-Guzman, and Brian Atkin, p 114.

35. Letter received from Per-Erik Eriksson, Office of the Swedish Attache of Technology, Los Angeles, CA, 1 July 1992.

36. Masumitsu Ito, Javier Ibanez-Guzman, and Brian Atkin, p 116.

37. Masumitsu Ito, Javier Ibanez-Guzman, and Brian Atkin, p 59.

38. Masumitsu Ito, Javier Ibanez-Guzman, and Brian Atkin, p 63.

39. Masumitsu Ito, Javier Ibanez-Guzman, and Brian Atkin, p 35.

40. National Science Foundation, p 41.

41. Masumitsu Ito, Javier Ibanez-Guzman, and Brian Atkin, p 37-38.

42. Letter received from Ferrers Clark, Industry Liaison for NRC-CNRC, Ottawa, Canada, September 23, 1992.

43. Japan Office of the Prime Minister, Science and Technology Agency, *Indicators of Science and Technology* (Tokyo, Japan, 1991), pp 44-45.

44. "Europe Proposes Huge Infrastructure Program," *ENR*, November 30, 1992, p 5.

REFERENCES

Advisory Commission on Intergovernmental Relations. *Towards a Federal Infrastructure Strategy: Issues and Options*, (A-120). Washington, DC: GPO, August 1992.

Aschauer, David Alan. *Public Investment and Private Sector Growth: The Economic Benefits of Reducing America's "Third Deficit"*. Economic Policy Institute, 1990.

Bernstein, Harvey M. "Tearing Down Roadblocks to Innovation." *APWA Reporter*, February 1992, pp 8-12.

Civil Engineering Research Foundation. *Federal Research: Opportunities for the Design and Construction Industry*. Report #92-N6003. Washington, DC, 1992.

Civil Engineering Research Foundation. *National Civil Engineering Research Needs Forum: Setting a National Research Agenda for the Civil Engineering Profession*. Report #91-F1003.E. Washington, DC, 1991.

Civil Engineering Research Foundation. *Transferring Research Into Practice: Lessons From Japan's Construction Industry*. Report #91-N5005. Washington, DC, November 1991.

Clark, Ferrers. Letter to CERF. September 23, 1992. NRC-CNRC, Ottawa, Canada.

COMAT Infrastructure/Construction Initiative. Briefing by the Federal Highway Administration. 1992.

Ellis, James E. "Rebuilding America: The Mind-Numbing Cost." *Business Week/Reinventing America*, Bonus Issue, 1992, pp 194-198.

Eriksson, Per-Erik. Letter to CERF. 1 July 1992. Office of the Swedish Attache of Technology, Los Angeles, CA.

"Europe Proposes Huge Infrastructure Program." *ENR*, November 30, 1992, p 5.

Federal Construction Council. *Addressing Infrastructure Problems on Government Installations: Summary of a Symposium*. Report No. 119. Washington, DC: National Academy Press, 1992.

The Federal Ministry for Research and Technology. *Facts and Figures 1990: Update of the Report of the Federal Government on Research 1988*. Bonn: Federal Ministry for Research and Technology, 1990.

Ito, Masumitsu, et al. *Construction R&D In Western Europe*. Tokyo: Institute of Technology/Shimizu Corporation, June 1991.

Japan Office of the Prime Minister, Science and Technology Agency. *Indicators of Science and Technology*. Tokyo, Japan, 1991.

Lemer, Andrew C. "We Cannot Afford Not to Have a National Infrastructure Policy." *APA Journal*, Summer 1992, pp. 362-367.

Munnell, Alicia H. "Policy Watch: Infrastructure Investment and Economic Growth." *Journal of Economic Perspectives*, Volume 6, Number 4, Fall 1992, pp 189-198.

Munnell, Alicia H., with assistance of Leah M. Cook. "How Does Public Infrastructure Affect Regional Economic Performance?" *New England Economic Review*, Federal Reserve Bank of Boston, September/October 1990b, pp 11-32.

National Council on Public Works Improvement. *Fragile Foundations: A Report on America's Public Works*. February 1988.

National Science Foundation. *Civil Infrastructure Systems Research*, Report of a Workshop Held by National Science Foundation. April 15, 1992. Washington, DC, September 1992.

Portland Cement Association. *Infrastructure: Investing in our Future*. Skokie, Illinois, 1992.

Swiss Bank Corporation: Equities Group. *The European Contractors*. London, June 1990.

Technology: the Engine of Economic Growth, A National Technology Policy for America. Clinton/Gore National Campaign Headquarters. September 1992.

U.S. Congress, Office of Technology Assessment. *Delivering the Goods: Public Works Technologies, Management, and Financing*, (OTA-SET-477). Washington, DC: GPO, April 1991.

U.S. Department of Transportation. *Moving America: New Directions, New Opportunities*. Washington, DC: GPO, February 1990.

APPENDICES

APPENDIX A

FEDERAL LABORATORY CONSORTIUM: LIST OF FEDERAL LABORATORIES

AIR FORCE ADVANCED MANUFACTURING TECHNOLOGY CENTER
MCCLELLAN AFB, CA

AIR FORCE ARMSTRONG LAB. CREW SYSTEMS DIRECTORATE
WRIGHT-PATTERSON AFB, OH

AIR FORCE ARMSTRONG LABORATORY
BROOKS AFB, TX

AIR FORCE ARNOLD ENGINEERING DEVELOPMENT CENTER
ARNOLD AIR FORCE BASE, TN

AIR FORCE ENGINEERING AND SERVICES CENTER
TYNDALL AFB, FL

AIR FORCE FRANK J. SEILER RESEARCH LABORATORY/CD
USAF ACADEMY, CO

AIR FORCE HQ
WASHINGTON, DC

AIR FORCE LEGAL SERVICES AGENCY
WALTHAM, MA

AIR FORCE LEGAL SERVICES AGENCY
WRIGHT PATTERSON AFB, OH

AIR FORCE MATERIAL COMMAND LAW CENTER
WRIGHT-PATTERSON AFB, OH

AIR FORCE MATERIALS COMMAND
WRIGHT-PATTERSON AFB, OH

AIR FORCE PHILLIPS LABORATORY
HANSCOM AFB, MA

AIR FORCE PHILLIPS LABORATORY
KIRTLAND AIR FORCE BASE, NM

AIR FORCE ROME LABORATORY
HANSCOM AFB, MA

AIR FORCE ROME LABORATORY
GRIFFISS AFB, NY

AIR FORCE SAF/AQT
WASHINGTON, DC

AIR FORCE SCHOOL OF AEROSPACE MEDICINE
BROOKS AFB, TX

AIR FORCE WRIGHT LABORATORIES
EGLIN AFB, FL

AIR FORCE WRIGHT LABORATORIES
WRIGHT-PATTERSON AFB, OH

AIR FORCES PHILLIPS LABORATORY
EDWARDS AFB, CA

ARMY AEROFLIGHTDYNAMICS DIRECTORATE
MOFFETT FIELD, CA

ARMY AEROMEDICAL RESEARCH LABORATORY
FORT RUCKER, AL

ARMY AEROSTRUCTURES DIRECTORATE
HAMPTON, VA

ARMY ARMAMENT RD&E CENTER
PICATINNY ARSENAL, NJ

ARMY ATMOSPHERIC SCIENCES
LABORATORY
WHITE SANDS MISSILE RANGE, NM

ARMY AVIATION APPLIED
TECHNOLOGY DIRECTORATE
FORT EUSTIS, VA

ARMY AVIATION RD&E CENTER
ST. LOUIS, MO

ARMY BALLISTIC RESEARCH
LABORATORY
ABERDEEN PROVING GROUND, MD

ARMY BELVOIR RD&E CENTER
FORT BELVOIR, VA

ARMY BENET LABORATORIES
WATERVLIET, NY

ARMY BIOMEDICAL R&D LABORATORY
FREDERICK, MD

ARMY CECOM ELECTRONICS
INTEGRATION DIRECTORATE
FORT MONMOUTH, NJ

ARMY CENTER FOR SIGNALS WARFARE
WARRENTON, VA

ARMY CHEMICAL RD&E CENTER
ABERDEEN PROVING GROUND, MD

ARMY COLD REGIONS RESEARCH &
ENGINEERING LAB
HANOVER, NH

ARMY COMMAND, CONTROL & COMM.
SYSTEMS DIRECTORATE
FT. MONMOUTH, NJ

ARMY COMMUNICATIONS
ELECTRONICS COMMAND
FORT MONMOUTH, NJ

ARMY COMMUNICATIONS
ELECTRONICS COMMAND - EW/RSTA
FT. MONMOUTH, NJ

ARMY CONSTRUCTION ENGINEERING
RESEARCH LABORATORY
CHAMPAIGN, IL

ARMY CORP OF ENGINEERS
WASHINGTON, DC

ARMY DUGWAY PROVING GROUNDS
DUGWAY, UT

ARMY ELECTRONIC PROVING GROUND
FT. HUACHUCA, AZ

ARMY ELECTRONICS TECHNOLOGY &
DEVICES LABORATORY
FT. MONMOUTH, NJ

ARMY ENGINEER WATERWAYS
EXPERIMENT STATION
VICKSBURG, MS

ARMY HARRY DIAMOND
LABORATORIES
ADELPHI, MD

ARMY HUMAN ENGINEERING
LABORATORY
ABERDEEN PROVING GROUND, MD

ARMY HYDROLOGIC ENGINEERING
CENTER
DAVIS, CA

ARMY INFORMATION SYSTEMS
ENGINEERING COMMAND
FT. HUACHUCA, AZ

ARMY INST. FOR RESEARCH IN MIC&CS
ATLANTA, GA

ARMY INSTITUTE FOR WATER RESOURCES
FORT BELVOIR, VA

ARMY INSTITUTE OF DENTAL RESEARCH
WASHINGTON, DC

ARMY INSTITUTE OF SURGICAL RESEARCH
SAN ANTONIO, TX

ARMY LABORATORY COMMAND
ADELPHI, MD

ARMY MATERIALS TECHNOLOGY LABORATORY
WATERTOWN, MA

ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
FREDERICK, MD

ARMY MEDICAL RESEARCH INST. OF CHEMICAL DEFENSE
ABERDEEN PROVING GROUND, MD

ARMY MEDICAL RESEARCH INST. OF INFECTIOUS DISEASES
FREDERICK, MD

ARMY MISSILE COMMAND RD&E CENTER
REDSTONE ARSENAL, AL

ARMY NATICK RD&E CENTER
NATICK, MA

ARMY NIGHT VISION AND ELECTRO-OPTICS DIRECTORATE
FORT BELVOIR, VA

ARMY PROPULSION DIRECTORATE
CLEVELAND, OH

ARMY RES. INST. FOR BEHAVIORAL & SOCIAL SCIENCES
ALEXANDRIA, VA

ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE
NATICK, MA

ARMY RESEARCH OFFICE
RESEARCH TRIANGLE PARK, NC

ARMY STRATEGIC DEFENSE COMMAND
HUNTSVILLE, AL

ARMY TANK-AUTOMOTIVE COMMAND
WARREN, MI

ARMY TOPOGRAPHIC ENGINEERING CENTER
FORT BELVOIR, VA

ARMY VULNERABILITY ASSESSMENT LABORATORY
WHITE SANDS MISSILE RANGE, NM

ARMY WALTER REED INSTITUTE OF RESEARCH
WASHINGTON, DC

ARMY YUMA PROVING GROUND
YUMA, AZ

ARMY-DOMESTIC TECHNOLOGY TRANSFER PROGRAM
ADELPHI, MD

ARMY-RESEARCH & LABORATORY MANAGEMENT
WASHINGTON, DC

CIA-FEDERAL LANGUAGE TRAINING LABORATORY
ARLINGTON, VA

DOC-CENTER FOR UTILIZATION OF FEDERAL TECHNOLOGY
SPRINGFIELD, VA

DOC-INSTITUTE FOR TELECOMMUNICATION SCIENCES
BOULDER, CO

DOC-NATIONAL INSTITUTE OF STANDARDS & TECHNOLOGY
BOULDER, CO

DOC-NATIONAL INSTITUTE OF STANDARDS & TECHNOLOGY
GAITHERSBURG, MD

DOC-NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
SUITLAND, MD

DOC-OFFICE OF TECHNOLOGY COMMERCIALIZATION
WASHINGTON, DC

DOC-OFFICE OF TECHNOLOGY UTILIZATION
WASHINGTON, DC

DOC-TECHNOLOGY ADMINISTRATION
WASHINGTON, DC

DOC/NOAA-ENVIRONMENTAL RESEARCH LAB
BOULDER, CO

DOD-DEPUTY DIRECTOR FOR TECHNOLOGY TRANSFER
ARLINGTON, VA

DOD-ODUSD (R&AT/RLM)
WASHINGTON, DC

DOD-STRATEGIC DEFENSE INITIATIVE ORGANIZATION
WASHINGTON, DC

DOD-STRATEGIC DEFENSE INITIATIVE ORGANIZATION
FALLS CHURCH, VA

DOD-UNIFORMED SERVICES UNIV. OF HEALTH SCIENCES
BETHESDA, MD

DOE-ALBUQUERQUE OPERATIONS OFFICE
ALBUQUERQUE, NM

DOE-ALLIED SIGNAL AEROSPACE
KANSAS CITY, MO

DOE-AMES LABORATORY
AMES, IA

DOE-ARGONNE NATIONAL LABORATORY
ARGONNE, IL

DOE-ASSISTANT GENERAL COUNSEL FOR PATENTS
WASHINGTON, DC

DOE-BOSTON OPERATIONS OFFICE
BOSTON, MA

DOE-BROOKHAVEN NATIONAL LABORATORY
UPTON, NY

DOE-CHICAGO OPERATIONS OFFICE
ARGONNE, IL

DOE-CONSERVATION AND RENEWABLE ENERGY
WASHINGTON, DC

DOE-CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY
NEWPORT NEWS, VA

DOE-ENERGY TECHNOLOGY ENGINEERING CENTER
CANOGA PARK, CA

DOE-ENVIRONMENTAL MANAGEMENT
WASHINGTON, DC

DOE-FERMI NATIONAL ACCELERATOR LABORATORY
BATAVIA, IL

DOE-FIELD OFFICE, RICHLAND
RICHLAND, WA

DOE-IDAHO NATIONAL ENGINEERING LABORATORY
IDAHO FALLS, ID

DOE-INSTITUTE FOR FUSION STUDIES
AUSTIN, TX

DOE-LAWRENCE BERKELEY LABORATORY
BERKELEY, CA

DOE-LAWRENCE LIVERMORE NATIONAL LABORATORY
LIVERMORE, CA

DOE-LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NM

DOE-MORGANTOWN ENERGY TECHNOLOGY CENTER
MORGANTOWN, WV

DOE-MOUND APPLIED TECHNOLOGIES
MIAMISBURG, OH

DOE-NATIONAL RENEWABLE ENERGY LABORATORY
GOLDEN, CO

DOE-NEW BRUNSWICK LABORATORY
ARGONNE, IL

DOE-NUCLEAR ENERGY NE-34/A-164
GERMANTOWN, MD

DOE-OAK RIDGE INSTITUTE FOR SCIENCE & EDUCATION
OAK RIDGE, TN

DOE-OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TN

DOE-OAK RIDGE OPERATION'S OFFICE
OAK RIDGE, TN

DOE-OFFICE OF FIELD OPERATIONS MGMT
WASHINGTON, DC

DOE-OFFICE OF SCIENTIFIC & TECHNICAL INFORMATION
OAK RIDGE, TN

DOE-OFFICE OF TECHNOLOGY UTILIZATION
WASHINGTON, DC

DOE-PACIFIC NORTHWEST LABORATORY
RICHLAND, WA

DOE-PITTSBURGH ENERGY TECHNOLOGY CENTER
PITTSBURGH, PA

DOE-PRINCETON PLASMA PHYSICS LAB
PRINCETON, NJ

DOE-ROCKY FLATS PLANT
GOLDEN, CO

DOE-SAN FRANCISCO OPERATIONS OFFICE
OAKLAND, CA

DOE-SANDIA NATIONAL LABORATORIES
LIVERMORE, CA

DOE-SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NM

DOE-SAVANNAH RIVER SITE
AIKEN, SC

DOE-STANFORD LINEAR ACCELERATOR CENTER
STANFORD, CA

DOE-SUPERCONDUCTING SUPER COLLIDER LABORATORY
DALLAS, TX

DOE-TECHNOLOGY TRANSFER DIVISION
WASHINGTON, DC

DOE-UCLA LAB OF BIOMEDICAL-ENVIRONMENTAL SCIENCE
LOS ANGELES, CA

DOE-WESTINGHOUSE HANFORD COMPANY
RICHLAND, WA

DOI-BUREAU OF MINES
WASHINGTON, DC

DOI-BUREAU OF RECLAMATION
DENVER, CO

DOI-FISH & WILDLIFE SERVICE
WASHINGTON, DC

DOI-U.S. GEOLOGICAL SURVEY
MENLO PARK, CA

DOI-U.S. GEOLOGICAL SURVEY
RESTON, VA

DOI/BOM-ALBANY RESEARCH CENTER
ALBANY, OR

DOI/BOM-DENVER RESEARCH CENTER
DENVER, CO

DOI/BOM-PITTSBURGH RESEARCH CENTER
PITTSBURGH, PA

DOI/BOM-RENO RESEARCH CENTER
RENO, NV

DOI/BOM-ROLLA RESEARCH CENTER
ROLLA, MO

DOI/BOM-SALT LAKE CITY RESEARCH CENTER
SALT LAKE CITY, UT

DOI/BOM-SPOKANE RESEARCH CENTER
SPOKANE, WA

DOI/BOM-TUSCALOOSA RESEARCH CENTER
TUSCALOOSA, AL

DOI/BOM-TWIN CITIES RESEARCH CENTER
MINNEAPOLIS, MN

DOJ-FEDERAL BUREAU OF INVESTIGATION
QUANTICO, VA

DOT-COAST GUARD R&D CENTER
GROTON, CT

DOT-FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, NJ

DOT-FEDERAL HIGHWAY ADMINISTRATION
WASHINGTON, DC

DOT/FHWA-TURNER-FAIRBANK HIGHWAY RESEARCH CENTER
MCLEAN, VA

DOT/FRA-TRANSPORTATION TEST CENTER
PUEBLO, CO

DOT/RSPA-OFFICE OF RESEARCH POLICY & TECH. TRANS.
WASHINGTON, DC

DOT/RSPA-TRANSPORTATION SYSTEMS CENTER
CAMBRIDGE, MA

EPA-ENGINEERING LABORATORIES
WASHINGTON, DC

EPA-ENVIRONMENTAL MONITORING SYSTEMS LAB
LAS VEGAS, NV

EPA-ENVIRONMENTAL RESEARCH CENTER
RESEARCH TRIANGLE PARK, NC

EPA-OFFICE OF TECHNOLOGY TRANSFER
WASHINGTON, DC

EPA-OFFICE OF TT & REG. SUPPORT
CINCINNATI, OH

FLC ADMINISTRATOR'S OFFICE
SEQUIM, WA

FLC WASHINGTON DC REPRESENTATIVE
WASHINGTON, DC

HHS-CENTERS FOR DISEASE CONTROL
ATLANTA, GA

HHS-NAT'L. INST. FOR OCCUPATIONAL SAFETY & HEALTH
CINCINNATI, OH

HHS-NATIONAL INSTITUTES OF HEALTH
BETHESDA, MD

HHS-PUBLIC HEALTH SERVICE
WASHINGTON, DC

HHS-PUBLIC HEALTH SERVICE
ROCKVILLE, MD

HHS/FDA-CENTERS FOR DEVICES & RADIOLOGICAL HEALTH
ROCKVILLE, MD

HHS/NIH-ROCKY MOUNTAIN LABS
HAMILTON, MT

HHS/PHS/FDA-NAT. CTR. FOR TOXICOLOGICAL RESEARCH
JEFFERSON, AR

MARINE CORPS SYSTEMS COMMAND
QUANTICO, VA

NASA AMES RESEARCH CENTER
MOFFETT FIELD, CA

NASA GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, AL

NASA GODDARD SPACE FLIGHT CENTER
GREENBELT, MD

NASA HEADQUARTERS
WASHINGTON, DC

NASA JET PROPULSION LABORATORY
PASADENA, CA

NASA KENNEDY SPACE CENTER
KENNEDY SPACE CENTER, FL

NASA LANGLEY RESEARCH CENTER
HAMPTON, VA

NASA LEWIS RESEARCH CENTER
CLEVELAND, OH

NASA LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TX

NASA STENNIS SPACE CENTER
STENNIS SPACE CENTER, MS

NATIONAL HIGH MAGNETIC FIELD LABORATORY
TALLAHASSEE, FL

NATIONAL INSTITUTE FOR PETROLEUM & ENERGY RESEARCH
BARTLESVILLE, OK

NATIONAL SCIENCE FOUNDATION
WASHINGTON, DC

NAVAL ACADEMY
ANNAPOLIS, MD

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FL

NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA

NAVAL AIR PROPULSION CENTER
TRENTON, NJ

NAVAL AIR SYSTEMS COMMAND
WASHINGTON, DC

NAVAL AIR WARFARE CENTER - AIRCRAFT DIVISION
INDIANAPOLIS, IN

NAVAL AIR WARFARE CENTER - AIRCRAFT DIVISION
PATUXENT RIVER, MD

NAVAL AIR WARFARE CENTER - AIRCRAFT DIVISION
LAKEHURST, NJ

NAVAL AIR WARFARE CENTER - WEAPONS DIVISION (CL)
CHINA LAKE, CA

NAVAL AIR WARFARE CENTER - WEAPONS DIVISION (PM)
POINT MUGU, CA

NAVAL BIODYNAMICS LABORATORY
NEW ORLEANS, LA

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CA

NAVAL COMMAND CONTROL OCEAN SURVEILLANCE CENTER
SAN DIEGO, CA

NAVAL EXPLOSIVE ORDNANCE DISPOSAL TECHNOLOGY CTR
INDIAN HEAD, MD

NAVAL FACILITIES ENGINEERING COMMAND
ALEXANDRIA, VA

NAVAL HEALTH RESEARCH CENTER
SAN DIEGO, CA

NAVAL INDUSTRIAL RESOURCES SUPPORT ACTIVITY
PHILADELPHIA, PA

NAVAL MEDICAL RESEARCH & DEVELOPMENT COMMAND
BETHESDA, MD

NAVAL MEDICAL RESEARCH INSTITUTE
BETHESDA, MD

NAVAL OBSERVATORY
WASHINGTON, DC

NAVAL OCEANOGRAPHIC & ATMOSPHERIC RESEARCH LAB.
STENNIS SPACE CENTER, MS

NAVAL OCEANOGRAPHIC OFFICE
STENNIS SPACE CENTER, MS

NAVAL ORDNANCE MISSILE TEST CENTER
WHITE SANDS MISSILE RANGE, NM

NAVAL ORDNANCE STATION
INDIAN HEAD, MD

NAVAL POLARIS MISSILE FACILITY, ATLANTIC
CHARLESTON, SC

NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA

NAVAL RESEARCH LABORATORY
WASHINGTON, DC

NAVAL SAFETY CENTER
NORFOLK, VA

NAVAL SEA SYSTEMS COMMAND
WASHINGTON, DC

NAVAL SHIP SYSTEMS ENGINEERING STATION
PHILADELPHIA, PA

NAVAL SPACE AND WARFARE SYSTEMS COMMAND
WASHINGTON, DC

NAVAL SPACE COMMAND
DAHLGREN, VA

NAVAL SUPPLY SYSTEMS COMMAND
WASHINGTON, DC

NAVAL SURFACE WARFARE CENTER
PANAMA CITY, FL

NAVAL SURFACE WARFARE CENTER DAHLGREN DIVISION
SILVER SPRING, MD

NAVAL SURFACE WARFARE CTR. CARDEROCK DIV.
BETHESDA, MD

NAVAL TRAINING SYSTEMS CENTER
ORLANDO, FL

NAVAL UNDERSEA WARFARE CENTER DIV., NEWPORT (RI)
NEW LONDON, CT

NAVAL UNDERSEA WARFARE CENTER DIV., NORFOLK
NORFOLK, VA

NAVAL UNDERSEA WARFARE CENTER-DIVISION KEYPORT
KEYPORT, WA

NAVAL WEAPONS EVALUATION FACILITY
ALBUQUERQUE, NM

NAVAL WEAPONS STATION EARLE
COLTS NECK, NJ

NAVAL WEAPONS SUPPORT CENTER
CRANE, IN

NAVY CLOTHING & TEXTILE RESEARCH FACILITY
NATICK, MA

NAVY ENVIRONMENTAL HEALTH CENTER
NORFOLK, VA

NAVY PERSONNEL R&D CENTER
SAN DIEGO, CA

NAVY-OFFICE OF NAVAL RESEARCH
ARLINGTON, VA

NAVY-OFFICE OF NAVAL TECHNOLOGY
ARLINGTON, VA

NSF-CENTER FOR EMERGING CARDIOVASCULAR TECH.
DURHAM, NC

NSF-CTR. FOR ADV. TECH. FOR LARGE STRUCTURAL SYS.
BETHLEHEM,, PA

NSF-ENGINEERING RESEARCH CTR. FOR NET SHAPE MFG.
COLUMBUS, OH

NSF-NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
BOULDER, CO

NSF-SYSTEMS RESEARCH CENTER
COLLEGE PARK, MD

TENNESSEE VALLEY AUTHORITY
KNOXVILLE, TN

USDA-EXTENSION SERVICE
WASHINGTON, DC

USDA-FOREST SERVICE RESEARCH LAB
WASHINGTON, DC

USDA-NATIONAL AGRICULTURAL LIBRARY
BELTSVILLE, MD

USDA/ARS-EASTERN REGIONAL RESEARCH CENTER
WYNDMOOR, PA

USDA/ARS-NAT. CTR. FOR AGRICULTURAL UTIL. RESEARCH
PEORIA, IL

USDA/ARS-NORTHERN PLAINS AREA
FORT COLLINS, CO

USDA/ARS-OFFICE OF COOPERATIVE INTERACTIONS
WASHINGTON, DC

USDA/ARS-PACIFIC WEST AREA
ALBANY, CA

USDA/ARS-PRODUCT UTILIZATION
BELTSVILLE, MD

USDA/ARS-SOUTHERN REGIONAL RESEARCH CENTER
NEW ORLEANS, LA

USDA/ARS-WESTERN REGIONAL RESEARCH CENTER
ALBANY, CA

USDA/FS-BOISE INTERAGENCY FIRE CTR.
BOISE, ID

USDA/FS-FOREST PRODUCTS
LABORATORY
MADISON, WI

USDA/FS-NORTH CENTRAL
EXPERIMENT STATION
ST. PAUL, MN

USDA/FS-NORTHEASTERN AREA
RADNOR, PA

USDA/FS-NORTHEASTERN FOREST EXP.
STATION
RADNOR, PA

USDA/FS-PACIFIC NW FOREST & RANGE
EXPER. STATION
PORTLAND, OR

USDA/FS-ROCKY MOUNTAIN FOREST &
RANGE EXPER. STA.
FORT COLLINS, CO

USDA/FS-SOUTHEASTERN FOREST
EXPERIMENT STATION
ASHEVILLE, NC

VA REHAB R&D CENTER
PALO ALTO, CA

VA-ATLANTA REHAB R&D CENTER
DECATUR, GA

VA-REHAB RESEARCH & DEVELOPMENT
CENTER
HINES, IL

APPENDIX B

SAMPLE: FEDERAL INFRASTRUCTURE R&D ANALYSIS QUESTIONNAIRE WITH COVER LETTER

Dear Federal Laboratory:

As a part of the on-going Federal Infrastructure Strategy Program, the University of Illinois and the Civil Engineering Research Foundation (CERF) have been asked to seek your invaluable assistance in assessing the scope and nature of federal activity in Public Works Infrastructure (PWI). **Since this information is of significant value to the Federal Laboratory Consortium (FLC), this request for your assistance is fully supported by the FLC Administrator and Locator Manager; we are pleased to include the attached letter of support.**

The objective is to identify, from a "macro" perspective, both the scope and the nature of PWI research and development, whether on-going or planned. We have developed the attached questionnaire in order to make the "capture" of this essential information as time and resource efficient as possible.

A significant result of this analysis will be a clearer understanding of the federal role and contribution to PWI R&D; these results can be expected to assist your laboratory and the entire federal sector in planning and executing PWI R&D with minimal unnecessary overlap, and conversely, with greater confidence that serious gaps have been averted.

This brief questionnaire should require approximately fifteen to twenty minutes to complete; a synopsis of infrastructure terms is attached in order to ensure a common frame of reference in responding. If you do not have the exact answer for a question, please provide your best estimate; your estimate is more important than no response. We believe that the final product will be of substantial value for you and the FLC.

Your assistance is vital to this effort and is deeply appreciated.

Warmest regards. Sincerely,

Carl O. Magnell
Director of Research

Civil Engineering Research Foundation

FEDERAL INFRASTRUCTURE R&D ANALYSIS QUESTIONNAIRE

SYNOPSIS OF INFRASTRUCTURE TERMS

The enclosed questionnaire considers five (5) principal PWI systems; these systems are defined as shown below. Please include all R&D associated with these PWI systems.

Transportation	Roads, bridges/tunnels, rail systems, mass transit, ports and harbors, airports and air control facilities, water transportation, etc.
Water Resources	All components, including dams, reservoirs, water supply (treatment and distribution), sewers and sewerage treatment, irrigation and land drainage, waterways.
Energy Sources/Delivery	Stations and sub-stations, distribution and transmission networks, monitoring centers, etc. related to hydro, fossil fuel, nuclear, solar and other power and energy sources.
Building/Structures	This category includes all types of federal facilities, for example defense installations, administrative and judicial facilities, research facilities, etc.,as well as general building and structure research.
Waste	All forms of solid waste and solid waste treatment, including landfills, incineration, bio-degradation, etc.

Please note that "Basic Research" refers to research without specific applications in mind; conversely, "Applied Research" is directed toward meeting a specific need.

Where this survey mentions "innovation," the reference denotes planned attempts to devise improvements in productivity; for "developments," the growth and advancement of prototypes and processes toward the production of useful materials, etc.; finally, "demonstrations" test whether a technology actually works.

Civil Engineering Research Foundation

FEDERAL INFRASTRUCTURE R&D ANALYSIS QUESTIONNAIRE

Please provide the following information:

NAME OF LABORATORY_____ **Point of Contact**_____
PHONE/FAX_____

1. Does your laboratory conduct Public Works Infrastructure (PWI) R&D? (circle one)

   a. Yes b. No **(please stop at this point/return questionnaire to CERF)**

2. What is your **total FY 1992** R&D budget, including both line item and reimbursable funds? (circle one)

   a. < $5,000,000
   b. $5,000,000-$9,999,999
   c. $10,000,000-$19,999,999
   d. $20,000,000-$39,999,999
   e. $40,000,000-$69,999,999
   f. $70,000,000-$99,999,999
   g. $100,000,000-$149,999,999
   h. >$150,000,000

3. What **per cent** of your R&D budget is allocated to PWI R&D. (circle one)

   a. < 10%
   b. 10%-32.9%
   c. 33%- 49.9%
   d. 50%-66.9%
   e. 67%-89.9%
   f. > 90%

4. Approximate funding (by fiscal year) for the various PWI systems; please respond by placing the letters in the appropriate locations on the matrix.

   a. < $1,000,000
   b. $1,000,000-$2,499,999
   c. $2,500,000-$4,999,999
   d. $5,000,000-$7,499,999
   e. $7,500,000-$9,999,999
   f. $10,000,000-$14,999,999
   g. $15,000,000-$19,999,999
   h. $20,000,000-$29,999,999
   i. $30,000,000-$49,999,999
   j. $50,000,000-$69,999,999
   k. > $70,000,000

SYSTEM\FY	FY90	FY91	FY92	FY93	FY94
Transportation	___	___	___	___	___
Water Resources	___	___	___	___	___
Energy Sources/Delivery	___	___	___	___	___
Buildings/Structures	___	___	___	___	___
Waste	___	___	___	___	___
Other	___	___	___	___	___

5. How many personnel (federal and contract employees) in your laboratory are engaged in PWI R&D? (select appropriate letter)

   Researchers____ **Administrative staff**____

   a. < 10 c. 20-49 e. 100-199 g. 300-399 i. >500
   b. 10-19 d. 50-99 f. 200-299 h. 400-499

6. Using the % distribution below, please answer the following by placing the appropriate letter next to each PWI system:

a. < 5%	c. 10%-19.9%	e. 30%-39.9	g. 50%-74.9%
b. 5%-9.9%	d. 20%-29.9%	f. 40%-49.9%	h. >75%

a. Percent of your **research** staff (researchers & technicians) allocated to **each** of the PWI systems?

Transportation___ **Water Resources**___ **Energy Sources/Delivery**___ **Buildings/Structures**___ **Waste**___

b. Percent of research that is **Basic** (w/o specific application), for **each** PWI system.

Transportation___ **Water Resources**___ **Energy Sources/Delivery**___ **Buildings/Structures**___ **Waste**___

c. Percent of your total PWI R&D effort in the following application areas.

a. Equipment____	d. Const.Mgmt____	g. Seismic____	j. Software____
b. Materials____	e. Automation/Robotics____	h. Other Natural Hazards___	k. Other____
c. Environment____	f. Land Use_____	i. Non-Destructive Eval____	

7. As a percentage of PWI funding, indicate both where your research is accomplished and the type of research (total should approximate 100%).

LOCATION	%	TYPE	%
a. In-house	_____	BASIC	_____
b. Other Laboratories	_____	APPLIED	_____
c. Academia	_____	DEMO	_____
d. Industry	_____	OTHER	_____
e. Research Institutes	_____		
f. Other	_____		_____
TOTAL	**100% (approx)**	**TOTAL**	**100% (approx)**

8. Please rank the following technology transfer (T^2) methods in their order of importance (1-12) to your laboratory;

a. licenses _____	d. Presentations _____	g. Demonstrations_____	j. SBIR_____
b. CRDAs_____	e. Publications _____	h. Displays _____	k. Support Centers_____
c. CPAR _____	f. Workshops _____	i. "800" Lines_____	l. Other_____

9. How often have you implemented the following T^2 mechanisms in your laboratory?

a. None b. 1-2 c. 3-5 d. 6-9 e. 10-14 f. >15

LICENSE___ **CRDA**___ **WORKSHOPS**___ **SBIR**___ **DEMOS**___

Please **RETURN** this questionnaire to: *Civil Engineering Research Foundation (CERF)*
1015 15th St. N.W. Washington, D.C. 20005
Or respond via fax: (202) 789-2943

APPENDIX C

TABLES

LIST OF TABLES

TABLE 3.1 Summary of Federal Agency Activity for Public Works Infrastructure Research and Development for FY92

TABLE 3.2 Summary of Federal Agency Research and Development Budgets for Public Works *Transportation* Infrastructure

TABLE 3.3 Summary of Federal Agency Research and Development Budgets for Public Works *Water Resources* Infrastructure

TABLE 3.4 Summary of Federal Agency Research and Development Budgets for Public Works *Energy Source/Delivery* Infrastructure

TABLE 3.5 Summary of Federal Agency Research and Development Budgets for Public Works *Buildings/Structures* Infrastructure

TABLE 3.6 Summary of Federal Agency Research and Development Budgets for Public Works *Waste* Infrastructure

TABLE 3.7 Summary of [illegible]al Agency Research and Development Budgets for P[illegible] Works *Other* Infrastructure

TABLE 3.8 Distribution of Research Among Infrastructure Systems

TABLE 3.9 Summary of Budget Allocations to Application Areas

TABLE 3.10 Percent of Agency Research Performed by Locations

TABLE 3.11 Distribution of Effort Among Various Types of Research

TABLE 3.12 Summary of Technology Transfer Preferences

TABLE 3.13 Frequency of Use of Selected Technology Transfer Methods

TABLE 3.1

SUMMARY OF FEDERAL AGENCY ACTIVITY FOR PUBLIC WORKS INFRASTRUCTURE RESEARCH AND DEVELOPMENT FOR FISCAL YEAR 1992

AGENCY	R & D BUDGET (in millions)		PWI R&D PERSONNEL (actual count)	
	Total	Allocated to PWI R&D	Research & Technicians	Administrative staff
Army Construction Engineering Research Lab	70 - 100	> 90%	200 - 299	100 - 199
EPA Engineering Laboratories	10 - 20	> 90%	100 - 199	20 - 49
Army Institute for Water Resources	10 - 20	> 90%	20 - 49	< 10
VA Rehab R&D Center	2	> 90%	20 - 49	< 10
USDA/FS Timber Bridge Information Resource Center	2	> 90%	< 10	< 10
DOT/FHWA Turner-Fairbank Highway Research Center	228	67 - 90%	50 - 99	20 - 49
Army Waterways Experiment Station	100 - 150	67 - 90%	> 500	300 - 399
Bureau of Reclamation	5 - 10	67 - 90%	100 - 199	50 - 99
DOE-Idaho National Engineering Laboratory	300	50 - 67%	> 500	> 500
DOE-Argonne National Lab	100 - 150	50 - 67%	> 500	50 - 99
NIST, Building & Fire Research Lab	20 - 40	50 - 67%	50 - 99	< 10
DOE-Pacific Northwest Lab	400 - 500	33 - 50%	> 500	> 500
Naval Civil Engineering Lab	40 - 70	33 - 50%	100 - 199	20 - 49
DOT/FRA-Transportation Test Center	10 - 20	33 - 50%	100 - 199	50 - 99
DOE-Brookhaven National Lab	300	10 - 33%	20 - 49	
DOT/RSPA Transportation Systems Center	100 - 150	10 - 33%	100 - 199	10 - 19
Army Cold Regions Research & Engineering Lab	20 - 40	10 - 33%	20 - 49	< 10
Air Force Civil Engineering Lab	20 - 40	10 - 33%	50 - 99	
USDA/FS-Forest Products Lab	10 - 20	10 - 33%	20 - 49	< 10
Army Hydrologic Engineering Center	4	10 - 33%	20 - 49	< 10
National Science Foundation	2700	< 10%	> 500	50 - 99
DOE-Los Alamos National Lab	1000	< 10%		
USDA-Agricultural Research Service	660	< 10%	> 500	> 500
DOE-Sandia National Lab	550	< 10%	300 - 399	50 - 99
DOE-Lawrence Berkeley Lab	200 - 250	< 10%	100 - 199	< 10
National Oceanic & Atmospheric Administration	102	< 10%	10 - 19	< 10
National Institute for Occupational Safety & Health	70 - 100	< 10%	5	3
USDA/ARS-Northern Plains Area	40 - 70	< 10%	10 - 19	
Army Topographic Engineering Center	20 - 40	< 10%	10 - 19	< 10
Bureau of Mines Albany Research Lab	5 - 10	< 10%	< 10	
DOT/FAA Technical Center	5 - 10	< 10%	50 - 99	20 - 49
Naval Academy	3	< 10%	< 10	< 10

TABLE 3.2

SUMMARY OF FEDERAL AGENCY RESEARCH AND DEVELOPMENT BUDGETS FOR PUBLIC WORKS *TRANSPORTATION* INFRASTRUCTURE

AGENCY	TRANSPORTATION R&D FUNDING FOR FISCAL YEAR (in millions $)				
	1990	1991	1992	1993	1994
DOT/FHWA Turner-Fairbank Highway Research Center	93	99	228	275	304
Army Waterways Experiment Station	50 - 70	50 - 70	50 - 70	70 - 80	70 - 80
DOT/RSPA Transportation Systems Center	20 - 30	20 - 30	30 - 50	30 - 50	30 - 50
DOE-Sandia National Lab	10 - 15	15 - 20	20 - 30	20 - 30	20 - 30
DOT/FRA-Transportation Test Center	15 - 20	15 - 20	15 - 20	15 - 20	15 - 20
DOE-Pacific Northwest Lab	15 - 20	15 - 20	15 - 20	15 - 20	15 - 20
DOT/FAA Technical Center	2.5 - 5	5 - 7.5	5 - 7.5	5 - 7.5	7.5 - 10
DOE-Idaho National Engineering Laboratory	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5
Army Construction Engineering Research Lab	2.5 - 5	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5
USDA/FS Timber Bridge Information Resource Center	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5
Army Institute for Water Resources	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5
DOE-Los Alamos National Lab	< 1	< 1	1 - 2.5	2.5 - 5	5 - 7.5
DOE-Argonne National Lab	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5
Bureau of Reclamation	< 1	< 1	1 - 2.5	< 1	1 - 2.5
Army Topographic Engineering Center	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5
Army Cold Regions Research & Engineering Lab	< 1	< 1	1 - 2.5	1 - 2.5	1 - 2.5
USDA/FS-Forest Products Lab	< 1	< 1	< 1	1 - 2.5	1 - 2.5
Naval Academy	< 1	< 1	< 1	< 1	n/a
National Science Foundation	< 1	< 1	< 1	< 1	< 1
DOE-Lawrence Berkeley Lab	< 1	< 1	< 1	< 1	< 1
DOE-Brookhaven National Lab	< 1	< 1	< 1	< 1	< 1
Bureau of Mines Albany Research Lab	< 1	< 1	< 1	< 1	< 1
Air Force Civil Engineering Lab	< 1	< 1	< 1	< 1	< 1

TABLE 3.3

SUMMARY OF FEDERAL AGENCY RESEARCH AND DEVELOPMENT BUDGETS FOR PUBLIC WORKS *WATER RESOURCES* INFRASTRUCTURE

AGENCY	WATER RESOURCES R&D FUNDING FOR FISCAL YEAR (in millions $)				
	1990	1991	1992	1993	1994
Army Waterways Experiment Station	30 - 50	30 - 50	50 - 70	50 - 70	70 - 80
DOE-Pacific Northwest Lab	30 - 50	30 - 50	30 - 50	30 - 50	30 - 50
DOE-Idaho National Engineering Laboratory	30 - 50	30 - 50	30 - 50	30 - 50	30 - 50
USDA-Agricultural Research Service	20 - 30	20 - 30	20 - 30	20 - 30	20 - 30
Army Institute for Water Resources	10 - 15	10 - 15	10 - 15	10 - 15	10 - 15
Army Construction Engineering Research Lab	7.5 - 10	10 - 15	10 - 15	10 - 15	10 - 15
Air Force Civil Engineering Lab	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5
Bureau of Reclamation	1 - 2.5	1 - 2.5	2.5 - 5	1 - 2.5	2.5 - 5
EPA Engineering Laboratories	2.5 - 5	2.5 - 5	1 - 2.5	1 - 2.5	1 - 2.5
DOT/RSPA Transportation Systems Center		< 1	1 - 2.5	1 - 2.5	1 - 2.5
DOT/FHWA Turner-Fairbank Highway Research Center	< 1	1 - 2.5	1 - 2.5	2.5 - 5	2.5 - 5
USDA/ARS-Northern Plains Area	< 1	< 1	< 1	< 1	< 1
National Science Foundation	< 1	< 1	< 1	< 1	< 1
National Oceanic & Atmospheric Administration	< 1	< 1	< 1	< 1	< 1
DOE-Sandia National Lab	< 1	< 1	< 1	< 1	< 1
DOE-Lawrence Berkeley Lab	< 1	< 1	< 1	< 1	< 1
DOE-Argonne National Lab	< 1	< 1	< 1	< 1	< 1
Bureau of Mines Albany Research Lab	< 1	< 1	< 1	< 1	< 1
Army Hydrologic Engineering Center	< 1	< 1	< 1	< 1	< 1
Army Cold Regions Research & Engineering Lab	< 1	< 1	< 1	< 1	< 1

TABLE 3.4

SUMMARY OF FEDERAL AGENCY RESEARCH AND DEVELOPMENT BUDGETS FOR PUBLIC WORKS *ENERGY SOURCE/DELIVERY* INFRASTRUCTURE

AGENCY	ENERGY SOURCE/DELIVERY R&D FUNDING FOR FISCAL YEAR (in millions $)				
	1990	1991	1992	1993	1994
DOE-Pacific Northwest Lab	50 - 70	50 - 70	50 - 70	50 - 70	50 - 70
DOE-Idaho National Engineering Laboratory	50 - 70	50 - 70	50 - 70	50 - 70	50 - 70
DOE-Argonne National Lab	50 - 70	50 - 70	50 - 70	50 - 70	50 - 70
DOE-Sandia National Lab	15 - 20	20 - 30	30 - 50	30 - 50	30 - 50
Army Construction Engineering Research Lab	7.5 - 10	10 - 15	10 - 15	10 - 15	10 - 15
DOE-Brookhaven National Lab	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5
NIST, Building & Fire Research Lab	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5
DOT/RSPA Transportation Systems Center		1 - 2.5	1 - 2.5	5 - 7.5	5 - 7.5
Bureau of Reclamation	< 1	< 1	1 - 2.5	< 1	1 - 2.5
USDA/FS-Forest Products Lab	< 1	< 1	< 1	< 1	< 1
Naval Academy	< 1	< 1	< 1	< 1	n/a
National Science Foundation	< 1	< 1	< 1	< 1	< 1
DOE-Lawrence Berkeley Lab	< 1	< 1	< 1	< 1	< 1
Air Force Civil Engineering Lab	< 1	< 1	< 1	< 1	< 1

TABLE 3.5

SUMMARY OF FEDERAL AGENCY RESEARCH AND DEVELOPMENT BUDGETS FOR PUBLIC WORKS *BUILDINGS/STRUCTURES* INFRASTRUCTURE

AGENCY	BUILDINGS/STRUCTURES R&D FUNDING FOR FISCAL YEAR (*in millions $*)				
	1990	1991	1992	1993	1994
National Science Foundation	20 - 30	20 - 30	20 - 30	20 - 30	20 - 30
DOE-Pacific Northwest Lab	20 - 30	20 - 30	20 - 30	20 - 30	20 - 30
Army Construction Engineering Research Lab	15 - 20	20 - 30	20 - 30	20 - 30	20 - 30
DOE-Lawrence Berkeley Lab	7.5 - 10	7.5 - 10	10 - 15	10 - 15	10 - 15
NIST, Building & Fire Research Lab	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5
DOT/FHWA Turner-Fairbank Highway Research Center	1 - 2.5	2.5 - 5	5 - 7.5	2.5 - 5	2.5 - 5
USDA/FS-Forest Products Lab	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5
Army Waterways Experiment Station	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5
Air Force Civil Engineering Lab	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5
VA Rehab R&D Center	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5	
DOT/RSPA Transportation Systems Center			1 - 2.5	1 - 2.5	5 - 7.5
DOE-Brookhaven National Lab	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5
Naval Academy	< 1	< 1	< 1	< 1	n/a
National Institute for Occupational Safety & Health	< 1	< 1	< 1	< 1	< 1
DOE-Argonne National Lab	< 1	< 1	< 1	< 1	< 1
Bureau of Reclamation	< 1	< 1	< 1	< 1	< 1
Army Cold Regions Research & Engineering Lab	< 1	< 1	< 1	< 1	< 1
Bureau of Mines Albany Research Lab	< 1	0	0	0	0

TABLE 3.6

SUMMARY OF FEDERAL AGENCY RESEARCH AND DEVELOPMENT BUDGETS FOR PUBLIC WORKS *WASTE* INFRASTRUCTURE

AGENCY	WASTE R&D FUNDING FOR FISCAL YEAR (in millions $)				
	1990	1991	1992	1993	1994
DOE-Idaho National Engineering Laboratory	> 70	> 70	> 70	> 70	> 70
DOE-Pacific Northwest Lab	50 - 70	50 - 70	50 - 70	50 - 70	50 - 70
EPA Engineering Laboratories	20 - 30	20 - 30	15 - 20	15 - 20	15 - 20
DOE-Los Alamos National Lab	2.5 - 5	7.5 - 10	10 - 15	20 - 30	20 - 30
Army Construction Engineering Research Lab	7.5 - 10	10 - 15	10 - 15	10 - 15	10 - 15
Air Force Civil Engineering Lab	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5	5 - 7.5
DOE-Brookhaven National Lab	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5
DOE-Argonne National Lab	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5	5 - 7.5
National Science Foundation	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5
DOE-Lawrence Berkeley Lab	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5	1 - 2.5
Army Waterways Experiment Station	1 - 2.5	1 - 2.5	1 - 2.5	2.5 - 5	2.5 - 5
DOT/RSPA Transportation Systems Center			< 1	1 - 2.5	1 - 2.5
Bureau of Reclamation	< 1	< 1	< 1	< 1	< 1
Bureau of Mines Albany Research Lab	< 1	< 1	< 1	< 1	< 1
DOT/FHWA Turner-Fairbank Highway Research Center				< 1	< 1

TABLE 3.7

SUMMARY OF FEDERAL AGENCY RESEARCH AND DEVELOPMENT BUDGETS FOR PUBLIC WORKS *OTHER* INFRASTRUCTURE

AGENCY	OTHER R&D FUNDING FOR FISCAL YEAR (in millions $)				
	1990	1991	1992	1993	1994
National Science Foundation	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5
Army Construction Engineering Research Lab	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5	2.5 - 5
DOE-Argonne National Lab	< 1	< 1	< 1	< 1	< 1
Bureau of Reclamation	< 1	< 1	< 1		< 1
Air Force Civil Engineering Lab	< 1	< 1	< 1	< 1	< 1

TABLE 3.8
DISTRIBUTION OF RESEARCH AMONG INFRASTRUCTURE SYSTEMS

AGENCY	Percent of research staff (researchers & technicians) allocated to various public works infrastructure systems. Numbers in parenthesis are percent budget allocations to basic research.									
	Transportation		Water Resources		Energy Sources/Delivery		Buildings/ Structures		Waste	
Air Force Civil Engineering Lab	10 - 20		20 - 30		5 - 10		5 - 10		20 - 30	
Army Cold Regions Research & Engineering Lab	30 - 40	(< 5)	30 - 40		< 5		< 5		< 5	
Army Construction Engineering Research Lab	5 - 10	(40 - 50)	10 - 20	(10 - 20)	10 - 20	(5 - 10)	30 - 40	(10 - 20)	10 - 20	(5 - 10)
Army Hydrologic Engineering Center	< 5	(< 5)	40 - 50	(< 5)	< 5	(< 5)	< 5	(< 5)	< 5	(< 5)
Army Institute for Water Resources	20 - 30	(20 - 30)	> 75	(> 75)						
Army Topographic Engineering Center	50 - 75	(< 5)								
Army Waterways Experiment Station	20 - 30	(20 - 30)	40 - 50	(40 - 50)			30 - 40	(30 - 40)	< 5	(< 5)
Bureau of Mines Albany Research Lab	< 5	(40 - 50)	< 5	(20 - 30)			< 5	(20 - 30)	< 5	(40 - 50)
Bureau of Reclamation	30 - 40	(< 5)	40 - 50	(< 5)	10 - 20	(< 5)	< 5	(< 5)	< 5	(< 5)
DOE-Argonne National Lab	10 - 20	(10 - 20)	< 5	(< 5)	50 - 75	(50 - 75)	< 5	(< 5)	10 - 20	(10 - 20)
DOE-Brookhaven National Lab	< 5	(> 75)			20 - 30	(> 75)	10 - 20	(> 75)	50 - 75	(> 75)
DOE-Idaho National Engineering Laboratory	10 - 20	(10 - 20)	20 - 30	(10 - 20)	40 - 50	(10 - 20)			40 - 50	(10 - 20)
DOE-Lawrence Berkeley Lab	< 5		< 5		< 5		5 - 10	(10 - 20)	< 5	
DOE-Los Alamos National Lab	< 5	(0)							< 5	(0)
DOE-Pacific Northwest Lab	5 - 10	(10 - 20)	10 - 20	(10 - 20)	20 - 30	(10 - 20)	30 - 40	(10 - 20)	20 - 30	(10 - 20)
DOE-Sandia National Lab	< 5	(< 5)	< 5	(< 5)	5 - 10	(< 5)	< 5	(< 5)	< 5	(< 5)
DOT/FAA Technical Center	< 5	(< 5)								
DOT/FHWA Turner-Fairbank Highway Research Center	5 - 10		5 - 10				10 - 20		< 5	
DOT/FRA-Transportation Test Center	> 75	(> 75)								

table continued

TABLE 3.8 CONTINUED

AGENCY	Transportation		Water Resources		Energy Sources/Delivery		Buildings/ Structures		Waste	
DOT/RSPA Transportation Systems Center	50 - 75	(0)	< 5	(0)	5 - 10	(0)	< 5	(0)	5 - 10	(0)
EPA Engineering Laboratories			20 - 30	(5 - 10)					50 - 75	(30 - 40)
National Institute for Occupational Safety & Health							< 5	(< 5)		
National Oceanic & Atmospheric Administration			< 5	(< 5)						
National Science Foundation	< 5	(90)	< 5	(90)	< 5	(90)	50 - 75	(90)	5 - 10	(90)
Naval Academy	10 - 20				40 - 50	(10 - 20)	40 - 50	(10 - 20)		
Naval Civil Engineering Lab	< 5	(< 5)	5 - 10	(< 5)	5 - 10	(< 5)	20 - 30	(< 5)	10 - 20	(< 5)
NIST, Building & Fire Research Lab					5 - 10	(< 5)	40 - 50	(10 - 20)		
USDA-Agricultural Research Service			5 - 10	(< 5)						
USDA/ARS-Northern Plains Area			10 - 20	(0)						
USDA/FS Timber Bridge Information Resource Center	> 75	(> 75)								
USDA/FS-Forest Products Lab	< 5	(100)			< 5	(100)	10 - 20	(100)		
VA Rehab R&D Center							> 75	(5 - 10)		

TABLE 3.9

SUMMARY OF BUDGET ALLOCATIONS TO APPLICATION AREAS

AGENCY	PERCENT OF TOTAL BUDGET ALLOCATED TO										
	Equipment	Materials	Environment	Const. Mgmt.	Automation/ Robotics	Land Use	Natural Hazards		Non-destructive Eval.	Softw-are	Other
							Seismic	Other			
Air Force Civil Engineering Lab	10 - 20	5 - 10	40 - 50	< 5	5 - 10	< 5	< 5	< 5	< 5	< 5	< 5
Army Cold Regions Research & Engineering Lab		40 - 50	30 - 40			< 5			< 5		5 - 10
Army Construction Engineering Research Lab	5	5	35	10	1	20	4	2	1	15	2
Army Hydrologic Engineering Center	< 5	< 5	< 5	< 5	< 5	< 5	< 5	30 - 40	< 5	30 - 40	< 5
Army Institute for Water Resources			10 - 20					40 - 50		< 5	10 - 20
Army Topographic Engineering Center			1								
Army Waterways Experiment Station	10 - 20	30 - 40	40 - 50				< 5			10 - 20	
Bureau of Mines Albany Research Lab		50	40							10	
Bureau of Reclamation	20 - 30	30 - 40	50 - 75								
DOE-Argonne National Lab	< 5	10 - 20	20 - 30	< 5	< 5	< 5	5 - 10	< 5	10 - 20	10 - 20	< 5
DOE-Brookhaven National Lab		40 - 50	40 - 50						< 5		
DOE-Idaho National Engineering Laboratory	10 - 20	20 - 30	20 - 30		5 - 10	< 5	< 5		20 - 30	10 - 20	
DOE-Lawrence Berkeley Lab	20 - 30	20 - 30	20 - 30								5 - 10
DOE-Los Alamos National Lab		1 - 2	5		1			1	< 5	5	< 5
DOE-Pacific Northwest Lab	10	15	30		10	10			10		5
DOE-Sandia National Lab	< 5	20 - 30	20 - 30	< 5	5 - 10	< 5	< 5	< 5	< 5	5 - 10	< 5
DOT/FAA Technical Center	5 - 10	10 - 20	10 - 20	5 - 10					5 - 10	10 - 20	50 - 75
DOT/FHWA Turner-Fairbank Highway Research Center	< 5	5 - 10	5 - 10	< 5	< 5	< 5	< 5	< 5	< 5	5 - 10	
DOT/FRA-Transportation Test Center	40 - 50		10 - 20	30 - 40					< 5	< 5	
DOT/RSPA Transportation Systems Center	30	10	10	5	20	5		5	5	10	
EPA Engineering Laboratories			> 75								
National Institute for Occupational Safety & Health			> 75								
National Oceanic & Atmospheric Administration						10 - 20		> 75			
National Science Foundation	5	15	5	3	5		40	5	10	5	7
Naval Academy	10 - 20	10 - 20	10 - 20	10 - 20	10 - 20					10 - 20	
Naval Civil Engineering Lab	< 5	< 5	10 - 20	< 5	< 5	< 5	5 - 10	< 5	< 5	10 - 20	
NIST, Building & Fire Research Lab	5 - 10	10 - 20	5 - 10				10 - 20		10 - 20		
USDA-Agricultural Research Service						90					10
USDA/ARS-Northern Plains Area			20			80					
USDA/FS Timber Bridge Information Resource Center		75	5	5				5	5	5	
USDA/FS-Forest Products Lab		93	2						5		
VA Rehab R&D Center	15				10					10	65

TABLE 3.10
PERCENT OF AGENCY RESEARCH PERFORMED BY LOCATIONS

AGENCY	LOCATION					
	In-house	Other Labs	Academia	Industry	Research Institutes	Other
Air Force Civil Engineering Lab		30	5	30		
Army Cold Regions Research & Engineering Lab	90		7	3		
Army Construction Engineering Research Lab	25	10	45	15	5	
Army Hydrologic Engineering Center	80		10	10		
Army Institute for Water Resources	45	5	25	20	5	
Army Topographic Engineering Center	40	20	20	20		
Army Waterways Experiment Station	60		3	25		12
Bureau of Mines Albany Research Lab	100					
Bureau of Reclamation	85	5	5	5		
DOE-Argonne National Lab	95	5				
DOE-Brookhaven National Lab	90	3	3	3		1
DOE-Idaho National Engineering Laboratory	70		10	10	10	
DOE-Lawrence Berkeley Lab	80	10	10			
DOE-Los Alamos National Lab	90			10		
DOE-Pacific Northwest Lab	65	10	10	10	5	
DOE-Sandia National Lab	50	7	8	30	5	
DOT/FAA Technical Center	15	25	5	45	10	
DOT/FHWA Turner-Fairbank Highway Research Center	20	1	35	43	1	
DOT/FRA-Transportation Test Center	95		5			
DOT/RSPA Transportation Systems Center	35		5	55	5	
EPA Engineering Laboratories	20		20	60		
National Institute for Occupational Safety & Health	100					
National Oceanic & Atmospheric Administration	100					
National Science Foundation			90	10		
Naval Academy	70	30				
Naval Civil Engineering Lab	50	10	10	20	5	5
NIST, Building & Fire Research Lab	100					
USDA-Agricultural Research Service	95		5			
USDA/ARS-Northern Plains Area	80		10	10		
USDA/FS Timber Bridge Information Resource Center						100
USDA/FS-Forest Products Lab	95		5			
VA Rehab R&D Center	80	10	10			

TABLE 3.11
DISTRIBUTION OF EFFORT AMONG VARIOUS TYPES OF RESEARCH

AGENCY	PERCENT of RESEARCH			
	Basic	Applied	Demo	Other
Air Force Civil Engineering Lab	2	60	30	8
Army Cold Regions Research & Engineering Lab	5	85	10	
Army Construction Engineering Research Lab	10	75	10	5
Army Hydrologic Engineering Center		100		
Army Institute for Water Resources	10	80	10	
Army Topographic Engineering Center	40	60		
Army Waterways Experiment Station	25	50	25	
Bureau of Mines Albany Research Lab	80	20		
Bureau of Reclamation	5	85	10	
DOE-Argonne National Lab	30	70		
DOE-Brookhaven National Lab	80	10	10	
DOE-Idaho National Engineering Laboratory	20	70	10	
DOE-Lawrence Berkeley Lab	15	85		
DOE-Los Alamos National Lab		100		
DOE-Pacific Northwest Lab	10	80	10	
DOE-Sandia National Lab	15	40	25	20
DOT/FAA Technical Center	4	50	44	2
DOT/FHWA Turner-Fairbank Highway Research Center		85	10	5
DOT/FRA-Transportation Test Center	25	75		
DOT/RSPA Transportation Systems Center		60	30	10
EPA Engineering Laboratories	5	25	65	5
National Institute for Occupational Safety & Health		100		
National Oceanic & Atmospheric Administration		100		
National Science Foundation	90	10		
Naval Academy	30	70		
Naval Civil Engineering Lab	10	60	20	10
NIST, Building & Fire Research Lab	33	67		
USDA-Agricultural Research Service		95	5	
USDA/ARS-Northern Plains Area		100		
USDA/FS Timber Bridge Information Resource Center			90	10
USDA/FS-Forest Products Lab	98		2	
VA Rehab R&D Center	10	90		

TABLE 3.12
SUMMARY OF TECHNOLOGY TRANSFER PREFERENCES

AGENCY	RANK ORDER OF IMPORTANCE OF TECHNOLOGY TRANSFER METHODS (Rank order of methods - 1 is highest, 12 is lowest)											
	Licenses	CRDAs	CPAR	Presen-tations	Publica-tions	Work-shops	Demos	Displays	"800" lines	SBIR	Support Centers	Other
Air Force Civil Engineering Lab	3	1					4			2		
Army Cold Regions Research & Engineering Lab	8	7	4	5	2	3	1	6		10	9	11
Army Construction Engineering Research Lab	7	5	6	4	3	2	8	9	10	11	1	2
Army Hydrologic Engineering Center	12	12	12	2	1	3	12	12	12	12	12	1
Army Institute for Water Resources				2	1	3	4				5	
Army Topographic Engineering Center	7	6	5	1	4	2	3	8	12	11	10	9
Army Waterways Experiment Station	9	7	5	3	1	2	4	8		6		
Bureau of Mines Albany Research Lab	8	3	12	2	1	5	4	6	11	10	9	12
Bureau of Reclamation	4	1		5	2	7	6	3				
DOE-Argonne National Lab	5	2		3	1	7	4	6				
DOE-Brookhaven National Lab	3	4		2	1	5	6	7	10	9	8	
DOE-Idaho National Engineering Laboratory	2	1		5	4	6	7	3			8	9
DOE-Lawrence Berkeley Lab	5	4		2	1	3		6				
DOE-Los Alamos National Lab	2	1		4				5				3
DOE-Pacific Northwest Lab	1	2		6	5	4	3	7		8		
DOE-Sandia National Lab	2	1		4	3	6	7	8	9		5	
DOT/FAA Technical Center	6	1		4	5	3	7	8		2		
DOT/FHWA Turner-Fairbank Highway Research Center	9	8		5	3	4	1	7	10	6	2	11
DOT/FRA-Transportation Test Center												
DOT/RSPA Transportation Systems Center	8	7		3	4	1	2	5	9	6	10	11
EPA Engineering Laboratories	4	5		3	1	2	6	7	9	8	10	11
National Institute for Occupational Safety & Health	6	7		2	1	3	10	8	4	9	5	11
National Oceanic & Atmospheric Administration				2	1	4	3	5		6		
National Science Foundation				2	1	3				1		
Naval Academy		3		2	1				4			
Naval Civil Engineering Lab	2	1		5	3	4	7	8	10	6	9	11
NIST, Building & Fire Research Lab	4	3		1	5	2		6				
USDA-Agricultural Research Service	4	3		2	1	5	7	6				
USDA/ARS-Northern Plains Area	8	6		1	3	7	5					
USDA/FS Timber Bridge Information Resource Center				5	3	2	1	6		7	4	8
USDA/FS-Forest Products Lab	2	1		5	4	3	6	7				
VA Rehab R&D Center	1	1		2	2		2	2		3		

TABLE 3.13
FREQUENCY OF USE OF SELECTED TECHNOLOGY TRANSFER METHODS

AGENCY	NUMBER OF USES OF SELECTED TECHNOLOGY TRANSFER METHODS				
	License	CRDA	Workshops	SBIR	Demos
Air Force Civil Engineering Lab	1 - 2	3 - 5	3 - 5	> 15	> 15
Army Cold Regions Research & Engineering Lab	1 - 2	> 15	> 15	10 - 14	> 15
Army Construction Engineering Research Lab	3 - 5	3 - 5	> 15	> 15	> 15
Army Hydrologic Engineering Center	None	None	> 15	None	6 - 9
Army Institute for Water Resources			> 15		
Army Topographic Engineering Center	None	1 - 2		None	
Army Waterways Experiment Station	None	13*	> 15	10 - 14	> 15
Bureau of Mines Albany Research Lab	1 - 2	3 - 5	6 - 9	None	6 - 9
Bureau of Reclamation	3 - 5	10 - 14	1 - 2	None	1 - 2
DOE-Argonne National Lab	20	30 - 40	25		> 15
DOE-Brookhaven National Lab	> 15	1 - 2	> 15	1 - 2	> 15
DOE-Idaho National Engineering Laboratory	6 - 9	10 - 14	3 - 5	None	1 - 2
DOE-Lawrence Berkeley Lab	10 - 14	6 - 9	> 15		
DOE-Los Alamos National Lab	5 - 10	50	> 15		
DOE-Pacific Northwest Lab	> 15	> 15	> 15	1 - 2	> 15
DOE-Sandia National Lab	< 50	60	100	> 15	> 100
DOT/FAA Technical Center	1 - 2	> 15	3 - 5	> 15	3 - 5
DOT/FHWA Turner-Fairbank Highway Research Center	None	None	> 15	> 15	> 15
DOT/FRA-Transportation Test Center	None	None	None	None	None
DOT/RSPA Transportation Systems Center	None	1 - 2	> 15	10 - 14	> 15
EPA Engineering Laboratories	10 - 14	> 15	> 15	1 - 2	6 - 9
National Institute for Occupational Safety & Health	1 - 2	1 - 2	6 - 9	6 - 9	None
National Oceanic & Atmospheric Administration	None	None	10 - 14	1 - 2	> 15
National Science Foundation			> 15	> 15	
Naval Academy	None	1 - 2	1 - 2	None	None
Naval Civil Engineering Lab	3 - 5	3 - 5	> 15		> 15
NIST, Building & Fire Research Lab	1 - 2	6 - 9	> 15	None	None
USDA-Agricultural Research Service	> 15	> 15	> 15		
USDA/ARS-Northern Plains Area	1 - 2	3 - 5	1 - 2	None	3 - 5
USDA/FS Timber Bridge Information Resource Center			10 - 14		10 - 14
USDA/FS-Forest Products Lab	3 - 5	40			
VA Rehab R&D Center	1 - 2	3 - 5		None	

* CPAR

APENDIX D

LIST OF ACRONYMS

ACIR	Advisory Commission on Intergovernmental Relations
ARS	Agricultural Research Service
ASCE	American Society of Civil Engineers
CEL	Civil Engineering Laboratory
CERF	Civil Engineering Research Foundation
CERL	Civil Engineering Research Laboratories
COE	Corps of Engineers
CRDA	Cooperative Research and Development Agreement
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FCC	Federal Construction Council
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FLC	Federal Laboratory Consortium
FRA	Federal Railroad Administration
GDP	Gross Domestic Product
GNP	Gross National Product
GSA	General Services Administration
HUD	Department of Housing and Urban Development
IWR	Institute for Water Resources
NCPWI	National Council for Public Works Improvement
NIST	National Institute of Standards and Technology
NRC	National Research Council
NSF	National Science Foundation
OTA	Office Technology Assessment
PWI	Public Works Infrastructure
RSPA	Research and Special Programs Administration
USDA	United States Department of Agriculture
WES	Waterways Experiment Station

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 1993	

4. TITLE AND SUBTITLE
The Federal Infrastructure Strategy Program - Federal Works Infrastructure R&D: A New Perspective

5. FUNDING NUMBERS

6. AUTHOR(S)
Carl O. Magnell

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Civil Engineering Research Foundation
1015 15th Street, N.W., Suite 600
Washington, DC 20005

8. PERFORMING ORGANIZATION REPORT NUMBER
CERF Technical Report Series- Report Number - 92-F1003

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Institute for Water Resources
Casey Building
Fort Belvoir, VA 22060-5586

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
IWR Report 93-FIS-5

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report provides the Federal Infrastructure Strategy Initiative with a "snap-shot" in time of Federal resources committed to infrastructure research and development (R&D). Resources are defined as levels of funding, and the number of Federal laboratories engaged in infrastructure related R&D. This is the fourth in a series of interim reports prepared to support the Federal Infrastructure Strategy Initiative, a 3-year program to explore the development of an integrated multi-agency Federal infrastructure strategy.

14. SUBJECT TERMS
Infrastructure, engineering, innovation, public works, research and development, Federal funding

15. NUMBER OF PAGES
97

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited