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Policy Studies

Budget Constraints and Decision Making:

Development of Policy Guidelines for Planning of Civil Works Programs and Projects

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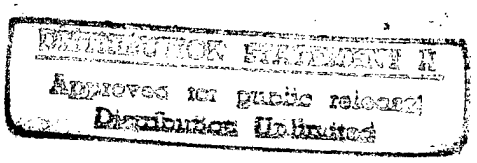

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19980126 041

NOVEMBER 1997

IWR REPORT 97-PS-1

TABLE OF CONTENTS

EXECUTIVE SUMMARY vii

INTRODUCTION 1
What To Do and When To Do It: Objectives of This Study 1
Background and Definitions 1

FROM THE HISTORICAL RECORD 3
Where Does the Concern over Budget Constraints Come From? 3
What About Construction Activities? 5

WHAT CAN BE DONE IN THE EVENT OF SEVERE FEDERAL CONSTRAINTS? 7
Demand for Water Resources Projects 7
Will the Current Rule of Maximizing Net Benefits Still Be Valid? 10
Does "First Come, First Served" Remain an Appropriate Allocation Approach 13

WHAT STEPS CAN BE TAKEN AT THE DISTRICT LEVEL TO ACCOUNT FOR FEDERAL BUDGET CONSTRAINTS? 17
Institutionalize current ad hoc approaches 17
Develop a partial funding approach 18

HOW CAN NATIONAL WELFARE OBJECTIVES BE MAXIMIZED? 21

CONCLUSIONS 25

REFERENCES 27

APPENDIX A: Historical Trends in Civil Works Appropriations A-1

APPENDIX B: Cost Sharing Trade-off Model B-1

APPENDIX C: Case Studies Demonstrating Integer Programming for Optimum Plan Selection C-1

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LIST OF FIGURES AND TABLES

LIST OF FIGURES

Figure 1 Civil Works Appropriations 3
Figure 2 Civil Works Appropriations--1995 Dollars 6
Figure A-1 Civil Works Appropriations A-1
Figure A-2 Price Indices A-4
Figure A-3 Civil Works Appropriations A-5
Figure A-4 Civil Works Appropriations--Percent of Federal Budget and GDP A-6
Figure A-5 Civil Works Appropriations--Current Dollars A-7
Figure A-6 Civil Works Appropriations--Investigations as % of Construction A-8
Figure A-7 Civil Works Appropriations--1995 Dollars A-8
Figure A-8 Civil Works Appropriations--Category Percentages A-9
Figure B-1 Trade-Off Between Costs and Benefits B-3

LIST OF TABLES

Table A-1 Budget Data A-11
Table A-2 Appropriations by Category A-13
Table A-3 GDP Deflators A-14
Table C-1 Data for Hypothetical Case C-1
Table C-2 Results for Hypothetical Case C-3
Table C-3 Data for Sioux Falls C-5
Table C-4 Results for Sioux Falls C-6

EXECUTIVE SUMMARY

The purpose of this policy study is to determine how the Corps' various planning, development and maintenance programs, the selection of Corps projects, and the decision making criteria regarding these programs and projects should adjust to the prospect of increasing budget constraints. The fundamental research question was: *How will severe Federal budget constraints affect the way in which the Corps plans and recommends projects?* A corollary question was: *How imminent do any required changes in Corps procedures seem?*

There are two main conclusions from this policy study, proceeding from the two research questions above. The first conclusion relates to selection of alternative plans. If Federal budget constraints become truly binding, then selection of plan alternatives for all projects will have to be done at the national level. The decision rule of recommending a project alternative which maximizes net benefits will not lead to national optimality in the face of Federal budget constraints. The nationally optimal selection of projects will require interproject economic comparisons so that the most cost beneficial alternatives are constructed. The information needed to make final recommendations on projects will not be available during the plan formulation and evaluation process. Plan elements and alternatives will have to be referred to a central authority for evaluation and selection based on criteria developed from data on budgets and funding availability.

Two methods for selecting plan alternatives were identified in this study. First, a cut-off benefit-cost ratio, which can be determined from an analysis of projects actually under construction, may be used to screen out projects with inadequate returns. Second, a mathematical programming approach could be used to optimize economic efficiency at the national level.

The second conclusion of this study answers the corollary question of how imminent truly binding Federal budget constraints might be. There is little evidence that binding Federal budget constraints have had a significant impact on the Corps' Civil Works program, the policies which guide it, or the water resources projects selected for construction. This conclusion is based on the historical record of appropriations, the fact that little construction backlog was found which was due to unavailable Federal funds, and the fact that a decision rule of benefits exceeding costs has been used, without serious problems in allocation of Federal funds, for an extended period of time. This does not mean that there are not constraints on the Civil Works program. It is just that these constraints are, at the Federal level, non-economic. The local sponsor may be constrained both economically and otherwise. It is probable that the truly binding constraints on the Civil Works program have been the local economic ones; this hypothesis deserves further study. Also, if the Federal government does actually take the steps necessary to balance the Federal budget, the Federal budget constraint is likely to become the most binding one. Although action to change planning policies does not appear necessary in the near future, the effects of current efforts to balance the Federal budget should be closely monitored to ensure appropriate changes can be put in place effectively, if and when required.

Budget Constraints and Decision Making: Development of Policy Guidelines for Planning of Civil Works Programs and Projects

INTRODUCTION

What To Do and When To Do It: Objectives of This Study

Does the Corps' planning process need any adjustments in the event of severe Federal budget constraints? How serious will these constraints be on the Civil Works program? What should be the direction and pace of development of policy guidelines for planning under severe Federal budget constraints?

Availability of funds is always a concern to any government agency. Appropriated money allows the agency to provide its services to the public. Concern within the Corps has been heightened by real declines in appropriations since 1973, no doubt exacerbated by FY95 appropriations. That year's appropriations of $3.3 billion were nearly 10% less than the FY94 level.

Heightened concern prompted this policy study to consider the questions raised above. The fundamental research question was: ***How will severe Federal budget constraints affect the way in which the Corps plans and recommends projects?*** A corollary question was: ***How imminent do any required changes in Corps procedures seem?*** This second question spawned a review of historical Civil Works appropriations. The historical record provides context for the full study, so the second question is the first to be investigated.

Background and Definitions

One problem central to any type of investing, private or public, is the portfolio problem. Each individual investment has performance characteristics, but decisions have to be made about

the portfolio or group of individual investments to choose to satisfy overall performance objectives. For example, investors in the stock market assess how individual companies will perform under various market conditions, then select a group of stocks, their portfolio, to maximize return given their risk aversion and their prognosis for future market conditions. For the Corps, individual projects have benefits and costs, but if not all projects can be funded then different subsets of those projects will affect national welfare differently.

The Corps' portfolio is defined, for this study, as all projects completed and in place plus the group of projects authorized and funded for construction. It is the sub-group of the projects authorized and funded for construction in a given year or budget cycle that is the subject of this study. This will be referred to as the annual increment to the portfolio. As an accounting point, this annual increment is not identical to items included in the Civil Works construction appropriation. It includes traditional new starts of authorized projects, plus rehabilitation projects, construction on Mississippi River and tributaries (MRT) projects, and any operations and maintenance (O&M) work of a capital nature.[1] Being funded for construction (with the assumption of project completion), rather than the investigation or authorization steps, is the relevant point in the process for a study of budget constraints. It is only upon construction that the investment is able to perform and provide benefits to the Nation. Also, in analyzing budget effects, it is important to follow the flow of the bulk of the program's money. The aspects of the Civil Works program which add to the Corps portfolio are budgetarily more significant than other areas, such as investigations, regulatory, or what is spent on operations and annual maintenance.[2]

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[1]A significant part of the O&M budget seems to have the characteristics of capital spending, that is, work performed only periodically which is expected to have a useful life of several years. Examples might be confined disposal facilities (CDF) for materials dredged from navigation channels or paving of roads and parking lots in recreation areas.

[2]Construction of new projects drives increases in the O&M portion of the Corps' budget. For the most part, O&M of existing projects is committed. As a result, decisions to construct or to not construct new projects have both direct and indirect effects on controlling the budget. One approach to decreasing the proportion of the Corps' budget dedicated to O&M is the divestiture of Federal projects to other governmental units or to private enterprises. Consideration of the indirect effects of Civil Works construction and approaches to controlling it are beyond the scope of this study, but they are suitable subjects for future research.

FROM THE HISTORICAL RECORD

Where Does the Concern over Budget Constraints Come From?

Figure 1 depicts the history of appropriations to the Corps' Civil Works program. (See Appendix A for an overview of Corps budget history.) Does the present concern about shrinking

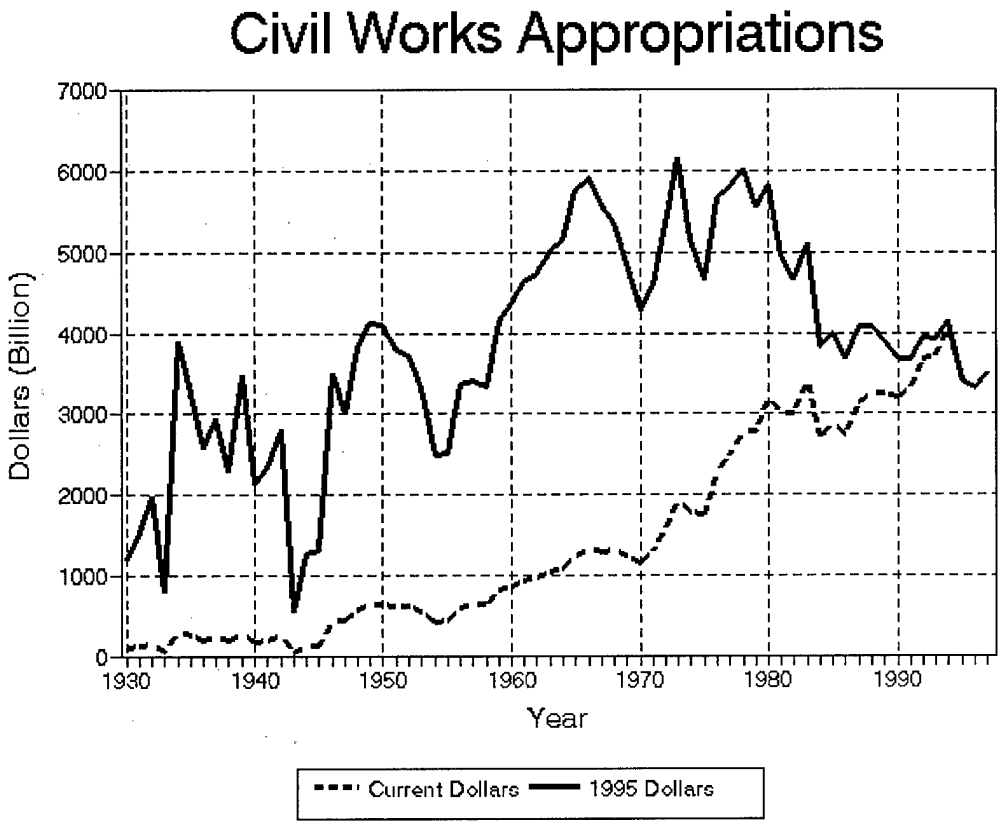

Figure 1. Civil Works Appropriations

Civil Works budgets come from historical trends? As Figure 1 shows, the Corps' Civil Works budget, in real terms, is now just over half of what it was at its peak in 1973. In 1983, it was over five billion dollars, compared with 3.5 billion in FY97. To some observers, this represents an ominous trend for the Corps.

This view appears to take history out of context. In real dollar terms, the Civil Works program is approximately the same size it was 35 years ago. There have been years with sharp

increases and sharp decreases over that interval, and Civil Works purchasing power was significantly higher in the 1960s, 1970s, and early 1980s. Since the mid 1980s, appropriations in real terms have been fairly stable. The ten percent drop in FY95 appropriations was noted above, but the FY97 budget is back above the FY95 level. There has been relative stability since about 1984, and a more holistic view of history says that this trend is probably the best budgetary history upon which to rely.[3] The relative stability in this period, if extrapolated into the future, does not occasion undue concern. Projections contained in the President's FY98 budget support this view.[4]

Because Corps projects respond to local initiatives, there is not explicit interproject economic comparisons. All projects with net economic development benefits are considered justifiable and, if they remain consistent with Federal and local policy, could be funded and built.[5] Historically, there is no evidence that budgets have been more than temporary constraints on project funding, so Federal budget constraints do not seem to have played a significant role in portfolio decisions in Civil Works.

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[3]Two events of historical significance to the Civil Works program seem to support greater reliance on trends since 1984. First, the Principles and Guidelines (P&G) used to evaluate water resources projects were promulgated in 1983 and affected projects considered thereafter. Second, the passage of the Water Resources Development Act of 1986 (WRDA86) significantly changed cost sharing and other policies which affect planning of water resources development. These two events changed, to some degree, the rules under which the Civil Works program operates.

[4]The FY98 Budget of the President calls for water resources appropriations to the Corps of Engineers as shown in this table:

Year	1998	1999	2000	2001	2002
Million $	3,671	3,305	3,342	3,273	3,306

These projected appropriations occur over the time interval during which the Administration proposes to eliminate the Federal deficit, which otherwise might lead to an expectation of sharply declining budgets.

[5]Benefit-cost analysis has been used to both justify and evaluate projects. The former is relative to requirement of the Flood Control Act of 1936. The latter influences project selection. Eckstein [1961] writes, "the Budget Bureau and the Congress, while perhaps considering this hurdle of economic justification to be a necessary preliminary step, are free to place their stamp of approval on any 'justified' project, and will be free to make the actual choice on political grounds. In practice, the rate at which benefits exceed costs, as expressed by the ratio, also has an important influence on the choice of projects....participants in the long decision process will tend to favor 'good' projects over dubious ones, and will weigh the economic merit along with the other determinants. Thus the benefit-cost analysis serves both for justification and for relative evaluation of projects." (p. 47-48)

This is not to say that current concern over Federal budget constraints is misplaced. However, the basis for concern is not the trend of past Corps appropriations. Rather, the concern seems due to projecting the ramifications of current political discourse regarding future Federal budgets. Stated goals of Congress and the Administration to balance the Federal budget by 2002 will, if attained, shrink Federal programs significantly. Domestic discretionary expenditures, in which Corps funding is found, will be trimmed disproportionately.[6] Competition for funding may become intense, and will likely threaten the existence of a number of agencies. In the face of such severe future cuts, past experience will not be especially helpful in creating coping mechanisms.

It is not certain that there will remain the political will to meet stated budgetary goals (and here history suggests past accords on austerity have not carried much weight). However, it is not the purpose of this study to predict the probability that budgetary goals will be met. The only conclusion here is that the probability is high enough to warrant preparing to meet the eventuality (which is the main purpose of this study), but low enough that no immediate action is necessary.

The potential of a new budgetary order seems to provide a reasonable basis for preparing to work within these possible budget constraints, recognizing that any implementation would be at some future time.

What About Construction Activities?

While the concern over Corps budget constraints comes from prospective rather than historical trends, the construction budget has been shrinking over time. Figure 2 illustrates the trends. In the 20 years since 1977, construction funding, in real terms, has declined by 67%. The Corps has been building water resource projects for almost a century and a half. The impressive inventory of completed projects now requires significant resources to operate and maintain. As shown in Figure 2, the O&M budget has been growing over the last two decades, surpassing construction as the largest budget category in 1983. O&M claimed more than half of

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[6]Domestic discretionary funds make up approximately 16% of the Federal budget, about $266 Billion in 1996. Covering current deficits in the order of $150 to $200 Billion is clearly a larger proportion of the discretionary funds than of the total budget.

the Civil Works budget in FY96. By almost any measure, funds for construction, in real terms, have fallen off, but the downward trend has abated considerably since 1983.

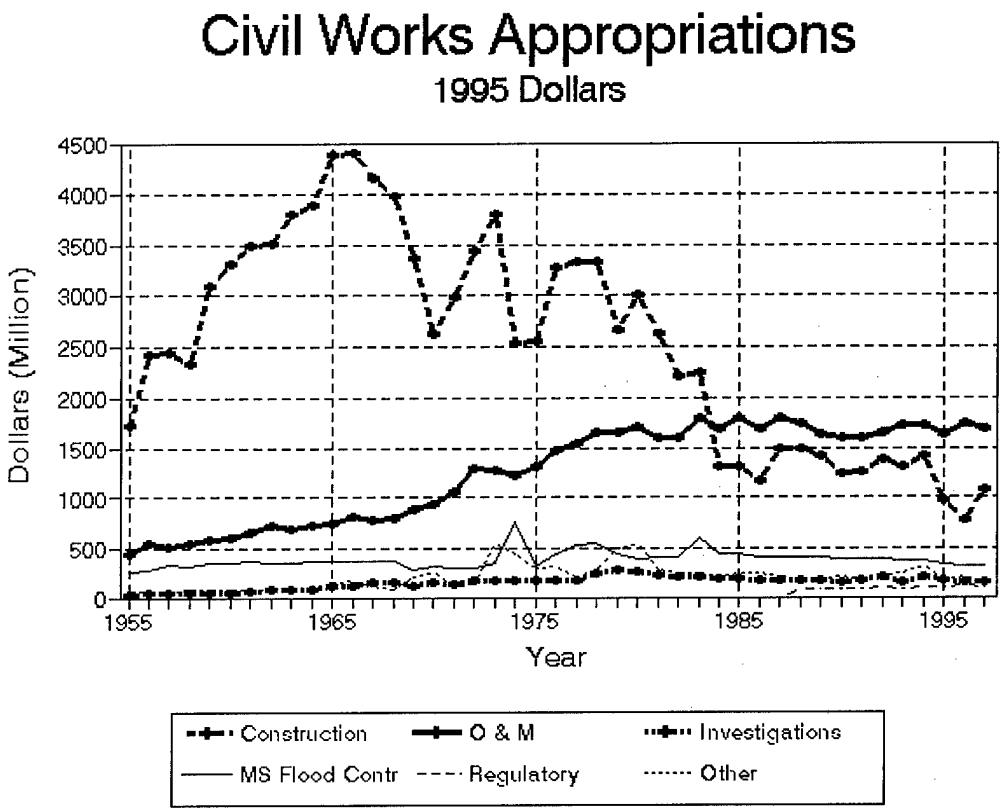

Figure 2. Civil Works Appropriations--1995 Dollars

As with the total appropriations, the historical record does not necessarily provide the basis for predicting future trends. The Office of Management and Budget (OMB) wrote in a Statement of Administration Policy dated July 30, 1996 that, "actual appropriations for ongoing Corps construction projects and priority new starts are likely to be approximately $1 billion for the foreseeable future." [Office of Management and Budget 1996] The President's Budget for FY98 includes $380 million for new construction starts (FY98 marks a shift to full funding up-front for new construction). The future of Corps construction is not unambiguously evident, and only time will tell the direction of the program.

WHAT CAN BE DONE IN THE EVENT OF SEVERE FEDERAL CONSTRAINTS?

The primary question of this policy study is: What can the Corps do to modify its planning process if Federal budget constraints become severe? The discussion starts with some theoretical and practical reasons why modification of the planning process may be required. This is followed by some interim steps which the Districts could be directed to employ as Federal budget constraints become binding. Finally, the steps required to select a nationally optimal group of water resources projects are outlined.

The historical review concluded that Federal budget constraints are not currently the ones binding the Civil Works program. The prospect of such constraints looms, depending on actions in the political arena. At what point would the Federal budget be considered binding? This question leads to a consideration of demand for Corps Civil Works projects.

Demand for Water Resources Projects

Nothing happens in water resources development, or any other economic activity, without preferences and resources to satisfy them. Preferences and resource constraints are intimately and inseparably linked in establishing the level of demand for goods and services in an economy. For the Corps, have constrained budgets limited its ability to build desired projects? Contrarily, has lack of demand for water resources development lead to lowered budget requests?

To answer these questions, it is necessary to look at the backlog of projects. If the budget had been limiting, one would expect a significant backlog to have developed. Local sponsors would have been identifying needs and requesting Corps assistance. However, with the exception of certain shore protection projects,[7] there is no backlog of projects awaiting General Investigation or Construction initiation. The existing backlog is essentially the function of the time required to complete multi-year construction projects. This means the cause of the decrease in construction funding must be attributed to decreased demand for Corps outputs.

Why has the demand fallen off? Demand, as noted above, is a function of preferences for a good and the resources available with which to purchase it. Is decline in demand for Corps

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[7]This backlog of shore protection projects may be due in part to Administration policy unrelated to the budget.

outputs due to changes in desirability or a change in affordability? The population of the United States, and its affluence, is increasing, but other changes are also occurring in the society. These affect each of the traditional Corps mission areas.

In flood damage prevention, despite projects constructed and attempts to limit floodplain development, annual flood damages have been increasing [Department of the Army 1995]. New development has occurred near streams,[8] and the value of existing properties has risen. The increase in expected annual damages is an indication of increased "need" from which increased demand could be expected. However, the resource constraint, for the local sponsor as well as for the Corps, must also be considered. Investments in flood control provide a diminishing marginal rate of return, if one assumes that the most cost-beneficial projects have already been built. This increases the price of flood protection. Another factor which increases the price of protection to the local sponsor is cost sharing.[9] These price increases decrease demand for flood loss reduction.

Demand for environmental protection has been increasing. To the extent that flood control projects are seen as hurting the environment, preferences and thus demand for them will decline (economic substitution based on opportunity cost). Actual change in demand is determined by a combination of these forces and can only be determined empirically. A decrease in demand due to societal preference changes and the affordability of protection to local sponsors could explain the decrease in Corps construction spending.

The same forces are at work in most other Corps mission areas, such as hydropower, water supply, recreation and other Corps outputs. Demand could be expected to follow the growth of population and of the economy. Prices, technology (including changes in environmental regulations), and substitution could trim demand.

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[8]Some of this floodplain development is economically justified, where the activity depends on proximity to the water as the basis for productivity and profitability. However, floodplain regulations are not in place everywhere, and existing regulations, due to coverage and degree of enforcement, are not completely effective in controlling development. Moreover, substantial development is occurring just outside regulatory floodplains (i.e., just outside the 100 year floodplain limits).

[9]An increase in local share of cost for most flood damage prevention projects from 25 to 35 percent was included in WRDA 96.

Demand for Corps outputs is affected by social preferences and available resources, but is also actively managed by the Federal government. Legislated program constraints such as cost sharing, up front financing, and a high discount rate relative to market rates are Congressional demand management. The Administration, through OMB, institutes policies to shift demand. Various limiting criteria have been imposed, for example:[10]

- Budget funds only for those projects having a benefit-cost ratio greater than 1.2, rather than 1.0. This screen excludes otherwise economically justifiable projects. Projects in question have been optimized based on net benefits, not on benefit-cost ratios.
- Require projects to have benefit-cost ratio of at least 1.0 at a discount rate substantially higher than the currently applicable "normal" rate (e.g, 10% instead of 7⅝%). This screen favors projects with relatively greater return in earlier years of project life versus return dependent on long term economic growth.
- Require projects to have benefit-cost ratio of at least 1.0 with separable recreation benefits and costs excluded.
- Require voluntary contributions by non-Federal sponsors. (An example has been confined disposal facility construction costs for certain harbor projects) This approach introduces bias against less affluent communities, and breaches implied commitments.

Administration measures to shift demand tend to be done on an ad hoc basis, sometimes open to criticism that a temporary "budgetary policy" tends to be in contradiction of general policies, and may be counterproductive over the long term.

The inseparability of preferences and resource constraints in setting demand will always be a problem in considering the ramifications of budget levels. Ultimately, it is a matter of judgement whether preferences or resources are the limiting factor. This study concludes that preferences are controlling at the Federal level. However, the budget constraint may be the binding constraint for the local sponsor. How might this constraint enter the decision process? NED is a measure of national benefits, and it is the objective to be maximized by the Federal water resources agencies under the P&G [Water Resources Council 1983]. However, it is not the

[10]Ultimately, however, these constraints do not appear to have significantly affected eventual appropriations.

only criterion to be considered in water resources development decisions. Regional effects are important in decision making, and the P&G recognizes this in distinguishing the RED and OSE accounts and enumerating criteria of completeness and acceptability. Local acceptability will depend on a variety of factors, but it will necessarily be a function of funding availability in the budget of the local sponsor. The importance of regional issues, particularly the limitations of local funding, has grown with the requirement for increased cost sharing instituted by WRDA86[11]. Sponsors will allocate their resources to optimize benefits to citizens of the region. They will substitute benefits from, for example, flood damage prevention with those from other sources, based on their relative opportunity costs.

Budget history shows the Federal budget has not been a significant constraint on development of water resources projects. There have been periods when ad hoc adjustments, such as modified discount rates, added cost share, or delayed implementation, were made. However, locally desired projects have historically been approved and paid for at the scale recommended. What is occurring is that the local budget constraints have been more binding than the Federal. How can the local budget constraint enter the Corps' planning process? It enters during the scoping process through the application of the acceptability criterion.[12]

Will the Current Rule of Maximizing Net Benefits Still Be Valid?

The rule of maximizing net benefits in the Federal planning and selection of projects will continue to identify an optimal portfolio of projects as long as it is the local budget constraint which is binding. The correct criterion in all cases is that the benefits per last dollar spent should be equal for all projects. The NED maximizing criterion is the special case where that equality happens to occur at a ratio of 1.0 because there are sufficient Federal funds to pursue all projects meeting that requirement. The conditions for this special case may not exist if the Federal budget constraint becomes the binding one.

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[11]Language in WRDA96 increases local cost sharing for most flood damage reduction projects from 25% to 35%.

[12]Plans which lead to projects by definition satisfy local budget constraints. However, in cases where an NED plan devised by the Corps prompts the local sponsor to withdraw from the project because it is too expensive, there is an indication that the local constraint was not adequately considered.

The effects of budget constraints are illustrated by a model which considers two agents, the Federal government (through an agency such as the Corps) and the local sponsor. Benefits arise from the total expenditures of both, and each is constrained by respective budgets. If neither budget constraint is binding, the marginal cost should equal the marginal benefit for each agent. This is the theoretical model underlying the rule of maximizing net benefits. If a constraint is binding, the marginal benefits of individual projects must exceed the marginal costs by some factor, increasing with the tightness of the limitation. The benefit-cost ratio must be enough greater than one that some marginal benefits must be foregone, meaning net benefits are not maximized.

The model extends the analysis of Eckstein [1961][13] Welfare is a function which subtracts the cost of a project, C, from the social benefits, B, added by it:

$$\Delta W = B - C$$

However, benefits and costs of a project are related through the production function. The formula for welfare change is then:[14]

$$\Delta W = B(C) - C$$

This makes intuitive sense because benefits are being purchased by the project costs.[15] Welfare

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[13]The analysis proceeds under normal economic assumptions. These are that a change in welfare is equal to the sum of the changes in utility of the individuals in the society and that the marginal utility of income is equal for all individuals.

[14]Eckstein [1961] makes this point explicitly in his technical notes on the benefit cost criterion (pp. 73, 75).

[15]More expenditures will lead to more benefits. Project specific conditions, the production function, must be known to determine how much benefit comes from a given expenditure. Benefits cannot be infinite, and it is the budget constraints of individuals within the society which limit their utility and thus the welfare improvement from a project. It is important to recognize and remember that benefits are not independent of costs. A change in project expenditure will change benefits in two ways. First, through the production function, a different bundle of benefits will arise. Second, through individual utility functions and the effect of project expenditure on individual budget constraints, there is a trade off between flood damage prevention benefits and other sources of utility.

is maximized by maximizing the Lagrangian, Ψ:

$$\Psi = B(C_f, C_s) - C_f - C_s - \mu(C_f - D_f) - \lambda(C_s - D_s)$$

where:

B = *Benefit*
C = *Cost*
D = *Funding Available*
f = *Federal*
s = *Local Sponsor*
λ, μ = *Lagrange Multipliers*

There are two cases of interest. The first assumes that the budget constraints are not binding, that is, $C = D$. The second case is one with constraints, such that $C > D$. In the first case, assuming the second order conditions are met, the first order maximum conditions are:

$$\frac{\partial B}{\partial C_f} = 1$$

and

$$\frac{\partial B}{\partial C_s} = 1$$

Marginal benefits will equal marginal costs. This occurs when net benefits are maximized, because then every possible component which is cost-beneficial will have been included in the project.

Now consider the second case. Adequate funds are not available, $C > D$. Again, assuming the second order conditions are met, the first order maximum conditions are:

$$\frac{\partial B}{\partial C_f} = 1 + \mu$$

and

$$\frac{\partial B}{\partial C_s} = 1 + \lambda$$

Thus if both the Federal and local authorities are facing budget constraints, the marginal benefits must exceed the respective costs by some factor related to the tightness of the constraint. If only one of the parties has a budget constraint, they will use different decision rules. This case is discussed further in a later section.

One insight of this model is that there will be a trade off between local and Federal preferences which varies depending on the fraction of cost sharing, the scale of the project, and the tightness of the respective budget constraints. For example, a local sponsor with a budget constraint would respond only to local benefits (monetary and non-monetary) and select a different (presumably smaller) plan than a Federal agency would design. This point is explored further in Appendix B.

Does "First Come, First Served" Remain an Appropriate Allocation Approach?

The Corps has historically left portfolio decisions to the "first come, first served" approach.[16] This means water resources problems were tackled in the order in which they were identified by local sponsors. No serious and lasting budget-induced backlog of projects, for

[16]This is true for economic analysis. Other factors affect the decision, such as the criteria of completeness and acceptability, the need to protect the environment, and the allocation of certain costs to the locals. Judgements based on these other factors are not made in ignorance of economic analysis; projects with dubious economic justification may be sorted out by the other factors.

investigation, for authorization, or for construction, has occurred, so all projects reported favorably could be authorized and constructed. (Of course, not all were, but Federal budget constraints were not why.) With no backlog, the "first come, first served" approach functioned well enough.

There is a question of what assurances there are that the best projects have been done. Theoretically, project order should follow the locus of points tracing out the diminishing marginal rate of return of the sequence. Measurement and proof that the order has been rational is difficult. However, local sponsors with the biggest problems would be expected to request assistance first. Assuming all else equal, the biggest problems are opportunities for the greatest returns. Thus it may well be that the best projects were done first. Two other ways of answering this question lend support to this conclusion. First, the decisions to authorize and fund projects are ultimately political ones. Public choice theory frequently assumes optimality of such political outcomes. Second, professional judgement, both within the Corps and in political institutions, has probably been effective in promoting the public welfare. Thus, while the historical correlation between "first come, first served" and socially optimal is not assured, the case for it appears strong.

Now consider that the budget constraint becomes binding. How does "first come, first served" perform? Demonstrating its fallibility only requires finding a hypothetical case in which it does not give the efficient result. Such a case is easily found. Assume three projects of equal cost, but different benefit cost ratios (all over one). Also assume budget constraints allow funding of only two projects. Assume that the project with the lowest benefit cost ratio is the first to seek approval and funding. If no interproject comparison is done and this first project is constructed based on its promise of positive NED benefits, then the national welfare is not maximized.

The failure of "first come, first served" to achieve efficiency is not its only potential short coming. An acceptable geographical and jurisdictional dispersal of projects is important to maintain the currency and relevance of the Corps' mission and to retain political support for the Civil Works program. As long as all justified projects could be funded, all regions and lower levels of government had access to the program. It would be hard to believe a perception of

fairness could be kept if those at the end of the queue were refused consideration. It is easier to believe that the Corps planning process would be pressed to become a race to funding. Another less obvious but perhaps more distressing problem with the "first come, first served" approach would be in the credibility of Corps commitments, implied or otherwise, to local sponsors. This approach would continue existing planning processes, but projects entering the system after available funds were completely allocated would not be constructed. Local sponsors will have expectations that, having participated in the planning and paying toward the Feasibility Study phase, their project should be built if it is justified. This is not an unreasonable expectation, even if not legally enforceable.[17] Political support for the Civil Works program would be inclined to fade if the expectations of too many local sponsors are dashed after a cost-beneficial project has been identified.

However, these undesirable effects of "first come, first served" are not likely to have much practical effect. They are based on the assumptions that Corps budgets are cut significantly and that the entire planning process remains unaltered. If Corps budgets become so constrained that the effects described above are evident, then there will almost certainly be changes in the processes for planning and selecting projects for construction. Possible directions for these changes are the subject of the next two sections of this report.

[17]Any unmet local expectations could provide an incentive for Congress to increase construction funding, either by increasing Corps approriations or by shifting money from O&M.

WHAT STEPS CAN BE TAKEN AT THE DISTRICT LEVEL TO ACCOUNT FOR FEDERAL BUDGET CONSTRAINTS?

As shown in the previous section, binding Federal budget constraints will require interproject comparisons in order to achieve a nationally optimal selection of plan alternatives. The information to do this will not be available until individual studies are available for interproject comparisons. However, if a nationally optimal approach, such as described in the next section, is not adopted, there may be ways in which better decisions can be made at the project level. Two ways are discussed below.

Institutionalize current ad hoc approaches

A number of ad hoc requirements have been included in past guidance for annual budget preparation. These have included:

- requiring justification at a higher (10%) discount rate
- requiring a voluntary additional contribution from local sponsors
- requiring certain priority outputs at certain levels.

These could be promulgated as permanent policy. The intent of each is either to increase the share of project costs borne by the local sponsors or to make the project less desirable to the sponsor, both of which will decrease interest in flood damage prevention projects and thus lessen demand for funding. There are problems associated with these approaches. First, the ability of distressed communities to afford protection would be decreased, requiring additional recourse to "ability-to-pay" regulations (which in turn might counteract the effects of these policies). Second, higher discount rates may shift recommended plans to those with lower capital cost and higher O & M costs (with obvious ramifications for types of Corps expenditures).

Other techniques to modify budget processes could also be used. A narrower definition of the Federal interest could be promulgated, thus focusing the reduced funding but allowing all projects meeting the new definition to be built. A "gatekeeper" function could be added to the start of the Corps planning process. This would, based on some budget forecast, allow a feasibility study to be initiated only if funding for the project is in the budget forecast. (This approach might not optimize the selection of projects, depending on the criteria judged by the gatekeeping decision rules.)

All the ad hoc approaches share an additional problem. As noted above, projects screened out would probably still be pursued by the local proponents. The potential for perverse incentives will be created or enlarged, and this could lead to rent seeking behavior.[18] Projects' proposals might be modified to satisfy an ad hoc requirement and get funding. For example, if the ad hoc requirement were for a higher discount rate for economic analysis, shifting costs from capital ones to O & M would make projects appear better. A project would be cheaper initially, but it would be less durable. If the project was funded on this basis, local residents would be better off but national net benefits would be sacrificed.

Develop a partial funding approach

This "partial funding" approach could be considered to be generating supply curves for meeting project objectives.[19] There are a number of ways in which to implement the approach, but this discussion starts with an identified NED plan.[20] First, the NED plan is identified following current guidance.

Second, Federal support is postulated for smaller projects at certain fractions of the NED plan. These might be 25, 50, and 75 percent of the NED plan cost, but planning resources must be focused on the expected range of interest based on projections of budget shortfall[21]. Enough points must be selected to provide a meaningful curve, but there is a trade off with increased analysis costs. (The implications for study costs and how to control them would require further study if an approach using these steps were to be pursued. The process may require limits on the

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[18]Rent seeking refers to eforts to gain or keep claims to economic factors of production which are kept in fixed supplies by government actions. Beneficiaries of the artificial scarcity will oppose attempts to increase supplies of the factor or to allow others a claim to the fixed supply. Rent seeking activities include lobbying, legal actions, and public relations campaigns. These can be costly, but they do not increase production. They only determine who gets the income from existing economic output.

[19]Supply curves relate quantities of outputs to their prices.

[20]Where one starts to draw the supply curve is immaterial. Starting from the NED point does have the advantage of preparing a supply curve for a range of outputs of greatest interest to decision makers.

[21]If the projected Federal budget shortfall was 15 percent, planners might focus their attention on points in the range of 70 to 100 percent of the original NED plan cost.

range of project scales for which projects should be formulated.[22]) Larger projects may warrant more points on the curve. Only project alternatives smaller than the NED plan could have greater benefit-cost ratios, but a point larger than the NED cost would provide insight on the cost function both above and below the identified NED point. (The higher cost point should be available from the economic analysis which identified the NED plan.) Also, some flexibility in selecting the points will be required, as there are discontinuities in the cost and benefit functions.

Third, for each postulated level of funding, a plan will be formulated which maximizes net benefits subject to the budget constraint. As noted above, these constrained plans should represent local optima of net benefits (that is, discontinuities should be considered such that small changes of scale in the alternative plan will not improve the benefit cost ratio). The plans formulated will require some change of scope: geographical extent, level of protection, project life, type of protection measures (structural or non-structural), other dimensions of interest, or some combination of these. For plans with decreased Federal funding, the total net benefits will be lower, but the benefit-cost ratio will be higher as less productive components or increments (counting on decreasing marginal returns) are dropped from the plan.

Fourth and finally, a plan can be selected with an explicit recognition of the marginal cost of increased output. The shape of the supply curve, usually where the slope changes significantly, may indicate that a scale other than the NED plan gives the "best value" and should be selected.[23] A mechanism, either an exemption from the NED requirement or some new guidance, could be used to implement this approach. To the extent that plans less expensive than the NED plan are chosen, the strain on Corps funding will be lessened.

This approach uses a supply curve to make explicit the trade-off between project costs and benefits, with these parameters measured at the margin. This marginal analysis is a valuable improvement offered by this approach.

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[22]For example, a minimum project size might be set to avoid trivially small or clearly local projects with very high benefit-cost ratios. Also, size ranges for various types of measures could be negotiated between the Federal agency and the local sponsor, although it may be difficult, a priori, to accurately identify such ranges with adequate precision.

[23]The procedure is analogous to the ECO-EASY model developed as part of the EEIRP program for evaluation of alternative plans for environmental restoration.

HOW CAN NATIONAL WELFARE OBJECTIVES BE MAXIMIZED?

This is a complex and difficult question. It is relevant and central, especially in the era of the National Performance Review (NPR) and the Government Performance and Results Act (GPRA). The first part of the answer is that it will require an economic analysis which includes interproject comparisons of costs and benefits.[24] Under a binding Federal budget constraint the optimum choice of projects cannot be made solely at the local level. It requires coordination (interproject comparison and evaluation) on a national level.

Consideration of this section's question was deferred until project analyses using the partial funding or supply curve approach were introduced. National level evaluations depend on a modification of this approach. The first three steps are performed as described above. However, the final selection of a planning alternative is made at the national level. Two ways to implement the final selection process are noted, although other decision rules and processes are possible.

The first approach was suggested by Eckstein [1961]. As he notes, "At the optimum the following condition must hold: *the benefits produced by the marginal dollar of expenditure must be the same on all projects (and on all purposes).* [author's italics]" (p. 67)[25] As a practical matter, he recommends the following policy:

> 1. On the basis of recent experience with and examimation of the shelf of potential projects, each agency (or ideally the Bureau of the Budget) should recommend to its district offices the cutoff point of benefit-cost ratios of separable segments. The cutoff should be based on the benefit-cost ratio of the poorest project which has recently been or will actually be constructed in the coming period, justification for which largely rests on its economics....
> 2. With the scale of development so determined [by combining the segments above the cutoff],

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[24]Eckstein [1961] notes that net benefits is an appropriate criterion only if all prices represent real costs, "and if all projects for which B[enefits] exceeds C[osts] are actually constructed." (p. 66) He then says that optimality requires, "the benefit produced by the marginal dollar of expenditure must be the same on all projects (and on all purposes)." (p. 67)

[25]The portfolio of Corps projects was defined to include new starts of authorized projects, rehabilitation projects, and any O&M work of a capital nature. This allows for consistency with this notion of equal marginal benefits on all projects and all purposes. The idea is to get the best possible return for each dollar spent. Delayed capital maintenence increases risk of reduced project benefits, but expected return calculations could be used to empirically incorporate the concept of risk. Analysis becomes more complex, but this is generally the case the closer one approaches to efficient conditions. (The extension of the analysis to all Corps program areas could go even further to cover all government infrastructure investments, although such an examination is beyond the scope of this report.)

the benefit-cost ratios of different projects can be used to rank the economic worth of different projects. If the economic evaluation were the only criterion, the projects with the highest ratios should be chosen.

3. Serious consideration should be given to designing construction plans in a more flexible manner, which would permit partial development now without surrendering the remaining potential permanently. [Eckstein 1961; pp. 68-69]

The second approach to interproject evaluation at the national level is by the use of mathematical programming. The computing power to implement this approach was not available in 1961, and the size of the programming problem for the Corps may strain modern computing capacity. However, this approach would provide a direct way of solving the portfolio problem. From the reports of all potential projects, the cost and benefit data for each separable element and plan alternative at prescribed scales (eg., 25, 50, 75, and 100 percent) are entered into the problem statement. The mathematical program (for this application an integer programming model would actually used) has an objective function to maximize the net benefits for a selected group of plans. The maximization is performed subject to the Federal budget constraint and to mutual exclusivity of the planning alternatives. (This last requirement is what separates this mathematical programming approach from a simple interproject evaluation based on benefit-cost ratio.) The solution of the mathematical programming problem is an optimum group of plans which can be funded given the limited financial resources of the time period of interest. As with Eckstein's process above, this economic analysis will be augmented by evaluation based on other criteria. The use of mathematical programming is not intended to suggest a need for greater computational precision. The key point is that both these approaches implement the logic of making economic adjustments at the margin to satisfy the general efficiency criterion.

The integer programming approach was used by Davis [1968] in his study of options for Potomac estuary water quality improvement. Appendix C presents case studies applying the procedure. The first case is hypothetical; the second uses alternative plans from the Sioux City Feasibility Study [U.S. Army Corps of Engineers 1993] report.

There is an additional consideration in implementing any national level selection process. The planning process supports the decision making of elected Federal officials. The decision rules of Eckstein or the results of mathematical programming might not be acceptable to those officials because their opportunity to trade off costs and benefits might be restricted by the

opacity of the view of the process. For example, if elected officials made even small changes to the mathematical programming results, there might be significant losses of efficiency (felt at many points in the system of water development projects), depending on which of the programming constraints were binding. However, the use of mathematical programming may actually make available more information about trade-offs between costs and benefits. Outcomes of proposed changes could be analyzed by running modifications of the original mathematical programming problem.[26] Effects on the group of projects selected or on the Federal budget due to either modification of plan alternatives or changes in planning objectives could be iteratively explored until a result suitable to the decision makers is reached.

[26]This is an example of sensitivity analysis.

CONCLUSIONS

There are two main conclusions from this policy study. The first relates to selection of alternative plans. If Federal budget constraints become truly binding, then selection of plan alternatives for all projects will have to be done at the national level. The decision rule of recommending a project alternative which maximizes net benefits will not lead to national optimality in the face of Federal budget constraints. The nationally optimal selection of projects will require interproject economic comparisons so that the most cost beneficial alternatives are constructed. The information needed to make final recommendations on projects will not be available during the plan formulation and evaluation process. Plan elements and alternatives will have to be referred to a central authority for evaluation and selection based on criteria developed from data on budgets and funding availability.

Two methods for selecting plan alternatives were identified in this study. First, a cut-off benefit-cost ratio, which can be determined from an analysis of projects actually under construction, may be used to screen out projects with inadequate returns. Second, a mathematical programming approach could be used to optimize economic efficiency at the national level.

The second conclusion of this study answers the corollary question of whether or how imminent truly binding Federal budget constraints might be. There is little evidence that binding Federal budget constraints have had a significant impact on the Corps' Civil Works program, the policies which guide it, or the water resources projects selected for construction. This conclusion is based on the historical record of appropriations, the fact that little construction backlog was found which was due to unavailable Federal funds, and the fact that a decision rule of benefits exceeding costs has been used, without serious problems in allocation of Federal funds, for an extended period of time. This does not mean that there are not constraints on the Civil Works program. It is just that these constraints are, at the Federal level, non-economic. The local sponsor may be constrained both economically and otherwise. It is probable that the truly binding constraints on the Civil Works program have been the local economic ones; this hypothesis deserves further study. Also, if the Federal government does actually take the steps necessary to balance the Federal budget, the Federal budget constraint is likely to become the

most binding one. Although action to change planning policies does not appear necessary in the near future, the effects of current efforts to balance the Federal budget should be closely monitored to ensure appropriate changes can be put in place effectively, if and when required.

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Appendix A

Historical Trends in Civil Works Appropriations

Overall Trend

Corps Civil Works appropriations, as shown in Figure A-1, grew from approximately $100 Million in 1930 to over $4 Billion in 1994. The growth, obviously, has not been smooth. Funding increased as New Deal programs were started to counteract the Great Depression. Appropriations were low during World War II as military priorities crowded out Civil Works. Funds were made available following the war, with a slowdown during the Korean conflict. There appears to be an increase in the growth rate during the 1970s, but high inflation accounts for much of that increase. Appropriations since then have shown more variability. After the peak of 1994, appropriations have fallen to approximately $3.4 Billion in FY96.

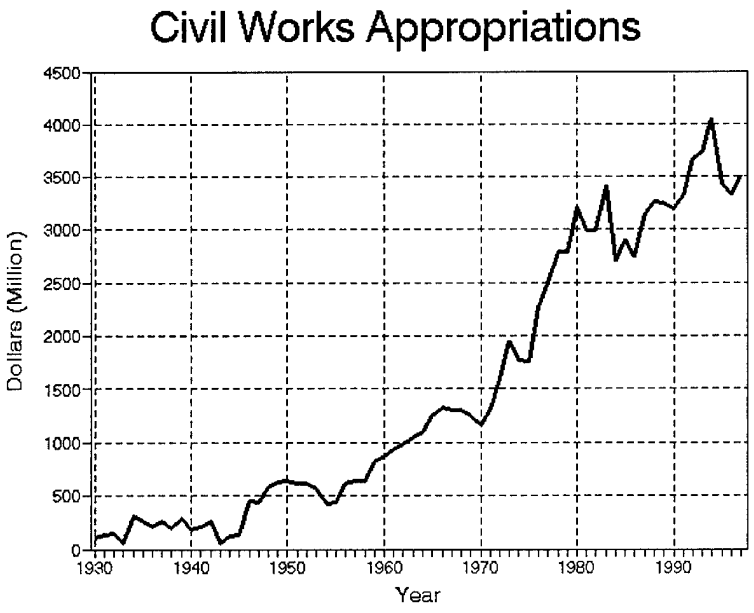

Figure A-1. Civil Works Appropriations

While Figure A-1 does show the overall trend, more information is needed to allow adequate analysis of budget trends. Inflation must be taken into account. There are also interesting trends in funding of programs within Civil Works. This Appendix first

discusses the sources and treatment of budget data and then the inflation adjustment process. Once that information has been presented, a more thorough and complete presentation and analysis of appropriation trends is made.

Data Sources

A great deal of information has been collected on the funding levels of the Civil Works program. It is sometimes difficult to retrieve the data, as continuous reporting by consistent categories has not been done. Data are available for funds budgeted, appropriated, and spent in various years. Administration priorities need not match Congressional priorities, so budgeted and appropriated amounts need not be equal. Also, spending frequently occurs in years later than the year of appropriation, especially for large construction projects requiring a number of years to complete. Appropriation data were most available, and have been used for this study. Corps spending may also be a useful statistic, if it were available, because actual levels of economic activities should be somewhat less subject to annual variations. Table A-1, attached at the end of this Appendix, includes the total Corps Civil Works appropriations for the years 1930 to 1996.

Corps appropriations data were drawn from the "Annual Report of the Chief of Engineers" for various years. Data on total appropriations were collected back to 1930, in order to see the effects of the Great Depression, the war years, and the post-war expansion.[1] Data on appropriation by category, that is, construction, operation and maintenance (O&M), investigations, Mississippi River flood control, regulatory, and other, were also taken from the annual reports. Some data by category were available back to 1930, but the data prior to 1955 are incomplete and not reported here. A certain amount of interpretation has been required. "Other" appropriations were found by difference between the funds accounted for in the five named categories and those in the total appropriation. Also, the regulatory program is a recent addition to the Corps' duties; appropriations for this function are only reported in 1987 and

[1]There is one anomaly in the data series. The Federal government adjusted its fiscal year in 1976. The third quarter of calendar 1976 became a transition quarter, with separate data on appropriations. However, in order to avoid a discontinuity in the annual time series, the appropriation data were adjusted (by adding the transition quarter appropriations to those for 1976 then taking 4/5 of the total).

afterward. Table A-2, attached at the end of this paper, presents the Corps appropriations by category for the years 1955 to 1996.

Two data series other than Corps appropriations are referred to in the discussion which follows. These are data on the total Federal budget and on the national economy. The Federal budget data were drawn from the "Budget of the United States" (1995). The GDP was used as the measure of the national economy,[2] and it was taken from statistical abstracts and available databases. These data series are included in Table A-1.

Inflation Adjustment

Economic data in the U.S. are reported in dollars, but it is important to consider the value of those dollars in understanding the economic incentives created. The objective of inflation adjustment is to make economic data comparable by using the value of the dollar at a single point in time. The adjusted data represent the purchasing power of the money rather than the actual number of dollars. The historical trends in this study are indicated by time series of economic data, for example Figure A-1. However, it is also important to look at the purchasing power of the dollars, that is using constant dollars or considering the data in real terms. These three phrases are used interchangeably in this discussion.

Inflation adjustment appears to be a simple process, done by multiplying the actual dollar amount by a ratio of the value of the dollar at that time and the value at some baseline year. However, measuring the value of the dollar to use is not straightforward and is complicated by a number of theoretical problems beyond the scope of this discussion. The measure must focus on the sectors of the economy in which the actual dollar amount was spent, under the assumption that the production technology used has not changed significantly. In practice, inflation adjustment often employs one of a number of published inflation measures. The Consumer Price Index (CPI) records the relative price of a bundle of goods purchased by a typical urban consumer. The Producer Price Index (PPI) does the same for inputs to enterprises. Construction

[2]GDP is now usually used as the measure of annual economic activity. However, until several years ago the GNP was more frequently reported. These measures differ in accounting for activities of multinational firms; GDP measures activities by location of business establishments while GNP is by location of firm ownership. For the United States, GNP and GDP are nearly equal (due to a preponderance of both ownership and establishment of firms being within the country and a balance of ownership and establishments for multinational firms).

cost indices (CCI) are based on the prices of inputs to construction projects; the best known index is published by Engineering News Record. Since 1967 the Corps has calculated its own cost index (CWCCI), weighted to reflect the construction of water resources projects. Another index which is prepared by the Federal government is the GDP deflator. This index uses a bundle of goods and services representing the entire national economy, weighted by their relative importance within it.

The choice of an index is a matter of judgement; they all capture the same general trends in the economy. This is demonstrated by Figure A-2, which shows the CPI, Engineering News Record CCI, and the GDP deflator for 1955 to 1995. For this study the GDP deflator was chosen because Civil Works activities span the sectors of the economy and the GDP deflator best represents the overall economy. Civil Works activities require a different bundle of goods than urban consumers, and construction is now less than half of expenditures. The GDP deflator is available from various sources; Table A-3, which follows the other tables at the end of this Appendix, lists the GDP deflators for 1955 to 1995. Data for 1996 and 1997 which is used in this paper have not been adjusted for inflation. However, recent inflation has been moderate so adjustment will have little impact.

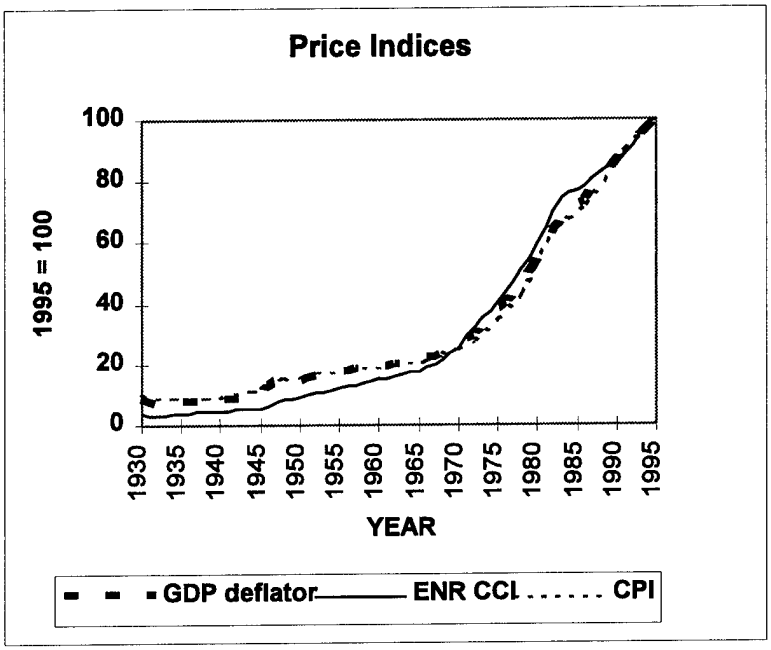

Figure A-2. Price Indices

Analysis of Appropriation Trends

In order to understand what has been happening to the Corps' appropriations, it is necessary to go beyond the overall trend presented in Figure A-1. The inflation adjustment

discussed above was applied to the total appropriations. Figure A-3 shows the constant dollar appropriations as well as the line from Figure A-1. There are several interesting points shown by this graph. One, the inflation adjustment has accentuated the variations in the budget,[3] even showing that actual budget increases resulted in decreased purchasing power. Inflation in the U.S. economy was especially high during the 1970s, and it is particularly during this time that rising appropriations only held real spending about constant. Two, in real dollar terms, the Civil Works Program is approximately the same size it was 35 years ago. There appears to have been a modest increase in activity during the late 1960s and 1970s and a noticeable drop off in the early 1980s. Since the mid 1980s, appropriations in real terms have been fairly stable. Three, the decline in appropriations during 1995 and 1996, again in real dollars, is smaller than short term variations seen in the recent history of the program. These two years probably should not be taken as a trend; only future years will show if this is a short term trough or the start of a longer term tendency. Appropriations for 1997 totaled approximately $3.5 billion, above the level of the two prior years even after inflation adjustment.

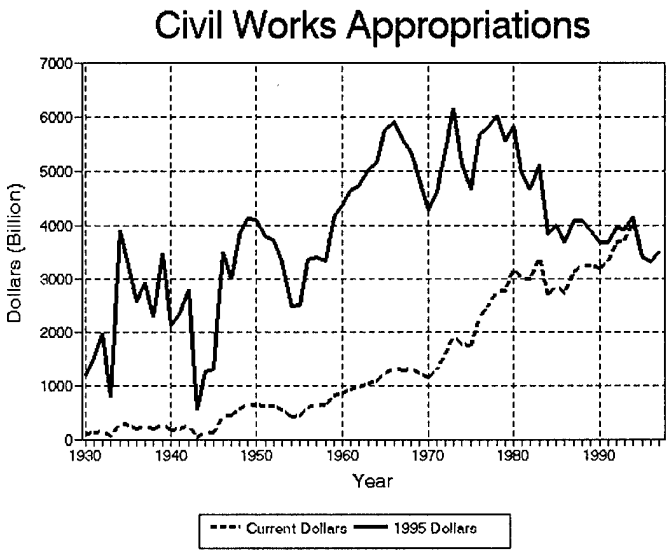

Figure A-3. Civil Works Appropriations

In addition to obvious trends in the data, it is important to consider the effects of historical events. One metric for the time axis is Presidential administrations. For example, appropriations were rising throughout Kennedy's term and about level during Bush's. It is interesting that, except during the Bush administration, there was a sharp decline in

[3]These are appropriations data; spending does not occur at the same rate. It is likely that variability in spending has been less than in appropriations.

appropriations during each administration when the president and the Congress were of different parties. Another series of events significant to the economy is business cycles. Recessions have occurred in 1958, 1971, 1974, 1981-1982, and 1991. Each of these downturns was followed by a sharp rise in Corps funding.[4] Discretionary infrastructure spending can be a tool of counter cyclical fiscal policy, and one interpretation of Figure A-3 is that Corps funding has, to some extent, been used that way. Finally, several authors (for example, Krugman (1994), and Rivlin (1992)) have recently identified the period of 1973-1975 as the start of a new and fundamentally different era in the U.S. economy. As a result of local, national, and global influences, there have been significant changes in relative importance of sectors of the economy, a move toward services rather than manufacturing, and a divergence rather than convergence in incomes. Although there is a great deal of variability in appropriations during that time interval, Figure A-3 appears to indicate trends consistent with the notion of such a fundamental shift. Corps appropriations, in real terms, peaked in 1973.

Another way of looking at Civil Works appropriations in real terms is as a percent of the Federal budget or of the national economy (as indicated by GDP), as shown in Figure A-4. Just prior to World War II, the Civil Works budget was between one and five percent of the Federal budget; recently, it has been less than one half percent. Relative to GDP, the percentage has shrunk to less than one tenth percent. Recalling Figure A-3, it is clear that the downward trends in Figure A-4 are largely the result of growth in the economy and the total Federal budget. Further, the

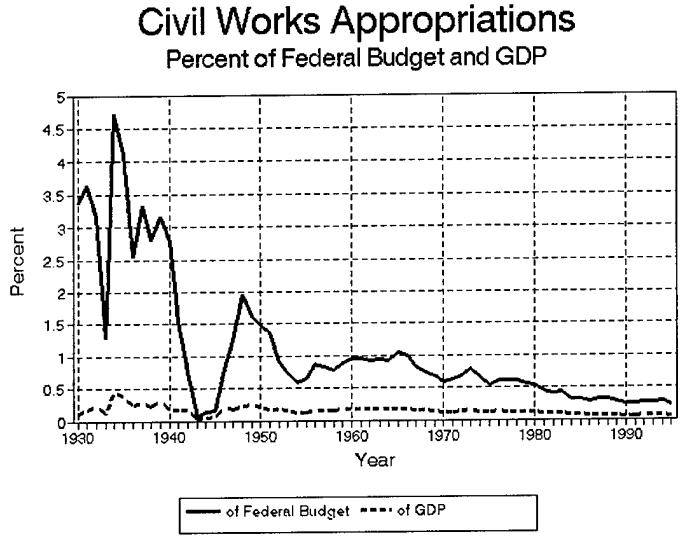

Figure A-4. Civil Works Appropriations--Percent of Federal Budget and GDP

[4]The response in later years was moderated, probably by the magnitude of the federal deficit and other political factors.

convergence of the lines on the graph show how much the Federal budget has grown relative to the total economy. Nevertheless, Figure A-4 provides some interesting insights relative to Corps budget constraints. First, the Civil Works program should expect to garner less interest from Congress and other government agencies when it makes up 0.5% of the budget than when it was five percent. Second, the perception of tightening budget constraints in the Corps may be exacerbated by the decrease in influence resulting from shrinking relative size more than real decline in appropriations. Third, considering that only about 16% of the Federal budget is domestic discretionary funding, any significant future Civil Works appropriations cuts cannot be matched by cuts in non-discretionary programs. This means the Civil Works program, if cut further, will likely become an even smaller piece of the Federal budget. Wildavsky (1987) notes that it is also likely the smaller the fraction of the total is a program, the greater the chances of reorganization or elimination of the program.

Analysis of Trends by Category of Expenditure

Figure A-5 plots the appropriations by category. The two largest categories are construction and O&M, combining to absorb approximately 80% of the available funds. The other categories are all small relative to these two. Investigations appropriations have grown over time and are now about four percent of the Civil Works total. The increase in investigation funding combined with a decrease in that for construction

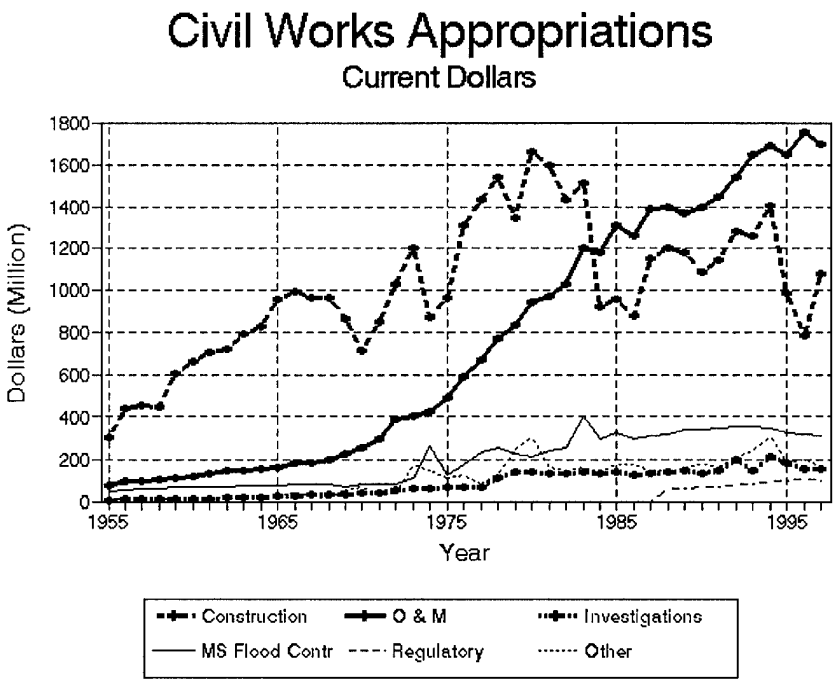

Figure A-5. Civil Works Appropriations--Current Dollars

means their ratio has grown from less than two percent to over 15% over 35 years, as shown in Figure A-6. This growth may have ramifications for the allocation of resources within the Corps. The recent addition and small size of the regulatory program is evident from Figure A-5.

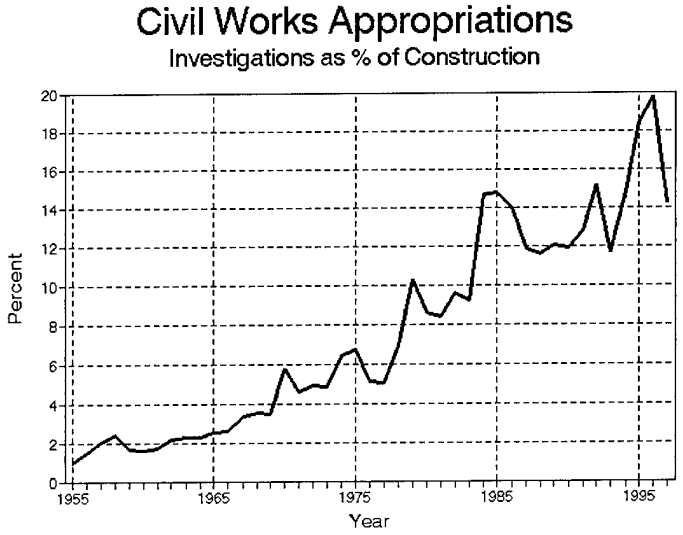

Figure A-6. Civil Works Appropriations--Investigations as % of Construction

The most important point on the graph in Figure A-5 is probably the intersection, in 1983, between the construction and O&M appropriations. O&M funding had been and continued to grow at a nearly constant rate. This is not surprising considering the increasing inventory of completed Corps projects. Along with the number of projects, their increasing age and consequent need for repair contributed to the rise in O&M funding. The decrease in Civil Works appropriations since 1994 appears to be almost completely accounted for within the construction category.

Interpreting the trends for construction and O&M funding in real terms tells a somewhat different story, as shown in Figure A-7. O&M appropriations have

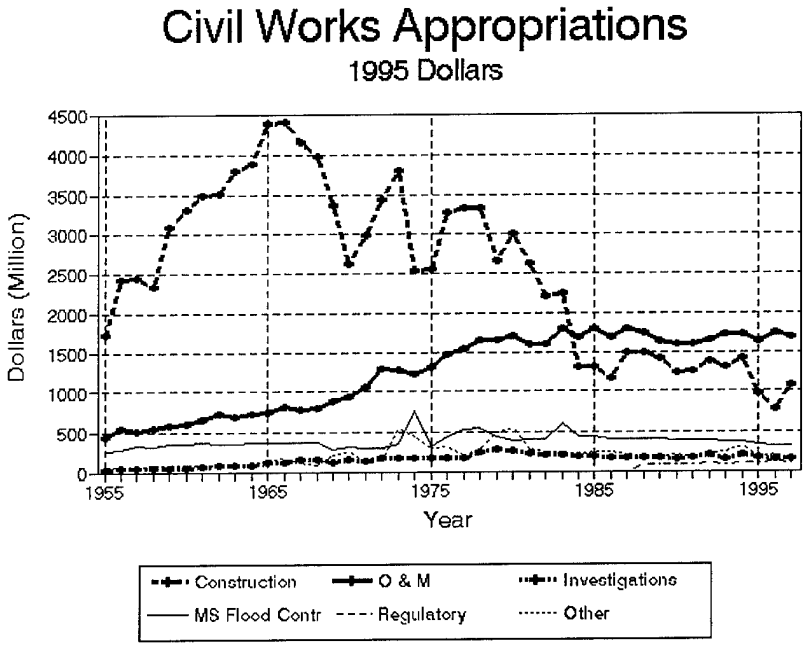

Figure A-7. Civil Works Appropriations--1995 Dollars

grown, although only slowly and hardly if at all since 1982. The purchasing power of construction funding has declined, and almost all of the decrease in real Civil Works appropriations since 1975 has come from the construction category.

Figure A-8 presents the information in Figures A-5 and A-7 in a different way. This is a bar graph[5] of the appropriations by category, but as a percent of the total for Civil Works. This graph highlights the shrinking of construction and the growth of O&M over time.

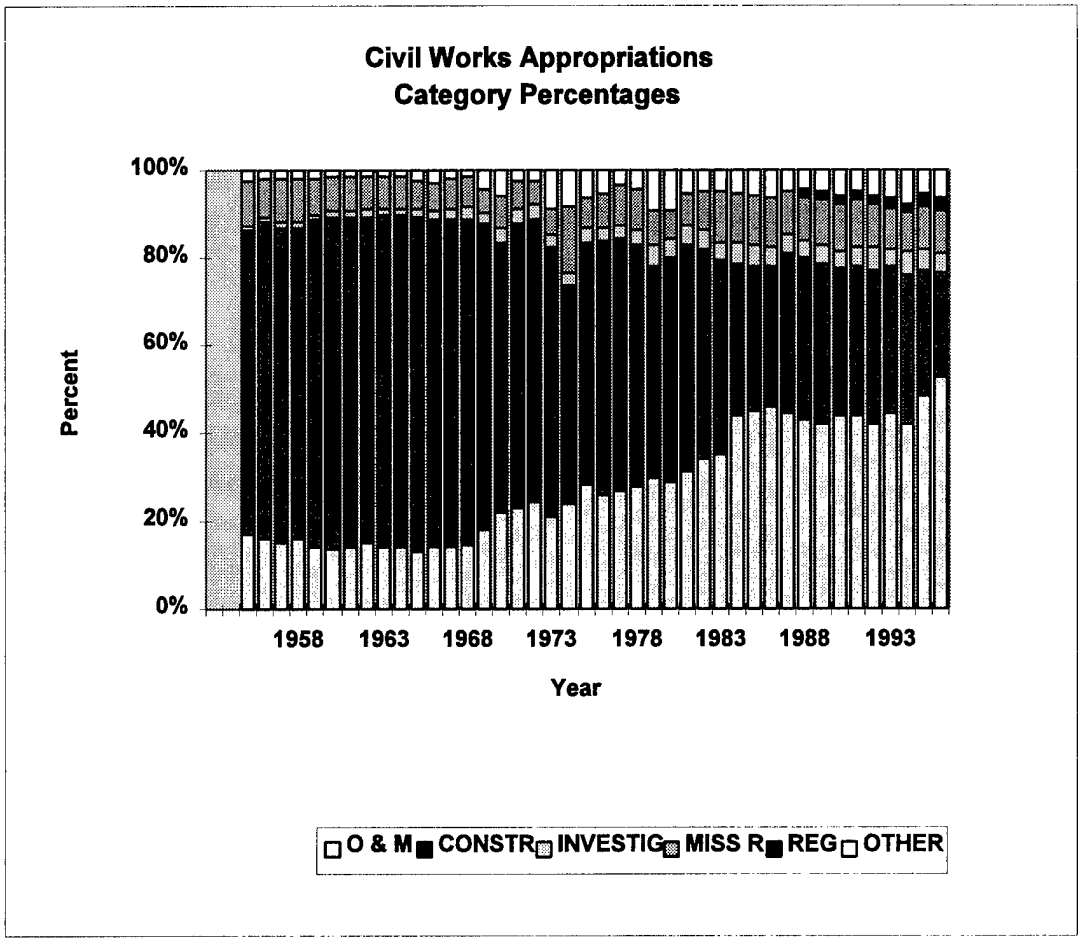

Figure A-8. Civil Works Appropriations--Category Percentages

[5]A bar graph is more appropriate for the appropriation data in this study, as it represents the data as discrete units, which they are, rather than as continuous variables. However, the line graphs are used here because they more easily show the important trends. The number of data points is high enough that the interpolation lines on the line graphs are short and not likely to bias the presentation.

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TABLE A-1 BUDGET DATA		
YEAR	CIVIL WORKS	FED BUDGET
	APPROPRIATIONS	$1000 CURRENT
1930	$112,078,906	$3,320,000
1931	$130,586,117	$3,577,000
1932	$147,794,371	$4,659,000
1933	$59,085,657	$4,598,000
1934	$308,829,962	$6,541,000
1935	$263,864,732	$6,412,000
1936	$209,622,838	$8,228,000
1937	$252,250,044	$7,580,000
1938	$192,556,378	$6,840,000
1939	$289,244,842	$9,141,000
1940	$180,141,467	$6,468,000
1941	$210,055,564	$13,653,000
1942	$264,382,388	$35,137,000
1943	$52,547,039	$78,555,000
1944	$122,256,984	$91,304,000
1945	$132,825,573	$92,712,000
1946	$448,918,777	$55,232,000
1947	$432,994,361	$34,496,000
1948	$583,241,938	$29,764,000
1949	$628,020,865	$38,835,000
1950	$635,416,090	$42,562,000
1951	$618,717,314	$45,514,000
1952	$616,586,353	$67,686,000
1953	$561,806,600	$76,101,000
1954	$424,231,600	$70,855,000
1955	$442,364,100	$68,444,000
1956	$610,327,514	$70,640,000
1957	$637,720,627	$76,578,000
1958	$638,667,797	$82,405,000
1959	$815,520,646	$92,098,000
1960	$872,637,123	$92,191,000
1961	$935,844,190	$97,723,000
1962	$975,129,364	$106,821,000
1963	$1,046,400,546	$111,316,000

TABLE A-1 BUDGET DATA		
YEAR	CIVIL WORKS	FED BUDGET
	APPROPRIATIONS	$1000 CURRENT
1964	$1,096,725,968	$118,528,000
1965	$1,253,879,234	$118,228,000
1966	$1,329,961,739	$134,532,000
1967	$1,294,569,010	$157,464,000
1968	$1,304,987,994	$178,134,000
1969	$1,245,587,445	$183,640,000
1970	$1,156,576,440	$195,649,000
1971	$1,310,025,372	$210,172,000
1972	$1,589,193,369	$230,681,000
1973	$1,952,374,275	$245,707,000
1974	$1,770,168,736	$269,359,000
1975	$1,756,877,000	$332,332,000
1976	$2,274,336,800	$371,792,000
1977	$2,487,028,000	$409,218,000
1978	$2,789,412,000	$458,746,000
1979	$2,790,300,000	$503,485,000
1980	$3,201,000,000	$590,947,000
1981	$2,997,000,000	$678,249,000
1982	$2,997,000,000	$745,755,000
1983	$3,419,000,000	$808,380,000
1984	$2,690,665,000	$851,846,000
1985	$2,901,000,000	$946,391,000
1986	$2,740,000,000	$990,336,000
1987	$3,136,900,000	$1,003,911,000
1988	$3,258,900,000	$1,064,140,000
1989	$3,246,765,000	$1,143,172,000
1990	$3,196,589,000	$1,252,705,000
1991	$3,314,262,000	$1,323,793,000
1992	$3,668,133,000	$1,380,856,000
1993	$3,730,343,000	$1,408,205,000
1994	$4,049,130,000	$1,483,829,000
1995	$3,420,898,000	$1,518,945,000
1996	$3,318,746,000	$1,596,877,000
1997	$3,503,203,000	

Table A-2 APPROPRITIONS BY CATEGORY						
YEAR	O & M	CONSTR	INVESTIG	MISS R	REG	OTHER
	(MILLION CURRENT DOLLARS)					
1955	$76	$306	$3	$45	$0	$11
1956	$99	$441	$6	$52	$0	$12
1957	$96	$458	$9	$63	$0	$11
1958	$104	$450	$11	$61	$0	$13
1959	$115	$608	$10	$68	$0	$15
1960	$118	$661	$10	$69	$0	$14
1961	$130	$707	$12	$72	$0	$15
1962	$147	$724	$16	$73	$0	$15
1963	$146	$793	$18	$74	$0	$16
1964	$156	$827	$19	$78	$0	$17
1965	$163	$957	$24	$78	$0	$32
1966	$186	$994	$25	$85	$0	$39
1967	$180	$967	$32	$87	$0	$28
1968	$194	$968	$34	$87	$0	$22
1969	$227	$866	$30	$70	$0	$54
1970	$253	$712	$41	$81	$0	$70
1971	$302	$851	$39	$84	$0	$34
1972	$390	$1,025	$51	$86	$0	$38
1973	$408	$1,204	$58	$112	$0	$171
1974	$427	$874	$56	$265	$0	$149
1975	$495	$966	$65	$120	$0	$110
1976	$590	$1,313	$67	$179	$0	$125
1977	$668	$1,430	$72	$231	$0	$86
1978	$769	$1,538	$107	$253	$0	$123
1979	$833	$1,344	$138	$223	$0	$252
1980	$946	$1,660	$142	$211	$0	$303
1981	$973	$1,594	$134	$238	$0	$162
1982	$1,030	$1,430	$137	$256	$0	$148
1983	$1,206	$1,508	$139	$403	$0	$165
1984	$1,184	$927	$136	$302	$0	$141
1985	$1,308	$955	$141	$322	$0	$175
1986	$1,260	$880	$123	$301	$0	$176
1987	$1,390	$1,149	$136	$311	$0	$151
1988	$1,400	$1,200	$139	$318	$55	$147
1989	$1,370	$1,179	$142	$338	$64	$154
1990	$1,398	$1,084	$129	$336	$68	$181
1991	$1,451	$1,143	$146	$345	$71	$158
1992	$1,538	$1,284	$194	$356	$86	$209
1993	$1,652	$1,260	$147	$351	$86	$234
1994	$1,689	$1,401	$208	$349	$92	$311
1995	$1,646	$984	$181	$328	$101	$181
1996	$1,750	$785	$156	$319	$106	$203
1997	$1,697	$1,082	$154	$310	$101	$159

TABLE A-3

GDP DEFLATORS

YEAR	GDP DEFLATOR (1995=100)	YEAR	GDP DEFLATOR (1995=100)
1930	9.3	1965	21.8
1931	8.4	1966	22.6
1932	7.5	1967	23.3
1933	7.3	1968	24.4
1934	7.9	1969	25.7
1935	8.1	1970	27.0
1936	8.1	1971	28.5
1937	8.6	1972	29.8
1938	8.4	1973	31.7
1939	8.3	1974	34.5
1940	8.4	1975	37.8
1941	9.0	1976	40.2
1942	9.4	1977	42.9
1943	9.6	1978	46.3
1944	9.7	1979	50.3
1945	10.2	1980	55.1
1946	12.8	1981	60.6
1947	14.4	1982	64.4
1948	15.4	1983	67.0
1949	15.3	1984	69.9
1950	15.5	1985	72.5
1951	16.4	1986	74.4
1952	16.5	1987	76.8
1953	16.9	1988	79.8
1954	17.1	1989	83.3
1955	17.6	1990	87.0
1956	18.1	1991	90.4
1957	18.7	1992	93.0
1958	19.1	1993	94.9
1959	19.7	1994	97.7
1960	20.0	1995	100.0
1961	20.2		
1962	20.7		
1963	20.9		
1964	21.3		

Appendix B

Cost Sharing Trade-off Model

The welfare maximizing model of Federal and local involvement in a project shows that there will be a trade off between local and Federal preferences which varies depending on the fraction of cost sharing, the scale of the project, and the tightness of the respective budget constraints. For example, a local sponsor with a budget constraint would respond only to local benefits (monetary and non-monetary) and select a different (presumably smaller) plan than a Federal agency would design.

This trade-off is illustrated in Figure B-1. The graph[1] shows net national benefits as a function of expenditure by the Federal government and the local sponsor. The plane with zero Federal expenditure models the situation prior to Federal involvement in water resources infrastructure. Projects, if done, were small, with localized benefits. The plane of zero local spending means the federal government pays all project costs, approximating the case of flood control projects following the 1938 Flood Control Act. Historically, Federal Civil Works projects have been bigger than those built locally, costing more but claiming greater and more dispersed benefits. The magnitude of the required projects was, in the 1930s, an important rationale for there being a Federal interest in water resource development.

The interesting cases in Figure B-1 fall between the two extremes. A vertical plane through the origin represents a division of project costs, with the actual split depending on the angle from the planes over the axes. Budget constraints will limit feasible projects to a triangular prism adjacent to the origin. Efficient project scale will be limited by the horizontal projection of the maximum of the benefit surface.[2] As both local cost sharing increases and

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[1]The graph in Figure B-1 shows a surface which is believed to represent the behaviors involved. However, it was not generated by mathematically modeling the agents' behavior and aggregating their results. Such an enhancement of the model should prove insightful and is proposed as future research.

[2]The scale may be limited by local net benefits, which would be represented by a surface below the net national benefits surface in the benefit space. For example, if the Federal government were paying all project costs and then required local participation, the locals would probably have an incentive to decrease the scale of the project. Even though national welfare gains could come from adding local funds to Federal ones, some of the marginal benefits would be outside the local region.

federal budget constraints tighten, it is clear that the preferences of the local sponsor will dominate economic behavior. While this model puts no quantitative scale on when the transition will occur, it seems likely to be important if Federal Civil Works budgets are squeezed and as cost sharing requirements are increased (both to shift the cost to other levels of government and to further the principle of beneficiaries paying for their benefits).[3]

This model can be further extended, at least in a qualitative way, by considering indivisibilities in water resources projects. There are discontinuities in these projects. The cost of widening a levee may jump when the expansion moves from currently owned property to tracts which must be purchased. Benefits would not likely jump at the same change of scale, although they may depending on the changing slope and thus density of development of the protected area. Net benefits from sources other than flood damage prevention may also have indivisibilities or discontinuities. These effects will result in local optima in the benefit surface of Figure B-1. It is also likely that, in the usual cases where the local budget constraint is considered through the acceptability criterion, the locally acceptable point is the one local optima which is identified as the NED plan in the Corps planning process.[4]

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[3]The history of the wastewater treatment plant constuction grants program in the 1972 Federal Water Pollution Control Act may be instructive. The incentive created as the required local share increased was not linear.

[4]The hypothesis of local optima is illustrated by considering a range of completed Civil Works projects. If cost were no object, could larger projects be identified which have more benefits (but which include those of the existing project) and still have a benefit cost ratio above one. In many cases, these hypothetical projects seems to exist. For example, local flooding could be decreased by a series of upstream reservoirs, each of which also provide benefits in their local areas. The total of these benefits may well be greater than the costs. Still, if the local sponsor of the region with the original problem were required to pay a percentage of the entire cost, it is unlikely they would pursue the project. Nevertheless, the local protection project would be at best a local optima of net national benefits. (Other Corps guidance, such as claiming benefits only for primary mission areas or using different rates of interest to deflate future benefits, limit the consideration of projects beyond the scale of interest to local sponsors.)

Trade-Off Between Costs and Benefits

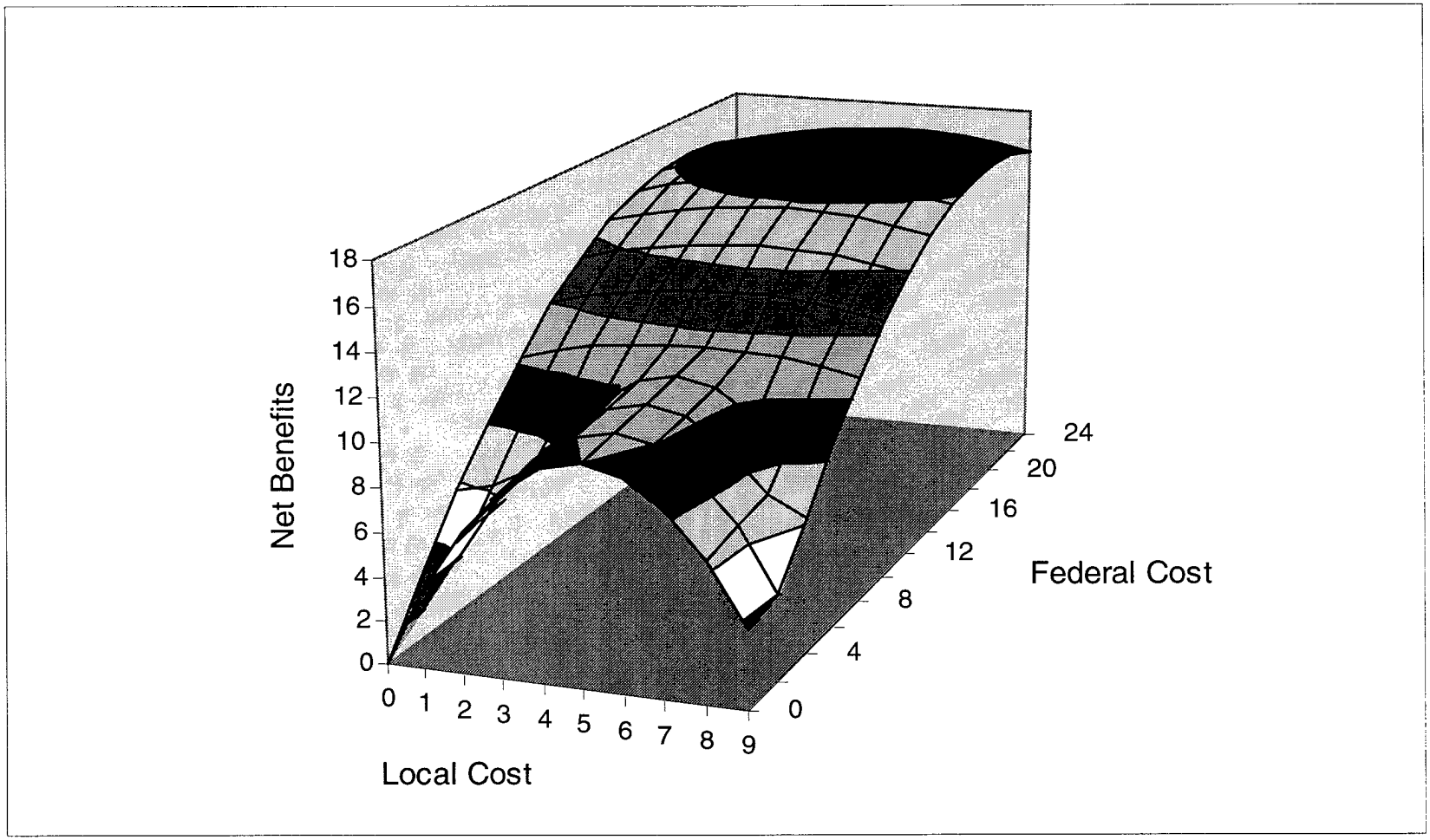

Figure B-1. Trade-Off Between Costs and Benefits

Appendix C

Case Studies Demonstrating Integer Programming for Optimum Plan Selection

Hypothetical Case Study

Data for this case study were made up to demonstrate the approach. It is assumed that there are five projects seeking funding in the current time period. Each project has three alternative plans. The costs, benefits, net benefits, and benefit-cost ratio for each alternative are shown in Table C-1. In the column titled "Alternative," the first number refers to the project and the second to the alternative plan.

Table C-1
Data for Hypothetical Case

Alternative	Project Cost ($)	Benefits ($)	Net Benefits ($)	B-C Ratio
1-1	3,500,000	3,700,000	200,000	1.057
1-2	5,000,000	5,204,000	204,000	1.041
1-3	6,000,000	6,212,000	212,000	1.035
2-1	2,000,000	2,140,000	140,000	1.070
2-2	3,000,000	3,160,000	160,000	1.053
2-3	4,000,000	4,180,000	180,000	1.045
3-1	2,000,000	2,120,000	120,000	1.060
3-2	3,000,000	3,125,000	125,000	1.042
3-3	4,000,000	4,140,000	140,000	1.035
4-1	1,000,000	1,060,000	60,000	1.060
4-2	3,500,000	3,582,000	82,000	1.023
4-3	7,500,000	7,590,000	90,000	1.012
5-1	2,000,000	2,040,000	40,000	1.020
5-2	3,200,000	3,240,000	40,000	1.013
5-3	5,000,000	5,040,000	40,000	1.008

These data were entered into a computer on which optimization software was available. The integer programming problem was set up to maximize net benefits over all five projects, subject to a budget constraint.[1] No more than one alternative plan can be selected for any one project. First the unconstrained case and then several levels of budget constraint were entered. Results of the calculations are shown in Table C-2.

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[1]The integer program is as follows:

$$Max \sum_{i=1}^{5} \sum_{j=1}^{3} G_{ij} (E_{ij} \quad C_{ij})$$

subject to

$$\sum_{i=1}^{5} \sum_{j=1}^{3} G_{ij} C_{ij} \leq X$$
$$\sum_{j=1}^{3} G_{ij} \leq 1 \qquad \forall\ i = 1\ to\ 5$$
$$G_{ij} \in \{ 0, 1 \}$$

where

G_{ij} $\begin{cases} 1 \text{ if project } i \text{ and plan } j \text{ is selected} \\ 0 \text{ otherwise} \end{cases}$

E *benefits*

C *costs*

X *funding available*

i *index for projects*

j *index for alternative plans*

Table C-2
Results for Hypothetical Case

Constraint ($)	Objective (Net Benefits--$)	Cost ($)	Benefit-Cost Ratio	Plans Selected
None	662,000	26,500,000	1.025	1-3, 2-3, 3-3, 4-3, 5-3
15,000,000	622,000	15,000,000	1.041	1-1, 2-3, 3-1, 4-2, 5-1
10,000,000	540,000	9,500,000	1.057	1-1, 2-2, 3-1, 4-1
8,000,000	460,000	7,500,000	1.061	1-1, 2-1, 3-1

If there is no budget constraint, each of the projects will be built at maximum scale because net benefits are maximized.[2] This group of projects has a lower benefit-cost ratio than groups chosen under constrained budgets. When the budget constraint drops to $15,000,000, only one of the projects would still utilize the same alternative plan (project 2). Total project costs are decreased more than $10,000,000, although net benefits decrease by only $40,000.

With the budget constraint at $10,000,000, overall efficiency is attained by selecting plans for only four projects. Nothing would be constructed for project 5. Net benefits have gone down an additional $82,000, but the benefit-cost ratio rose to 1.057. Also, the actual cost is below the funding available because of the discontinuities between the plan alternatives. A larger number of projects would smooth the fit between the constraint and the actual cost, but some difference would be expected due to the nature of the integer constraint.

The $8,000,000 budget constraint requires that only the most cost-beneficial plans be selected, and then only for three projects. The benefit-cost ratio for this group of projects is the highest among the cases calculated.

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[2]Project number 5 presents an interesting circumstance. The net benefits are constant, regardless of the cost of the project. The mathematical program cannot distinguish between the three alternatives for this project; choosing any one of the three does not change the objective function (net benefits). The program will depend on some non-optimizing algorithm, such as the value most recently entered into the program, to select an alternative for this project. The software program used identified plan 5-3 for the unconstrained case. Plan 5-1 would have provided the same total net benefits for the unconstrained case at a total cost $3,000,000 less than shown in Table C-2. While the point may be interesting and worthy of explanation, the circumstance is unlikely to occur in the real world.

Project selection for funding levels below $8,000,000 can be done by inspection from the original data in Table C-1. It would, however, be difficult to select plans for the two previous cases without the assistance of a computer.

Case Study Using Plan Elements from Sioux Falls, South Dakota

The second case study attempts to demonstrate the integer programming process with data drawn from an actual Corps Feasibility Study. It is the local flood protection project for the Big Sioux River and Skunk Creek at Sioux Falls, South Dakota (U.S. Army Corps of Engineers 1993). The data are presented in Table C-3.

The data are for seven reaches of the Big Sioux River and Skunk Creek. For that study the reaches must be considered in relation to each other. Here the data are used differently. It is assumed that each reach is an independent project. At most one alternative plan for each of the seven assumed projects can be selected.

The integer programming problem is fundamentally the same as for the hypothetical case. The only difference is that the index numbers take on the ranges to seven for projects and to four for plans within each project. The results are shown in Table C-4. For this case, the unconstrained portfolio of projects was determined, along with their total cost. Then the budget was constrained to 75, 50, and 25 percent of the unconstrained cost. A final constraint of $100,000 was run to present a wider range of results.

The alternative plans for scale of 200 and 500 year protection were not efficient relative to smaller scale plans, so none were selected even for the unconstrained case. The portfolio of projects was the same with constraints of $921,000 and $614,000. This occurred because the costs for project 1 were so much larger than for any of the other projects.

Table C-3
Data for Sioux Falls

Plan	Scale	First Cost	Annual Cost	Annual Benefits	Net Benefits	Benefit-Cost Ratio
1-1	50-Year	$7,667,800	$632,800	$816,100	$183,300	1.289665
1-2	100-Year	$12,245,500	$1,010,600	$1,127,300	$116,700	1.115476
1-3	200-Year	$17,464,200	$1,441,300	$1,539,700	$98,400	1.068272
1-4	500-Year	$23,022,300	$1,900,000	$1,847,800	($52,200)	0.972526
2-1	50-Year	$280,900	$23,200	$148,200	$125,000	6.387931
2-2	100-Year	$1,203,600	$99,300	$250,100	$150,800	2.51863
2-3	200-Year	$3,511,900	$289,800	$305,600	$15,800	1.05452
2-4	500-Year	$5,690,300	$469,600	$396,200	($73,400)	0.843697
3-1	50-Year	$56,700	$4,700	$33,200	$28,500	7.06383
3-2	100-Year	$217,800	$18,000	$55,900	$37,900	3.105556
3-3	200-Year	$791,500	$65,300	$93,400	$28,100	1.430322
3-4	500-Year	$2,325,500	$191,900	$116,100	($75,800)	0.605003
4-1	50-Year	$405,400	$33,500	$115,000	$81,500	3.432836
4-2	100-Year	$789,200	$65,100	$149,900	$84,800	2.302611
4-3	200-Year	$1,803,900	$148,900	$187,800	$38,900	1.261249
4-4	500-Year	$3,934,800	$324,700	$207,200	($117,500)	0.638128
5-1	50-Year	$1,142,100	$94,300	$685,500	$591,200	7.269353
5-2	100-Year	$3,556,200	$293,500	$883,800	$590,300	3.011244
5-3	200-Year	$6,721,900	$554,800	$1,087,400	$532,600	1.959986
5-4	500-Year	$18,132,600	$1,496,500	$1,181,900	($314,600)	0.789776
6-1	50-Year	$759,100	$62,600	$341,500	$278,900	5.455272
6-2	100-Year	$1,664,500	$137,400	$424,500	$287,100	3.08952
6-3	200-Year	$3,112,800	$256,900	$508,200	$251,300	1.978202
6-4	500-Year	$11,256,300	$929,000	$547,500	($381,500)	0.589343
7-1	50-Year	$921,600	$76,100	$133,800	$57,700	1.758213
7-2	100-Year	$2,188,600	$180,600	$337,600	$157,000	1.869324
7-3	200-Year	$5,905,200	$487,400	$349,900	$137,500	0.717891
7-4	500-Year	$13,831,900	$1,141,500	$356,400	($785,100)	0.312221

Table C-4
Results for Sioux Falls

Constraint ($)	Objective (Net Benefits--$)	Cost ($)	Benefit-Cost Ratio	Plans Selected
None	1,492,100	1,227,500	2.22	1-1, 2-2, 3-2, 4-2, 5-1, 6-2, 7-2
921,000	1,308,800	594,700	3.20	2-2, 3-2, 4-2, 5-2, 6-2, 7-2
614,000	1,308,800	594,700	3.20	2-2, 3-2, 4-2, 5-2, 6-2, 7-2
307,000	1,162,800	294,400	4.95	2-1, 3-1, 4-1, 5-1, 6-1, 7-1
100,000	619,700	99,000	7.26	3-1, 5-1

In general, as the budget constraint becomes more binding, the scale of the projects becomes smaller. As with the hypothetical case, the benefit-cost ratio rises for the shrinking group of projects.

The results in this Appendix show how integer programming can be used to optimize alternative plan selection at a mathematically global, that is, national, level. It is not easy to obtain these results without the assistance of a computer; the correct answers do not stand out by inspection of the tabulated data. The actual problem facing the Corps in any funding year would be considerably more sophisticated, but the computing power for the needed operations is probably available. Finally, these cases show that the information to run the mathematical program, which requires both the data on alternative plans for all projects and the level of the budget constraint, would generally only be available at the Headquarters level.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate and any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Service, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204 Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1997	Final

4. TITLE AND SUBTITLE
Budget Constraints and Decision Making: Development of Policy Guidelines for Planning of Civil Works Programs and Projects

5. FUNDING NUMBERS

6. AUTHOR(S)
James L. Floyd and William C. Holliday

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USACE, Water Resources Support Center
Institute for Water Resources
Casey Building, 7701 Telegraph Road
Alexandria, VA 22315-3868

8. PERFORMING ORGANIZATION REPORT NUMBER
IWR Report - 97-PS-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
USACE, Headquarters
Directorate of Civil Works
Policy Review and Analysis Division
20 Massachusetts Avenue, NW
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, (703) 487-4650

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

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The purpose of this policy study is to determine how the Corps of Engineers' various planning processes and criteria might adjust to severe Federal budget constraints. A corollary purpose is to investigate whether budget driven changes in Corps procedures appear imminent. The first conclusion of this study is that, if Federal budget constraints become truly binding, then selection of plan alternatives for all projects will have to be done at the national level. The decision rule of recommending a project alternative which maximizes net benefits will not lead to national optimality. Plan elements and alternatives will have to be referred to a central authority for evaluation and selection based on criteria developed from data on budgets and funding availability. The second conclusion is that there is little evidence of imminently binding Federal budget constraints on the Corps' Civil Works program, the policies which guide it, or the water resources projects selected for construction. Although action to change planning policies does not appear necessary in the near future, the effects of current efforts to balance the Federal budget should be closely monitored to ensure appropriate changes can be put in place effectively, if and when required.

14. SUBJECT TERMS
Budgets, Appropriations, Budget constraints, Planning, Economic justification, Interproject comparisons, National economic optimality, Water resources, Public works, Corps of Engineers, Civil Works

15. NUMBER OF PAGES
60

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