THE GREENHOUSE EFFECT: RECENT RESEARCH AND SOME IMPLICATIONS FOR WATER RESOURCE MANAGEMENT

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PREFACE

This paper is one of a series on research in progress in the field of human adjustments to natural hazards. The series is intended to aid the rapid distribution of research findings and information. It was started in 1968 by Gilbert White, Robert Kates, and Ian Burton with National Science Foundation funds but is now self-supporting. The papers are produced by:

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SUMMARY

This paper describes some of the issues associated with potential anthropogenic global warming (the "greenhouse effect"), especially those of interest to water resource planners and managers. We describe the basis for growing concern that the global climate will warm at a rate unprecedented in human history over the next several decades, giving particular attention to uncertainties in predictions of climate change, and to methods for creating climate scenarios useful in studying impact and assessing response options.

We then review the literature regarding the impacts of climate change on water resources, finding indications in existing research that even small climate changes could lead to serious problems in water supply, flood control, and other resource planning areas. Water resources are immediately sensitive to climate change and potentially adversely affected by change in any direction: there could be more floods or more droughts in a "greenhouse world." Less evidence is available concerning potential climate impacts on elements such as water quality, user demand, and other environmental systems dependent on water such as fisheries and wildlife.

We conclude that the increasingly credible predictions of global warming and growing public concern now focused on the issue means, simply, that water resource managers must now seriously consider the potential for future climate change. However, the evidence does not currently recommend drastic changes in the planning and operating of water systems; it is not

yet time to begin designing systems differently. But, in connection with growing public concern, managers need to monitor closely developments in climate change research, assess how sensitive their systems are to climate fluctuations, and start to canvass feasible responses to rapid climate change.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

WHAT GROWING CONCERN OVER THE GREENHOUSE EFFECT MEANS TO NATURAL RESOURCE MANAGERS

The drought and heat wave which affected much of the United States during the summer of 1988 may well be remembered as the event which firmly imbedded the threat of global warming into the public and policy-maker consciousness. Both Time and Newsweek featured cover stories on global warming and ozone depletion, and congressional hearings, international conferences, and even discussions of a global treaty on climate protection, have placed the issue near the top of the political agenda.

The events of 1988 accelerated a growing concern fueled by increasingly credible predictions that anthropogenic climate changes are likely to emerge from natural climatic variability, or "noise", in the next decade or so. Global average temperatures 3°C to 5°C warmer than present are expected to result from the doubling of greenhouse gas concentrations sometime near the middle of the next century (see, for example, World Meteorological Organization, 1985; Schneider, 1989). Some analysts feel that greenhouse climate change is currently underway, or is imminent (Hansen, et al., 1988; Hansen and Lebedeff, 1988), and scientists point out that the warmest years since instrumental records began in the late 1800s have occurred in the 1980s.

Calls for Action

Impact projections indicate that even climate changes less than those expected to accompany a doubling of atmospheric carbon dioxide (CO_2) (along with increases in other greenhouse gases) can disrupt natural resource systems. This has led to calls for concrete policy actions even before current uncertainties are much reduced.

Although government response thus far has been only to urge and support further study, several credible social institutions have recommended more overt action. A March 1988 letter from 42 United States senators to President Reagan noted that "greenhouse gases will lead to substantial changes in the climate of our planet with potentially catastrophic environmental and socio-economic consequences." The senators called for

> the establishment of a high level working group to study potential responses to climate change, including greenhouse gas emissions reduction and adaptation [and] negotiation of a greenhouse gas convention.

The United Nations Environmental Programme (UNEP), which orchestrated the international protocol on ozone protection in 1987, urged the

> establishment of an intergovernmental coordinating body on climate change . . . 1995 is UNEP's target date for "agreement on appropriate and timely measures" to deal with climate change. With the ozone layer accord as a precedent, there is a reasonable expectation for successful international action. (United Nations Environment Programme, 1988, p. 1)

The declaration of the World Conference of the Changing Atmosphere held during June 1988, in Toronto, Canada, calls for

"an international framework convention . . . as well as national legislation to provide for protection of the global atmosphere," with the goal of reducing CO_2 emissions by approximately 20% of 1988 levels by the year 2005, and an ultimate reduction of 50% some time during the next century (World Meteorological Organization, 1989).

These calls for policy response have focused mostly on the need to reduce anthropogenic greenhouse gas emissions in order to limit, or at least delay, global warming. Less attention has been given to the question of whether systems for managing climate-sensitive resources such as water and forests can adapt to changes anticipated over the next few decades. Better understanding of adaptive potential is important because some climate change is likely in the near future even if greenhouse gas releases are reduced immediately (Jones et al., 1988). Due to past releases of greenhouse gases and to the thermal inertia of the atmosphere-ocean system, we are already "committed" to some degree of global warming.

A Resource Planning Conundrum

The greenhouse effect thus presents environmental managers with a unique planning conundrum. On one hand, global warming may have drastic and irreversible effects on resource systems being designed and implemented today, and anticipatory, rather than reactive, adjustments may be needed to ameliorate future impacts. On the other hand, predictions of global warming con-

tain a great deal of uncertainty, and scientists continue to debate the rate, spatial distribution, and physical details of greenhouse effects, and to disagree over the strength of empirical evidence for global warming, as described later in this paper.

Nevertheless, resource planners may soon be forced by public and political pressure to take actions to mitigate future climate impacts before the uncertainty is much reduced. Legislation to reduce and prepare for the greenhouse effect was introduced into the U.S. Senate during the summer of 1988 (Senate Bill 2667, the National Energy Policy Act, cf. Congressional Record, July 28, 1988), and credible social institutions worldwide are calling for preparatory action to prevent and/or adjust to global warming (United Nations Environment Programme, 1988). The U.S. Environmental Protection Agency's reports to Congress on climate change effects (Smith and Tirpak, in press) and the potential for limiting global warming (Lashof and Tirpak, in press), will surely stimulate additional policy concerns.

In this policy environment, then, resource managers need to be aware of the greenhouse issue and of the research which is driving public concern. This paper is meant to inform water resource managers about some of the research on, and implications of, the greenhouse effect. It first describes recent studies pointing to global warming and identifies some of the strengths, weaknesses, and points of controversy in those results. It then describes how scenarios of future climate are created for use in

impact studies. Next, specific impact assessments focused on water resources are reviewed. Finally, a brief annotated bibliography is provided to give the water resource planner a further base in the relevant literature.