Letter Report Assessing the USGS National Water Quality Assessment Program's Science Plan

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Committee on Preparing for the Third Decade (Cycle 3) of the National Water Quality Assessment (NASQA) Program; National Research Council

LETTER REPORT ASSESSING THE USGS NATIONAL WATER QUALITY ASSESSMENT PROGRAM'S SCIENCE PLAN

Committee on Preparing for the Third Decade (Cycle 3)
of the National Water Quality Assessment (NAWQA) Program

Water Science and Technology Board

Division on Earth and Life Studies

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Dr. Marcia McNutt
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Dear Dr. McNutt,

In 2009, the U.S. Geological Survey requested that the National Research Council's (NRC) Water Science and Technology Board review and provide guidance on the direction and priorities of the National Water Quality Assessment (NAWQA) Program. This review would include perspective on past accomplishments and the current and future design and scope of the program as it moves into its third decade of water quality assessment (Cycle 3). In response, the NRC formed the Committee to Review the USGS National Water Quality Assessment (NAWQA) Program to address a set of tasks agreed upon by the USGS and NRC (see attachment B, roster; see attachment C, statement of task). The NRC's Water Science and Technology Board has a history of advising the NAWQA Program since its conception in the mid-1980s. This committee has continued that advisory role authoring a letter report on the initial Cycle 3 planning document, the Science Framework (*Letter Report Assessing the USGS National Water Quality Assessment Program's Science Framework* (NRC, 2010)). Based on advice contained in that letter report, input from stakeholders, and additional reflection from the NAWQA Cycle 3 Planning Team, the Science Framework evolved into the Cycle 3 Science Plan[1]. The Science Plan is the high level planning document that will guide the NAWQA program through the next 10 years of water quality monitoring.

Your letter dated December 14th, 2010 asked the committee to provide additional advice on NAWQA's progress in the Cycle 3 planning process, focusing particularly on whether the draft NAWQA Science Plan sets forth adequate priorities and direction for the future. We are responding to your request through this letter report, which partly addresses our tasks 1 & 4 (see attachment C) to provide guidance "on the nature and priorities of current and future water quality issues facing the nation" and "to review strategic science and implementation plans for Cycle 3 for technical soundness and ability to meet stated objectives." Our committee's final report, anticipated in the summer of 2011, will address the entirety of the statement of task.

[1] Available online at: (ftp://ftpext.usgs.gov/pub/cr/co/denver/NAWQA%20Cycle%203%20 Science%20Plan/). The Science Plan is a working document and is the basis for the NAWQA Cycle 3 program. The committee reviewed the version from November, 2010.

The Science Plan

Over the past 20 years, the nation has invested in the NAWQA program to probe the status of, trends in, and understanding of the nation's water quality. This investment in NAWQA has resulted in methodological advances (e.g., national sampling protocols, analytical methods, groundwater field investigative tools), conceptual and intellectual advances such as the development and implementation of predictive tools (e.g., models), and national syntheses of critical water quality topics. Now, NAWQA is the nationally-recognized program responsible for evaluating the nation's water quality. To continue this evaluation into its third decade, the NAWQA Cycle 3 Science Plan contains four goals: 1) ***Data Collection and Trend Assessment***, 2) ***Interpretation and Understanding*** of these data relative to land use and climate variability; 3) targeted studies for the ***Determination of the Cause-Effect Relationships of Multiple Stressors and Multiple Effects***; and 4) using these data, understanding, and relationships to ***Forecast Future Trends*** of pollutants under different scenarios of land use, climate, and resource management.

NAWQA is poised, both within the USGS and the federal government, to continue the requisite sampling of our nation's waters (Goal 1) to understand the interplay between the complex factors that affect water quality (Goal 2). The committee supports the continuation of these priorities including the choice of four major stressors (contaminants, streamflow alteration, nutrients, and sediment). Yet NAWQA is now also in a position to produce an even larger payoff. The program has reached a threshold in which the value of achieving Goals 3 (effects of stressors) and 4 (forecasting) is greater than that achieved by the sum of its parts. In other words, NAWQA has evolved from a water quality program emphasizing data collection and trend assessments to one that has the potential to predict and forecast pollutant occurrence and trends under multiple scenarios at nationally significant scales. The program's scientific investments are maturing, enabling NAWQA to move past the current water quality monitoring to understanding the dynamics of water quality changes and using that understanding to forecast likely future conditions. By building on and maintaining the foundation from Cycle 1 and Cycle 2, NAWQA should move into the arena of "dynamic water quality monitoring" (Box 1). These are advances that the nation needs and the committee strongly supports.

Box 1
Traditional Water Quality Monitoring vs. Dynamic Water Quality Monitoring

In Cycle 1 and 2, NAWQA assessed the status and trends of the nation's water quality through a "Traditional Water Quality Monitoring" approach or by collecting data at regular intervals using a combination of fixed site and rotational sampling strategies. A "Dynamic Water Quality Monitoring" approach would assess the dynamics of water quality changes in addition to status and trends by a sampling design adaptable in both frequency and location overlaid on the traditional fixed sampling strategy. For example, changing sampling frequency to capture the dynamics of wet or dry spells associated with El Nino/La Nina events. By selectively increasing temporal and spatial resolution when and where it is needed, dynamic monitoring contributes to understanding of complex water quality phenomena and allows improved forecasting of likely future conditions.

The committee compliments the NAWQA Cycle 3 Team for envisioning a bold plan for the coming decade, with priority placed on dynamic water quality monitoring. Also, this version of the Science Plan responded to the comments made by the committee in the first letter report (NRC, 2010). Yet the Science Plan needs to continue to improve its clarity and NAWQA should continue to enhance the effectiveness of its communication of the ideas noted above. Although explaining the importance of the Cycle 3 goals and how NAWQA intends to accomplish these goals is essential, it is also critical to explain *why* these goals need to be pursued. Specifically, the plan needs to clarify "Why the USGS?", "Why now?", and "Why NAWQA?" much like it was presented to the committee in the fall of 2010 (October 26th, 2010 open session meeting of this committee). Why dynamic water quality monitoring is important now, and why the USGS via NAWQA can achieve this needs further clarity in the document although the concept and the need is compelling. Including points such as the following will enhance the draft Science Plan:

- Simply maintaining traditional water quality monitoring will result in USGS lagging behind in providing the necessary science to solve the nation's water problems as population growth, changes in land use, and climate variability continue to stress our nation's water resources;
- Water resources problems need to be addressed through a systems approach by considering a range of effects on water quality caused by multiple stressors;
- NAWQA is uniquely positioned to lead the nation in a dynamic national synthesis of water quality information and understanding because it has infrastructure in place, interdisciplinary and collaborative experience, state-of-the-art analytical capability, and modeling capacity to do this work (NRC 2002; NRC, 2009);
- NAWQA provides unique management-relevant assessments and tools within the public domain and has developed the capability and coordination to get needed science to decision makers (USGS, 2010);
- NAWQA Cycle 3 and the corresponding Science Plan are an excellent investment for the nation because Goals 3 and 4 provide considerable added value and logically evolve from the work proposed in Goals 1 and 2.

Outputs and Potential Outcomes

NAWQA's Science Plan has four goals, with objectives under those goals. The Science Plan should identify key expected outputs (the products) and potential outcomes from each objective. Outputs and potential outcomes are identified for the objectives under Goals 1 and 2. Outputs and potential outcomes are described under Goal 3, but are not objective specific. Outputs and potential outcomes are not provided for Goal 4. Developing outputs and potential outcomes for each goal is viewed as critical for the science plan's implementation, to help frame the significance of dynamic water quality monitoring, and to help NAWQA allocate its resources effectively and efficiently over the next 10 years. To the extent possible, NAWQA should estimate when the potential outcomes are expected to occur. (The committee acknowledges that what is practical within a research-oriented product approach may be different from what is needed in a public information-oriented product approach.) Description of deliverables and their timing will help NAWQA implement its Science Plan and help its partners and stakeholders plan how and when they will utilize NAWQA's work. USGS should strive to make NAWQA data, synthesis, and model projections available to users as quickly as practical, increasing the usefulness and relevance of its work.

Trends vs. Dynamics

Traditional monitoring assesses change by periodic measurements (for example, in the same seasons) to establish baseline water quality attributes and their seasonal averages. Results from regular sampling in time can help identify periodic changes in the state of the system with some recognition of climate or other changes in water quality, but cannot lead to a more fine-tuned understanding of trends and why change occurs. For example, the cumulative effects of changes in climate on the spatial-temporal attributes of water quality and ecosystem response may be sudden and dramatic (Lipp et al., 2001). A wet period may be marked by greater than average frequency and intensity of sediment entrainment and transport, leading to higher nutrient, pesticide and pathogen loadings into a receiving water body. A dry or quiescent period would be marked by the subsequent biogeochemical transformation of these loads in the water-soil columns. A dynamic sampling strategy designed to capture specific events and changes and not designed to follow a strict periodicity, would be able to contribute to understanding the relationships of variable and multiple stressors and their effects.

As NAWQA moves forward with a more dynamic approach to its program, the distinction between sampling parameters for traditional water quality monitoring and sampling for dynamic water quality changes becomes more important. NAWQA has utilized a periodic approach in assessments of pesticides in hydrologic systems and found remarkable added value (Box 2). NAWQA leaders should continue to recognize that aquatic systems constantly fluctuate, rather than assume they operate uniformly such that sampling can be done only in a uniform way. As such, the NAWQA monitoring and modeling design should reflect a dynamic sampling strategy overlain on top of a periodic sampling design (Box 1 and 2). The dynamic part of the sampling design would be question based, supporting Goals 2, 3, and 4, whereas the traditional design maintains documenting long term trends in water quality (Goal 1). This pairing provides an opportunity for innovation through an adaptive monitoring system that follows some of the key questions in the Science Plan.

Box 2
The Importance of Sampling for Dynamic Water Quality Monitoring

Beginning in the mid-1990s, NAWQA collected samples and probed the presence of the insecticide diazinon in an urban stream. Diazinon samples were collected yearly, rather than the 4 year rotational sampling design commonly employed by NAWQA, during Cycle 2. NAWQA continued sampling as diazinon was phased out both in indoor and outdoor residential use in the early 2000s. NAWQA developed a reliable time-series model for assessing long term changes in diazinon concentrations as residential use declined. The model showed a rapid water quality response to eliminating outdoor uses in 2002 and a continued decline in diazinon concentration through 2004. Furthermore, NAWQA examined the results as if the 4 year rotational sampling design was employed, i.e., if the model was based on sampling every 4th year. The resulting trend indicated an *increase* in diazinon through 2004, rather than the decrease in concentration that actually occurred as a result of phasing out use of the insecticide.

SOURCE: October 26th, 2010, personal communication, Robert J. Gilliom.

Ecosystem Services

Aquatic ecosystems both impact and are impacted by water quality (NRC, 1995; NRC, 1992). By focusing on how water quality impacts ecosystems, the Science Plan addresses only half of the picture. Consequently, aquatic ecosystems only appear subjected to degraded water quality. The Science Plan should recognize that biogeochemical processes in aquatic ecosystems also condition the water quality in those ecosystems or explain that the biogeochemical processes that are characteristic of aquatic ecosystems in good condition help restore and maintain water quality, i.e., there are feedback loops in the system. In addition, the Science Plan presents human and ecosystem needs for water as though they are two separate issues. In fact, meeting ecosystem needs for water ensures the maintenance of biogeochemical processes that result in high quality water for humans. To be clear, the letter report is only suggesting that NAWQA acknowledge these feedbacks and synergy in the Science Plan, not to change priorities as they are currently listed.

Linking Groundwater and Surface Water

The NAWQA Program has progressed greatly in its understanding and simulation of surface water - groundwater interactions. The initial Cycle 1 study unit design in the late 1980s specified 69 surface water study units and 54 groundwater study units with little consideration for the interconnection between surface water and groundwater within a given study unit. With advice from the NRCs *Committee to Review the USGS National Water Quality Assessment Pilot Program* (NRC, 1990), the USGS adopted a more integrated approach with respect to surface water and groundwater interaction by implementing 60 "integrated" study units in Cycle 1. (As a result of budget cuts, the number was reduced to 42 and eventually phased out in Cycle 2.) It is proposed to replace the study unit design in Cycle 3 with Integrated Watershed Studies (IWS) for surface water and the Principal Aquifer (PA) as the organizing unit for groundwater. Although surface water and groundwater are not segregated as in the original (pre-1990) NAWQA concept in the Science Plan, NAWQA should remain vigilant to ensure the proper characterization of surface water and groundwater interactions and their effects on water quality within the new design.

Sediment

Excess sediments and turbidity are among the top ten causes of impairment in U.S. rivers and streams (EPA, 2009). The inclusion of measures of sediment transport and impacts in Cycle 3 is a much needed addition to the NAWQA program. In its review of plans for Cycle 2, NRC recommended the inclusion of sediments, recognizing that USGS was the federal agency with unique expertise to tackle this problem (NRC, 2002). Budget constraints prevented this addition from happening in Cycle 2. Taking advantage of technological innovations, in Cycle 3 NAWQA now proposes to use surrogate measures (for example, optical backscatter or acoustic sensors) to develop estimates of sediment transport using statistical software. This approach promises to be an efficient way to provide valuable water quality information (Gartner, 2002; Gartner, 2004; Gartner et al., 2001; Thorne and Hanes, 2002). Furthermore, coupling sediment characterization in river systems with the SPARROW model offers considerable promise for management applications. On a smaller scale, SPARROW has been used to assess where management interventions would be most effective in reducing sediment transport in Chesapeake Bay watersheds (Brakebill et al., 2010). Incorporation of sediment measures in Cycle 3 offers the promise of this kind of application for priority-setting at multiple and larger scales. The Science Plan would be improved if these applications were more clearly articulated.

NAWQA's Value in a Reorganized USGS

To enhance the work of the agency, the USGS is currently realigning its leadership and budget structure around interdisciplinary themes or mission areas related to the science strategy "Facing Tomorrow's Challenges—U.S. Geological Survey in the Decade 2007-2017" (UGSG, 2007). The 2009 NRC report, *Towards a Sustainable and Secure Water Future*, pointed out that critical water-related issues occur within most if not all new USGS Science Strategy mission areas (NRC, 2009). NAWQA is well positioned to contribute to these mission areas, building on its success in multidisciplinary efforts within the USGS over the last few decades (Box 3), but this is not well articulated in the Science Plan. A discussion in the spirit of and building from the examples listed in the following paragraph should be articulated in the Science Plan.

Box 3

"…every preceding chapter of this report notes examples of cooperative efforts. In the committee's view, NAWQA program staff have done an excellent job of establishing cooperative relationships within the USGS and external programs. These efforts have strengthened NAWQA and have improved the viability and visibility of the USGS as a whole."

SOURCE: Chapter 7 of *Opportunities to Improve the U.S. Geological Survey National Water Quality Assessment Program* (NRC, 2002).

A continued relationship between NAWQA and programs in the *Ecosystems Mission Area* would be valuable to the USGS. NAWQA has integrated ecological components with physical and chemical measurements with the co-location of ecological and water quality sampling sites (NRC, 2009). NAWQA science has enhanced understanding of the effects of urbanization, mercury, and nutrients on stream ecosystems through Topical Studies in Cycle 2. NAWQA is currently developing a "data warehouse" for biological information, in collaboration with other disciplines and programs within the USGS. NAWQA and the Toxic Substances Hydrology program (now part of the *Energy and Minerals, and Environmental Health Mission Areas*) have a long history of successful, joint collaboration (NRC, 2009; NRC, 2002). The USGS leads the way in identification, tracking, and doing research on emerging contaminants, a role resulting in part from collaboration between the USGS Toxic Substances Hydrology Program and NAWQA (Kolpin et al., 2002). A NAWQA-Toxics effort produced a set of three papers on Mercury Cycling in Stream Ecosystems that were published in the April 15th, 2009 issue of *Environmental Science and Technology* and are one of the most comprehensive studies of stream mercury dynamics. One of NAWQA's noted accomplishments has been the linkage of land-use to water quality conditions. In Cycle 3, NAWQA proposes enhancing its consideration of climate change issues and water. This could be particularly valuable to and invite important collaborative opportunities with the *Climate and Land-Use Change Mission Area*. And certainly, NAWQA's long-standing work in data integration, as well as its experience developing a data warehouse to provide accessible data to other agencies and the public, is relevant to the work of the *Core Science Systems* mission.

NAWQA program leaders should seek further opportunities for collaboration within the agency. For example, in the early days of NAWQA the program pioneered internal capabilities for database management, communications, and external coordination to meet program needs that were either not available or were insufficiently developed within the Water Resources Division or the USGS at that time. Since then, the USGS has developed some of these services and resources more fully and offers support to all programs within the USGS. After 20 years of NAWQA operations in parallel with these significant changes in USGS capabilities, particularly in the USGS Office of Communications, the committee sees value in NAWQA management revisiting the relative merits of using NAWQA program funds to handle communications and possibly other program support services instead of drawing on comparable services and resources provided at the agency level.

As noted, NAWQA has a history of working in the multidisciplinary, collaborative interface and could serve as a useful resource and model to assist in the realignment of the agency to multidisciplinary and cross-disciplinary missions. Although defining collaboration and listing partners is important to

NAWQA planning efforts, true collaboration begins with identifying common questions or goals shared with other mission areas and USGS programs. To be effective in this effort, NAWQA must more clearly identify how its goals are linked to the newly formed USGS mission areas framed from themes in the USGS Science Strategy. NAWQA should make a systematic effort to communicate its capabilities and potential value to the relevant programs and offices within the USGS through the Science Plan. These communications are a two-way street, opening up the possibility of improved coordination within the USGS and potentially greater use of NAWQA data and analysis by the other program areas. Furthermore, fiscal realities highlight the need to seize these collaborative opportunities within the USGS and the re-organization is a window of opportunity for this to be fully realized.

Conclusion

The NAWQA program has matured over its two decades and is at a point where it should not simply continue its previous work but should do the dynamic water quality monitoring that is proposed for Cycle 3. This is a compelling plan for the program that the committee strongly supports; in Cycle 3 NAWQA will advance the understanding of the dynamics of water quality change and forecast likely future conditions. The committee supports the Cycle 3 priority of dynamic water quality monitoring. The Science Plan is technically sound and the NAWQA program has the scientific capability to achieve the Science Plan objectives. Yet the concept of dynamic water quality monitoring needs further development in the Science Plan. For example, a strong justification for why dynamic water quality monitoring is important, why now and why the USGS via NAWQA can achieve this remains unwritten. Further defining program outputs and potential outcomes will also help frame the significance of dynamic water quality monitoring. Moreover, thinking through a dynamic, question-driven sampling strategy to execute this concept will serve the program well.

The committee stresses that the NAWQA assessment of the nation's water quality through the long term benchmark data collection should not be discarded because of program movement towards dynamic water quality monitoring. However, the need to not just collect data at regular snapshots in time and document trends, but to also capture attributes of the events that define the baseline trends so that we have not just trend identification but also an attribution aspect as part of the assessment, is clear. The dynamic sampling strategy is intended as a complement to help with the latter. It does not mean dispense with the baseline data collection. Indeed the way NAWQA could become a more credible source of assessment information is if it could not only provide a spatially explicit benchmark of changes in water quality parameters, but also through dynamic sampling provide an explanation of the trends related to stressors and active management activities. As the NAWQA program moves forward with dynamic water quality monitoring, the committee urges NAWQA to evaluate trade-off's associated with and to achieve dynamic water quality monitoring. The committee hopes that the implementation of Cycle 3 will provide further clarity with respect to priorities and trade-offs. Also, in the final report the committee will answer the statement of task in its entirety and also speak to a number of issues and related topics raised during the review of this letter and deferred to the final report[2].

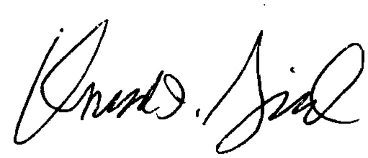
The NAWQA program has a history of working in the multidisciplinary interface, and this experience could benefit the USGS as it implements a re-alignment and in the face of certain fiscal

[2] Topics deferred to the final report include the history of NAWQA and what makes a national water quality assessment program, further probing priorities and trade-offs in light of current fiscal realities, a more detailed discussion of the technical aspects of the Science Plan, and a deeper discussion about internal collaborative approaches in light of the USGS reorganization.

realities. But again, the Cycle 3 Science Plan does not adequately describe how program goals are linked to not only the Water mission area but other mission areas in the realigned agency. NAWQA is a program of great value and strength to the USGS as the agency moves through this time of change, but the value and strength of NAWQA should be more fully articulated in the Science Plan. NAWQA should continue to seek collaborative opportunities within the agency and continue a common question and common goal oriented approach to collaboration.

Water availability, water use, and water quality will be among the nation's and the world's defining issues in the coming years. The interplay among water use, availability, and quality cannot be ignored: use affects quality and quality determines the availability of water for a particular use, including ecosystem use. The extent of water quality degradation from demographic and associated land use changes, agricultural chemicals, climate change, energy production, human use, and other factors must be characterized and quantified for effective water resources management. The NAWQA Program is looked to as a model for water quality monitoring outside the U.S. (Schindler, 2010). NAWQA is needed now more than ever to provide the scientific basis for wise management of water resources to provide clean water for humans and ecosystems and to strengthen the agency from within as it moves forward in this time of change.

Sincerely,



Donald I. Siegel, *Chair*
Committee to Review the USGS
National Water Quality Assessment
(NAWQA) Program

Attachment A: References
Attachment B: Committee Membership
Attachment C: Statement of Task
Attachment D: Acknowledgement of Reviewers
CC: S. Kimball & B. Werkheiser & D. Myers & S. Moulton & B. Wilber & G. Rowe

ATTACHMENT A

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ATTACHMENT B

COMMITTEE ON PREPARING FOR THE THIRD DECADE (CYCLE 3) OF THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

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ATTACHMENT C

STATEMENT OF TASK

The project will provide guidance to the U.S Geological Survey on the design and scope of the NAWQA program as it enters its third decade of water-quality assessments. The committee will assess accomplishments of the NAWQA program since its inception in 1991 by engaging in discussions with the Cycle 3 Planning Team, program scientists and managers, and external stakeholders and users of NAWQA data and scientific information. The committee will also review USGS internal reports on NAWQA's current design for monitoring, assessments, research, and relevance to key water topics. The main activities of the study committee will be to:

1. Provide guidance on the nature and priorities of current and future water-quality issues that will confront the nation over the next 10-15 years and address the following questions:
   - Which issues are currently being addressed by NAWQA and how might the present design and associated assessments for addressing these issues be improved?
   - Are there issues not currently being substantially addressed by NAWQA that should be considered for addition to the scope of NAWQA?
2. Provide advice on how NAWQA should approach these issues in Cycle 3 with respect to the following questions:
   - What components of the Program—Surface Water Status and Trends; Ground-Water Status and Trends; Topical Understanding Studies; National Synthesis— should be retained or enhanced to better address national water-quality issues?
   - What components of the program should change to improve how priority issues are addressed?
   - Are there new Program components that should be added to NAWQA to enable the Program to better address and analyze National water-quality issues and related public policy issues?
3. Identify and assess opportunities for the NAWQA Program to better collaborate with other federal, state, and local government, non-governmental organizations, private industry, and academic stakeholders to assess the nation's current and emerging water quality issues.
4. Review strategic science and implementation plans for Cycle 3 for technical soundness and ability to meet stated objectives.

ATTACHMENT D

ACKNOWLEDGMENT OF REVIEWERS

This letter report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We wish to thank the following individuals for their review of this report: Samuel N. Luoma, U.S. Geological Survey Emeritus; G. Tracy Mehan III, The Cadmus Group Inc.; Robert C. Ward, Colorado State University; Marylynn V. Yates, University of California, Riverside; and Jeanne M. VanBriesen, Carnegie Mellon.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Henry J. Vaux, Jr., University of California, Berkeley. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.