Desalination Research & Development
Workshop Report

PRESENTED BY
National Water Research Institute

IN COOPERATION WITH
United States Bureau of Reclamation

Kellogg West Conference Center & Lodge
California State Polytechnic University
Pomona, California

January 19-21, 2001

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FOREWORD

The National Water Research Institute (NWRI) was established in 1991 for the express purpose of creating new sources of water through research and technology. Since then, NWRI has engaged in research that has led to improving the level of understanding in membrane processes associated with desalting, desalination, and water reuse. As part of its strategy, NWRI has developed and sustained a program of collaborative research with the U.S. Bureau of Reclamation's Desalination and Purification Research and Development Program. A result of that collaboration was the establishment of the National Centers for Water Treatment Technology program, which is establishing a series of National Centers throughout the United States to carry out pilot and/or demonstration projects.

Launching a new period of collaboration, coincident with the new millennium, NWRI planned, organized, and presented this workshop to serve as the lead event in a collaborative research program with the Bureau. This workshop is a direct outgrowth of the Bureau's workshop, which was held in April 2000 in Golden, Colorado (*Growing the U.S. Water Supply Through Purification Technologies Workshop*).

As part of its research development process, NWRI has used the Nominal Group Technique (NGT), which it has refined and modified since 1992, to provide a forum for knowledgeable professionals to gather and deliberate significant water issues. The NGT method is an intensive experience and provides a rich and robust opportunity for participants to explore issues and reach consensus. The focus of this workshop was to address the question: What are the highest priority issues (scientific, technological, economic, environmental, and public policy) that need to be addressed now to speed the installation of cost-effective desalting/desalination facilities?

Part 1 of this document describes the results of the Working Groups that refined the information generated during the NGT component of the workshop. Each group prepared a report of the results of their deliberations from the initial issue identification phase of the workshop.

Part 2 reports the results of the consensus-building element of the workshop, which culminated in the consolidation of 96 issues identified by the participants. The fact that the participants were able to identify 96 issues demonstrated the significance of the workshop question from their individual perspectives.

This document reports the results of the creative efforts of all those who participated in the two-day event. The editorial staff exerted significant effort to maintain the integrity of each participant's contributions.

On behalf of the National Water Research Institute, sincere appreciation is extended to William S. Gaither, Ph.D., who masterfully facilitated the participants through the nominal group technique process to its final conclusion.

The success of the NGT workshop is in no small part due to the support provided by the professional staff. Special thanks are also extended to the Workshop Editors, Patricia Linsky and

Gina Melin; Word Processing Coordinator Tammy Dapkewicz; Joe Pezely, Graphics Coordinator; and his assistant Steve Lyon, who masterfully kept the flow of ideas in front of all the participants.

And a very special and sincere appreciation is extended to the all participants, many of whom traveled considerable distance to attend the workshop and share with everyone their wisdom and experiences.

Ronald B. Linsky
Executive Director
National Water Research Institute

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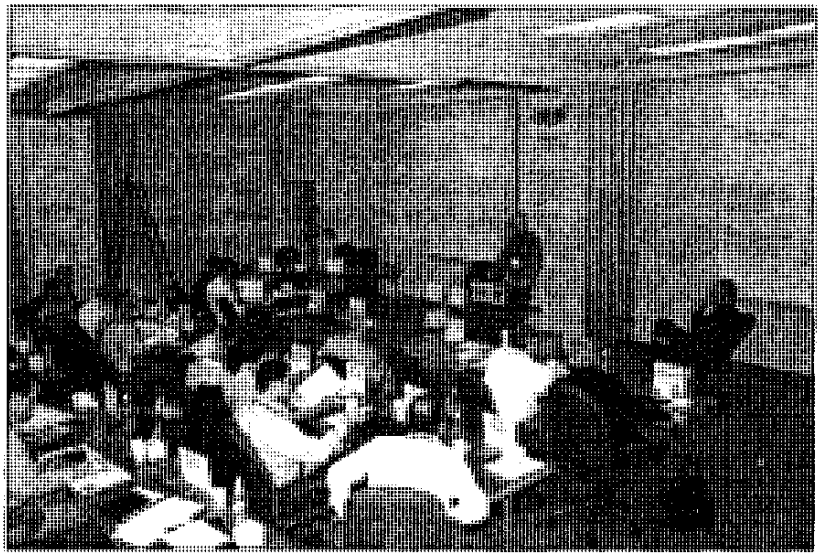
Participants

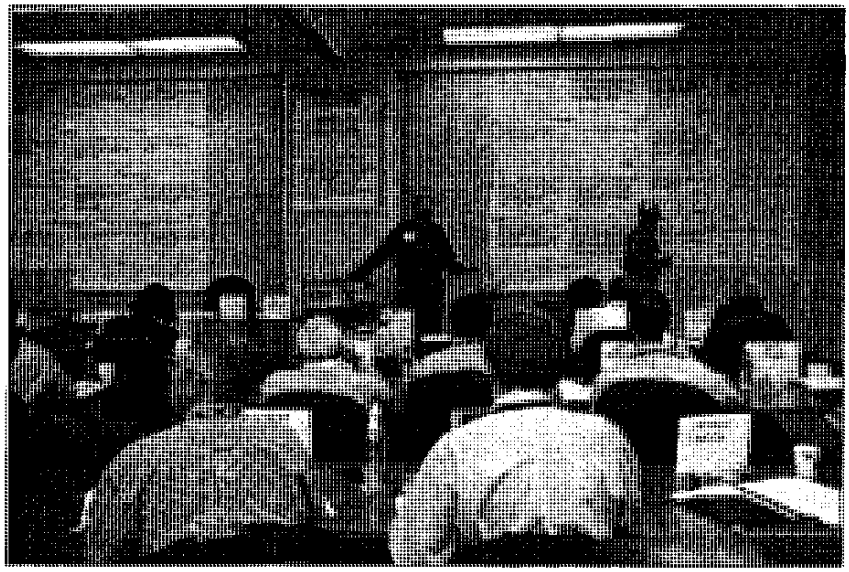
Top Row: Tim Williams (Word Processor), Michelle Chapman Wilbert, Doug Lloyd, Ariel Dinar, Ron Young, Jay Dusenbury, Jack Jorgensen, Dave Furukawa, Sandra Archibald, Rich Atwater

Standing: Bill Gaither (Facilitator), Rita Hintlian (Word Processor), Basil Sakr (Word Processor), Bob Carnahan, Randy Truby, Ernie Kartinen, Irv Moch, Ian Watson, Steve Lyon (Graphic Assistant), Joe Pezely (Graphics), Patricia Linsky (Editor)

Seated: Huali Chai, Dick Sudak, Bill Mills, Frank Leitz, Lynn Stevens, Bob Atlas, Tammy Dapkewicz (Word Processing Coordinator), Paul Shoenberger

Floor: Mark Clark, Gina Melin (Editor), Brad Coffey, Kevin Price, Jean-Daniel Saphores, Bob Riley, Bob Yamada, Ron Linsky (Secretary)





PART 1

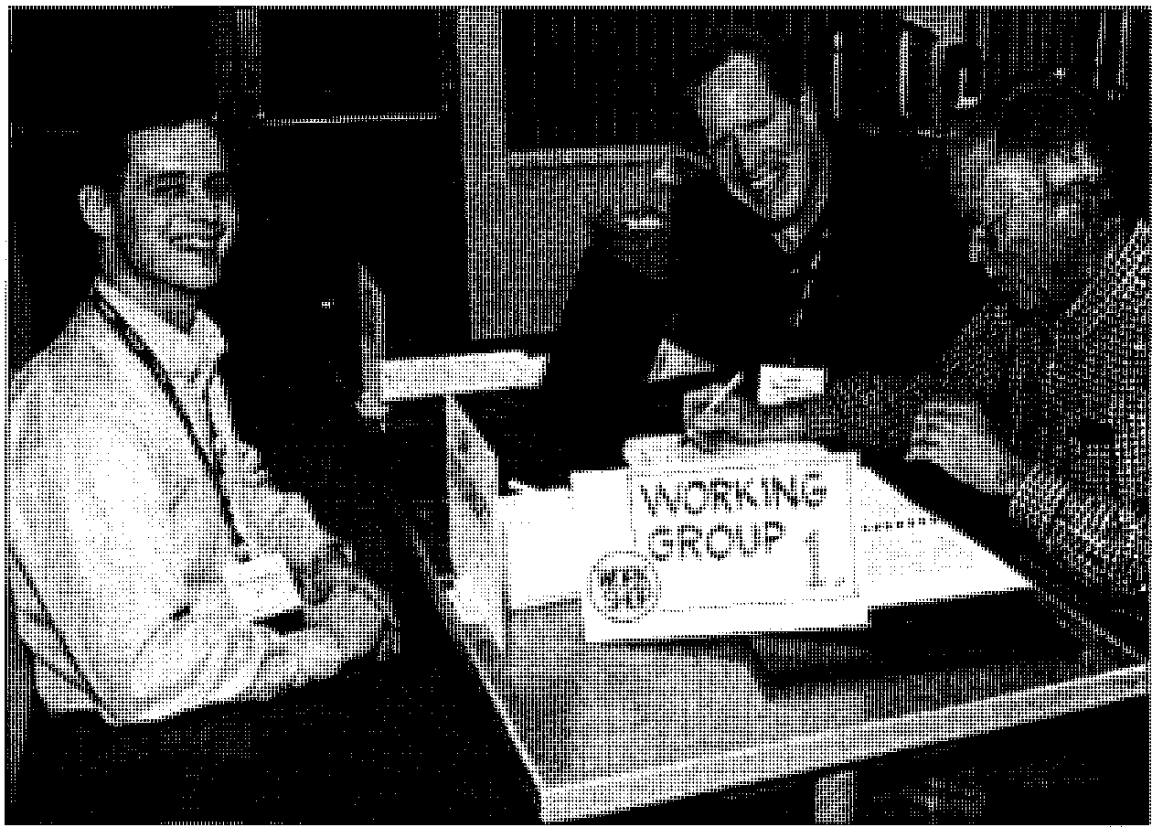
Working Groups' Reports

INTRODUCTION

Summary Descriptions of Highest Priority Issues (Scientific, Technological, Economic, Environmental, and Public Policy) That Need to Be Addressed Now to Speed the Installation of Cost-effective Desalting/Desalination Facilities

Following completion of the Nominal Group Technique (NGT) Workshop on Saturday evening, and the ranking of issues by the participants, the 10 highest priority issues were identified and posted on the workroom wall. Working groups were assigned to examine each of the issues that were consolidated under the highest priority major issue. The task of each of the working groups was to examine, digest, and synthesize the information contained in each of the write-ups from the NGT that had been consolidated under their priority issue. Following the process of mental digestion, the working group composed a succinct summary description that incorporated the most salient features of the NGT write-ups included in their assigned major issue. Working groups labored on their reports until late Saturday night and resumed their work the following morning.

On Sunday morning all participants re-assembled in the workroom to hear, and discuss, each working group report. Each working group was allotted 15 minutes to present their report and to provide time for discussion. Following each working group presentation, all participants were encouraged to submit written comments containing their observations and suggestions about how to improve, or modify, the working group report that they had just heard. Each signed comment is included immediately following each working-group report.


WORKING
GROUP 1

PRIORITY 1

Research and Development to Improve Membrane Process Technology

WORKING GROUP MEMBERS:

Dusenbury, Lyon, Riley, and Shoenberger

Issue Description:

The explosion of desalination over the last 10 years is primarily due to the rapid advancement of membrane technology and the development of better rejection, lower pressure, lower fouling, and increased recovery membranes. Membrane technology is now considered the best available water treatment technology for many water purification applications.

There exist numerous opportunities to further advance the performance of membrane process systems and treat a broader spectrum of source waters. There are two primary areas that need to be considered: first, a better understanding of membranes (e.g., construction, formulation, chlorine resistance) and, second, a fundamental understanding of the fouling process with membranes.

The current items of importance regarding membrane construction, formulation, and operation are:

- Reverse osmosis membrane and element development for improved flux and rejection of low molecular weight organic compounds of concern to public health regulators (e.g., assimilable organic carbon, nitrosidemethylamine [NDMA]).
- Antiscalent development to increase water recovery.
- Membrane physical and chemical modification to inhibit biofouling.
- Elimination of microbial passage or breakthrough.

The fouling process includes physical, chemical, microbial, and microbially mediated chemical fouling. By understanding what is happening at the atomic or molecular level, it is possible to develop strategies that can be applied at the macroscale. Further growth in desalination will be greatly enhanced by these additional advances.

***Rationale*:**

The development of improved membrane technologies will help to meet the potable water demands of burgeoning populations in water-limited regions of the world and meet more stringent future water-quality standards. Advances in the areas described under this topic will lead to a higher quality product water through a process that costs less to build, operate, and maintain and has improved long-term reliability.

Approach:

The approach to developing new membrane technology needs to be guided by an overarching strategy developed through a collaboration of government, industrial, research foundation, and academic partners. Research funding currently comes from a diverse variety of funding agencies. Under the current funding process, there are multiple funding sources of limited resources that only have the ability to fund short-term projects, which tend to fail in meeting long-term objectives due to the limited nature of the funding. More funding is necessary in the near future to implement desalination research and development. This should be accomplished through the development of a coordinated funding process established by a National Water Quality Improvement and Desalination Act.

The critical areas of desalination requiring immediate investigation are the topics described below, which are ranked by priority within their respective category, with the necessary level of funding identified for the next 5 years. A significant portion of this funding should be distributed under matching-fund programs to ensure the commitment of the partners within the research and development community. These areas fall into three main groups: membrane and membrane process development, improvements to reduce membrane fouling, and process control and quality assurance technology. Research includes:

<u>Membrane and Membrane Process Development ($15 Million over 5 years):</u>

- Develop a chlorine-tolerant desalination membrane for brackish water and seawater.
- Develop improved membranes for rejecting low molecular weight and small organic compounds.
- Develop chemical additives that become part of the membrane polymer to combat biofouling.
- Improve microfiltration (MF) membranes and process operations for reverse osmosis (RO) pretreatment.
- Improve the fundamental understanding of membrane manufacturing.

Improvements to Reduce Membrane Fouling ($20 Million over 5 years):

- Develop technology and techniques to reduce the fouling of membrane systems.
- Implement bacterial signaling compounds and biofilm-inhibiting compounds in the desalination process.
- Develop new feed spacer designs to enhance RO element efficiencies.
- Increase recovery of RO systems by evaluating and developing antiscalants.
- Improve the performance of reverse osmosis membranes with MF membrane pretreatment.

Process Control and Quality Assurance Technology ($10 Million over 5 years):

- Real-time or on-line monitoring of membrane integrity with regard to microbial removal.
- Real-time or on-line monitoring for microbial breakthrough.
- Encourage/accelerate a move toward standardizing MF/UF membranes.

Organizations Best Able to Address and Resolve This Issue:

The organizations most suited to administer the funding, coordinate, and manage the projects are:

- National Water Research Institute (NWRI)
- American Water Works Association Research Foundation (AWWARF)
- WateReuse Research Foundation (WRF)
- Water Environment Research Foundation (WERF)
- Electric Power Research Institute (EPRI)
- U.S. Bureau of Reclamation (USBR)
- U.S. Environmental Protection Agency (USEPA)
- Department of the Army
- Department of the Navy

- Department of Defense
- National Institute of Health (NIH)
- Department of Commerce (NIST)
- State of California Department of Water Resources (DWR)
- State of California Energy Commission

The organizations best suited to perform the proposed research and development are:

- Dow/FilmTech
- U.S. Filter
- Koch/Fluid Systems
- Hydranautics
- Separation Systems Technology
- Separation Processes Incorporated
- Orange County Water District
- West & Central Basin Municipal Water District
- University of Illinois, Urbana Champaign
- University of Texas, Austin
- University of Colorado, Boulder
- University of South Florida
- Montana State University, Center for Biofilm Research
- U.S. Army TACOM-TARDEC
- Bureau of Reclamation, Water Quality Improvement Center, Yuma

Comments:

"It would help to prioritize the programs in importance." – ***Robert Atlas***

"Funding for research and development to improve membrane and process technology should be addressed by a National Desalting and Water Quality Improvement Act (Priority Number 3). Through partnerships with the private sector and state and local government, the federal government can help intensify work in distinct technical areas and consolidate funding to achieve more efficient and powerful use of research and development dollars.

"It is also apparent that multiple federal agencies, including the military, possess knowledge and tested experience with diverse desalination methods, byproducts, and brine management, and that it is in the best interests of the public and private sector organizations to develop and engage in a thorough and practical sharing of their experience." – ***Huali Chai***

"Coordinate the pools of funding available in various federal agencies to make a larger sum of money available for research and development. Although a consortium (inter-agency) does exist, few outside the government are aware of its efforts or, moreover, of its accomplishments." – ***David Furukawa***

"More cooperative discussion should be done to develop research programs that support all sectors of government, university, and private industry." – ***Jack Jorgensen***

"Would it be possible to identify specific research projects, who might do the work, and what some idea of the budget and schedule might be?" – ***Ernest Kartinen***

"Good presentation." – ***Frank Leitz***

"Need an action plan to get funding and authorization from the federal government. Who will lead the effort?" – ***William Mills***

"I agree with the discussion that the 'how to accomplish this priority' is missing or needs more emphasis." – ***Irving Moch***

"This is an excellent list of priority target research areas that deserve attention for funding." – ***Ronald Young***


WORKING
GROUP

PRIORITY 2

Develop an Education and Public Relations Strategy to Facilitate the Implementation of Desalination Projects

WORKING GROUP MEMBERS:

Carnahan, Stevens, and Yamada

Issue Description:

This issue can be separated into the need for both immediate and long-term strategies.

There is an immediate need for strategies to educate the general public (including policy makers) regarding desalination and to develop a model of a local public outreach program to address specific project implementation concerns.

There is also a need for long-term strategies to address the continuing education of the general public, current and future engineers, designers, and owners and operators. This type of education could be achieved through the development of primary-, secondary-, and university-level studies and courses describing desalination technologies. Additional strategies could include expanding operator training and certification programs.

Rationale:

Public and political opposition could defeat the use of desalination. Without addressing these immediate issues, the public will be less likely to embrace the widespread application of desalination technology. In turn, without public acceptance, policy and decision makers will resist the implementation of the technology. There is an immediate need to dispel the myths regarding desalination, including the extreme misconceptions surrounding concentrate discharge and indirect potable reuse.

The public needs to better understand the true value of desalination, particularly its reliability and quality. Information regarding water quality, public health, cost, energy consumption, and environmental impacts need to be accurately portrayed to the public.

To sustain the ongoing development of desalination projects, it is essential to implement long-term strategies. Continuing education is critical to the emergence of new technologies as well as the evolution of existing technologies. This educational program would be designed to sustain a knowledge base regarding the technology.

Approach:

There is an immediate need to develop and implement public information programs to educate and inform the media, the public, and regulators of the real facts surrounding desalination technology. Specific strategies would be to:

- Develop a portable demonstration plant to show consumers how the technology works.
- Create public service announcements (e.g., television, newspaper, radio) to explain the technology and environmental impacts.
- Widely distribute publications such as *The Value of Water* (NWRI), *ABC's of Desalting* (International Desalination Association [IDA]), and *Desalting* Facts (American Membrane Technology Association [AMTA]).
- Develop a basic model that could be applied nationwide to communicate the real value of water, including desalted water.
- Develop a model local public outreach program that could be used nationwide to assist with the implementation of desalination projects.

For long-term strategies, specific actions would be to:

- Expand operator training and certification programs by working with professional organizations and universities.
- Develop a curriculum for the advanced training of engineers and scientists, which would include hands-on practical experience.
- Develop a curriculum for primary and secondary education students regarding desalination processes, focusing on a sustainable knowledge base for future generations.

Individuals and/or Organizations Best Able to Address and Resolve This Issue:

For immediate strategies, it will be necessary to work with a national public relations firm and national/international professional organizations (e.g., NWRI, AMTA, IDA, Southeast Desalting Association [SEDA]) to develop the messages and themes for the information that will be distributed to the public. In addition, it will be necessary to use these national advocacy

organizations to help educate specific groups, such as regulatory professionals and national policy makers.

Public relations firms, as well as local expertise, should be tapped to develop model local public outreach programs.

Look to NWRI to construct a working demonstration model of desalination technology.

For long-term strategies, look to existing education programs (e.g., the University of South Florida, University of Illinois, University of Texas) to develop curricula that could be applied on a wider scale. Look to professional organizations such as SEDA to develop training plans that could be expanded for nationwide application. Look to organizations such as NWRI to develop primary and secondary educational programs to educate students on desalting technology.

Comments:

"Need specific organizations to champion education – like water utilities." – ***Michelle Chapman Wilbert***

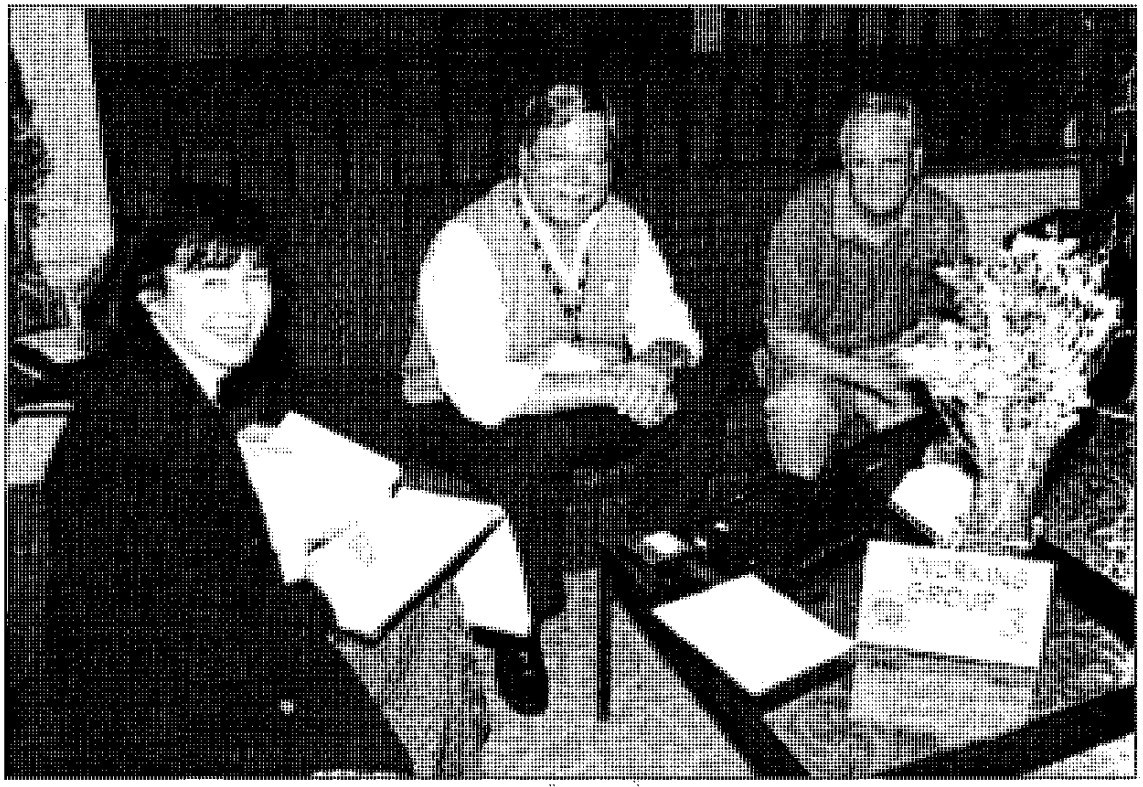
"Any education or public relations effort must be focused, as limited funds are available. Start with areas of most interest or with the greatest water problems." – ***David Furukawa***

"The NWRI videos have been very effective in educating school children on water issues. Schools will accept them and incorporate the water theme into their programs." – ***Jack Jorgensen***

"I suggest broadening organizations to 'educate' and then have them educate others. Be technically accurate, but not technical. Too technical would confuse people and, if they are confused, they will vote NO!" – ***Ernie Kartinen***

"This presentation provides a reasonable approach to a very wide and very important issue. Lack of funding may be a red herring." – ***Frank Leitz***

"A national program is quite ambitious and may be beyond the means of limited resources. The program needs to be focused to accomplish specific objectives." – ***Richard Sudak***



PRIORITY 3

National Desalting and Water Quality Improvement Act

WORKING GROUP MEMBERS:

Atwater, Chai, and Young

Issue Description:

A National Desalting and Water Quality Improvement Act would establish National Centers for Desalination Technology.

At present, government funding is inadequate to stimulate widespread research and development, testing, and implementation of desalination. The federal government has made the cost of water artificially low, thereby discouraging the development and use of new treatment technologies, such as desalination. Further, a Desalination and Water Purification Information Clearinghouse is needed to promote sharing of studies and experiences.

A National Center is needed to create a Desalination Research and Development Program and to provide federal financial support for desalination research and development, demonstration projects, and partnerships with private and public institutions and consortiums.

Cooperative research efforts should include investigation and analysis of desalination methods, longevity of materials, membrane cleaning and disinfection processes, operator-friendly materials and methods, and environmentally sound brine and desalination byproduct management.

A prime objective will be the construction of national seawater and other demonstration projects to test and illustrate the feasibility of desalination and to engender support for further desalination implementation.

Rationale:

Desalination and other water purification technologies have a significant opportunity to assist in meeting the United States' (and the rest of the planet's) water needs. Water purification and desalination technologies have the potential for application to a wide range of water quality

problems. Federal funding and coordination of basic research are critical components to advancing membrane and other potential desalination technologies. An Office of Water Research and Treatment Technology should be formed in the appropriate federal agency to coordinate all federal funding of water desalination technologies and to provide grants with non-federal partners (academic institutions, non-profit organizations, private industry and state/local governments) to develop practicable and cost-effective applications of desalination technologies.

In many regions of the United States, water quality problems and shortages of fresh water require the use of water purification technologies to meet the future water supply needs. Desalination would increase the water supply by allowing the use of poor-quality water or impaired sources of supply.

In addition, in the western United States salinity is a growing problem that requires the use desalination technologies and the management of salts to ensure the long-term viability of watersheds. Brine concentrate disposal and wastewater management of non-reclaimable water is a national long-term resource problem.

Seawater desalination has been viewed as an uneconomic and futuristic technology. But with a modest investment by the federal government in partnership with other public/private partners, there is a significant opportunity to advance the membrane and other desalination technologies for many cost-effective applications, including seawater desalting in coastal communities with limited alternative water supply options.

The Centers for Water Research and Technology also would include a federal information data clearinghouse for all water purification treatment technologies.

Similar model: U.S. Department of Energy (DOE) research program on renewable energy and micro turbines and other energy generating technologies. The DOE/General Electric micro turbines partnership (approximately $200 million in research and development funding) is an example of the potential benefit of this federal investment.

Approach:

- An Act of Congress to create the Office of Water Research and Desalination Technology (OWRDT).

- Title I – Create National Centers for Desalination Technology (NCDT) using Private-Public Partnerships to develop, test, and certify desalination and water purification technologies. The Centers will be in regions to emphasize desalination of seawater, brackish water, surface water and wastewater. Fund four centers at $20 million each.

- Title II – Support NCDT with basic research and development projects for 10 years. Fund projects at $3 million per year with equal matching funds from private sources and outside research agencies.

- Title III – Desalination Demonstration Projects. Develop at least 4 full-scale demonstration projects to showcase seawater, brackish water, surface water and wastewater desalination using state-of-the-art technologies. Authorize $200 million for design and construction, including a National Seawater Demonstration Project. Operation will be cost shared with local partners.

- Title IV – Develop Applied Research Projects for the application of technology to purify drinking water with emphasis on removal of contaminants, such as arsenic, perchlorate, etc. The purpose is to demonstrate "cutting edge" treatment technologies through full-scale operation to meet specific water quality goals. Authorize at least 10 projects with target pollutants for small to large utilities with $20 allocated.

- Title V – Desalination and Water Purification Information Clearinghouse. Establish an information clearinghouse for desalination technologies available to policy makers, scientific communities, and the public. Authorize $3 million per year.

- Title VI – Wastewater Recycling Treatment Technology Demonstration Projects. Authorize at least 4 projects, $100 million for design and construction. Local sponsors would be responsible for operations.

- Title VII – OWRDT – Develop regulations to coordinate environmental and desalination byproduct management approvals for project implementation.

Individuals and/or Organizations Best Able to Address and Resolve This Issue:

Congressional representatives and key committee members with support from all the water, wastewater, desalination and membrane professional organizations. Environmental groups and both federal and public research agencies:

- Senator Harry Reid, Nevada

- Senator Paul Simon (Ret.) So. Illinois University, Public Policy Institute

- Ian Watson, American Membrane Technology Association

- Patricia Burke, International Desalination Association

- Ron Young, WateReuse Research Foundation

- Ron Linsky, National Water Research Institute

- Jim Manwaring, AWWA Research Foundation

- Chuck Noss, Water Environment Research Foundation

Comments:

"The Act should feature desalination technology, not desalination. Various water quality problems (e.g., radon, arsenic, THM's, nitrates, NOM, etc.) exist throughout the United States. Forms of desalination technology can solve these problems." – ***David Furukawa***

"How do you answer the charge that desalination is a mature technology and that research, development and demonstrations should be supported by the manufacturers and users?" – ***Frank Leitz***

"Add Sen. Domenici (we are in a new Republican administration) who has shown interest. Also, include Sen. Durban who has expressed interest. He replaced Sen. Simon. Durban's staffer, who was following this, is Jim Jepsen." – ***Kevin Price***

PRIORITY 4

Develop a Comprehensive Framework to Guide the Decision-making Process for Potential Desalination Users

WORKING GROUP MEMBERS:

Chapman Wilbert, Coffey, and Saphores

Issue Description:

Alternative options to provide high-quality drinking water are frequently compared, yet there is no standard methodology for making such comparisons. A piecemeal approach—as opposed to a comprehensive analysis—may put desalination projects at a disadvantage because they are often compared with established projects for which some costs are omitted.

This project proposes the development of a comprehensive framework to guide the decision-making process for potential desalination users (i.e., public agencies, the desalination industry, and the public). The framework should include the following major elements:

- An integrated resource plan.
- A cost-benefit analysis.
- A sensitivity analysis (to highlight key variables and potentially future technological improvements).

Rationale:

Need for a Framework

Choosing an appropriate decision framework is critical in selecting the alternative that best meets the social, environmental, and financial needs of the community. When all costs and benefits are taken into consideration, the best option can be selected to meet the community's goals for sustainable development.

A framework is needed for evaluating competing water supply options. This framework would guide decision makers through the process of sorting out the economics, legalities, and environmental/technical/social implications of their choices. This framework would outline the steps that should be followed, their relative importance, and an estimate of the costs and time required.

There are different decision frameworks that can be used to guide public investment decisions. A cost-effectiveness framework implies that a goal has been selected (for instance, a given quantity of water of a specified quality will be delivered). If a membrane treatment process is indeed the least costly option, it will be selected. This framework is useful when benefits are difficult to quantify or when achievement of a given quality standard using that technology is mandated.

The alternative cost-benefit approach, suggested in this project, is preferred by economists for public investment decisions where benefits are weighed against costs of alternative supply options. Benefits and costs considered should include:

- Amortized capital costs.
- Operating costs.
- Waste processing costs.
- Environmental costs and benefits.
- Social costs and benefits.

For example, high salinity causes significant economic impacts for homeowners through corrosion and scaling of plumbing fixtures and appliances, as well as for agriculture, commercial and industrial processes. Recent studies have shown that salinity in the southern California region is increasing due in part to importing relatively high salinity Colorado River water with a total dissolved solids level (TDS) of 600 to 750 mg/L. It is estimated that for every 100 mg/L over 500 mg/L, coastal southern California incurs $95 million per year in damages to the public and private sectors. However, because this is a societal cost not borne exclusively by water agencies, the monetary benefit of TDS reduction is often not included in cost-benefit analyses. This is an example of an unanticipated cost that is often not considered when evaluating the importation of Colorado River water rather than the development of local water supplies. When a comprehensive cost-benefit framework is used in the decision process, these societal costs would be considered.

Integrated Resource Planning

Integrated resource planning is a way to collectively examine all available water resource options—both local and imported—together with conservation and reuse. The goal of an integrated resource plan is to develop a "roadmap," which meets a region's water reliability, water quality, and water affordability needs in an environmentally responsible manner.

Two primary steps are required during the preparation of an integrated resources plan. First, the potential shortfall between supply and demand (or the shortfall between predicted water quality and regulations) must be determined. Second, all possible resource options that could mitigate the quality or quantity shortfalls must be identified. In addition to exhaustive technical analyses, integrated resources planning must be an open and participatory process between all interested stakeholders, including the utilities, public interest groups, and regulatory agencies.

Cost-Benefit Analysis

Different approaches can be used to guide public investment. When a goal has already been selected, it is appropriate to try to find the least costly option to achieve it, i.e., a cost-effectiveness approach. This is useful when benefits are difficult to quantify or when a legal mandate must be met.

Whenever possible, economists prefer to employ a cost-benefit framework, which weighs benefits against costs for alternative supply options.

Several difficulties have to be overcome to properly implement a cost-benefit analysis. The first one is to properly identify all the benefits and costs that should be taken into account. At a minimum, these should include capital costs, operation and maintenance costs, transaction costs (e.g., permitting), external costs (e.g., environmental damages), and health costs.

The second difficulty is to identify all the relevant alternative options and to consider similar project lives, which often requires assumptions on options available in the future.

The third difficulty is to properly quantify *all* benefits and costs, which can be problematic in the presence of external costs. This is the case for environmental costs, which include the costs of withdrawing water from ecosystems, the costs of disposing of brines, and external energy costs. Quantifying environmental costs often requires using valuation techniques, such as the contingent valuation for the existence value of various ecosystems. Another category of difficult-to-quantify costs is health costs, which require estimating the occurrence of potential water diseases, the number of people that may be affected, and then translating this information into dollar amounts.

Finally, the fourth difficulty is to choose a proper rate of discount, adapted to the level of risk of the project considered, to discount future costs and benefits.

A properly performed cost/benefit analysis is always informative and helps organizing benefits and costs of a proposed project. Since Arrow and Fisher's work (1974), it is well known that a

standard cost-benefit analysis may be misleading in the presence of significant uncertainties and irreversibilities. It is thus important to incorporate new approaches that help mitigate this problem.

Sensitivity Analysis to Guide Technological Improvements

A well-formulated cost-benefit analysis allows decision makers to estimate the likelihood that technological advances could result in more favorable economics for desalination. The return on investment for technological advances can then guide decision makers to evaluate investments and risks of new technologies.

Often, however, the pursuit of technological advances precedes an understanding of how the value of the benefits can influence the overall cost-benefit analysis. For example, major technological improvements in membrane design or fouling control—though significant—may still be dwarfed by the energy or brine disposal costs.

Approach:

A blueprint should be developed that include guidelines and principles for conducting an economic/engineering research program.

A successful blueprint would include the following documents:

- Guidelines for decisions and investigations essential for successful water supply projects.
- Guidelines for process selection for different qualities of feed water.
- Standard specifications for hardware and materials used in construction.
- Guidelines on how to meet permitting requirements.

Realizing this blueprint would require the following research:

- Review current benefit/cost analysis frameworks and adapt them to desalination.
- Conduct an analysis of the environmental costs of desalination.
- Develop a framework for transferring estimates of environmental costs from one site to another.
- Conduct analyses of how to manage the risks of adopting desalination technology; a real-options approach appears promising.
- Conduct a study of the health risks associated with various sources of freshwater and ascertain the perceptions of these risks by the public.

- Review current practice and develop guidelines for performing sensitivity analysis for engineering projects, with an emphasis on water projects.

- Develop recommendations on how to streamline the permitting process for building desalination plants.

Individuals and/or Organizations Best Able to Address and Resolve This Issue:

This study must be completed under the direction of economists and planners who are experienced with the implementation of cost-benefit analyses. Technical experts must be used to evaluate both the costs of desalting and the economic damages associated with increasing salinity.

For cost-benefit analysis and various facets of water resources planning:

- Sandra O. Archibald, University of Minnesota (workshop participant)
- Ariel Dinar, The World Bank (workshop participant)
- Jean-Daniel Saphores, University of California, Irvine (workshop participant)
- John Boland, John Hopkins University
- Anthony Fisher, University of California, Berkeley
- Michael Hanneman, University of California, Berkeley
- Charles Howe, University of Colorado
- Richard Howitt, University of California, Berkeley
- Greg Poe, Cornell University

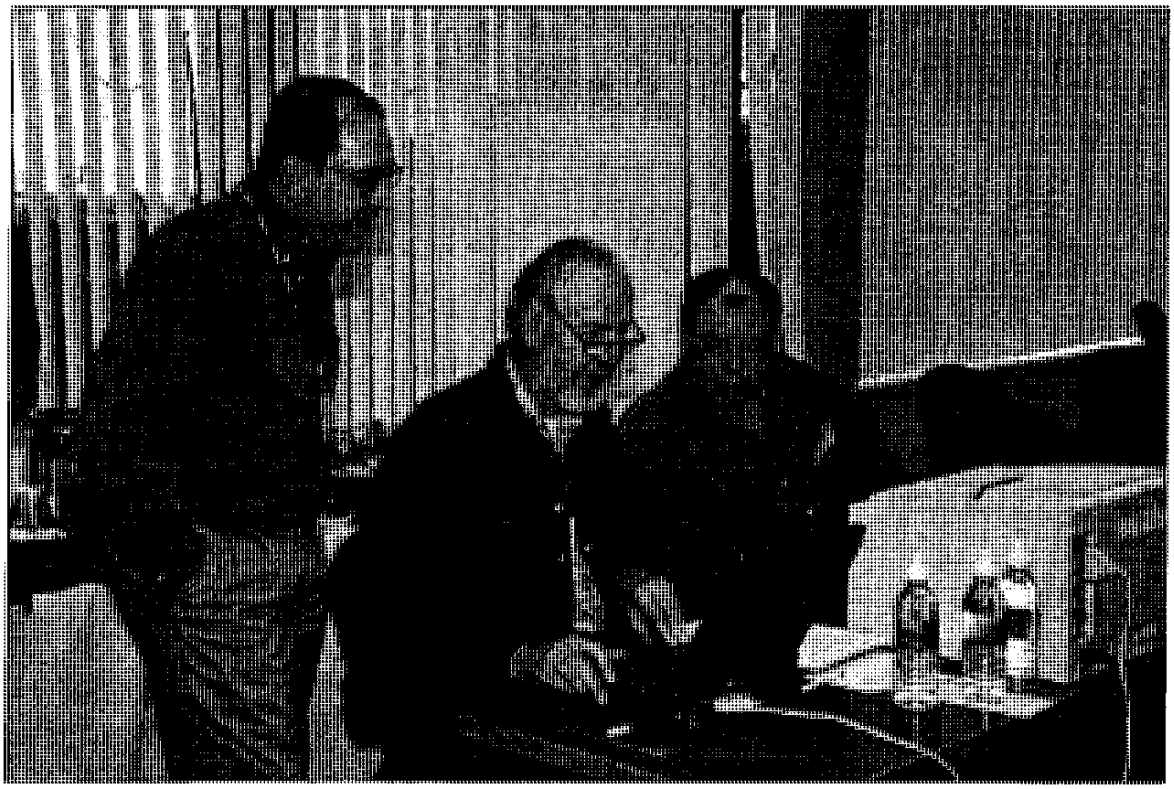
For real options:

- Michael Brennan, University of California, Los Angeles
- Eduardo Schwartz, University of California, Los Angeles
- Robert Pindyck, Massachusetts Institute of Technology

Note that this is by no means a comprehensive list of individuals who could contribute to this effort.

Comments:

"Much better title. The objectives of the program are very reasonable." – ***Frank Leitz***



PRIORITY 5

Concentrate and Waste Management

WORKING GROUP MEMBERS:

Dinar, Leitz, and Truby

Issue Description:

When dissolved and suspended materials are removed from water, they are generally left in a concentrated solution. This solution must be managed in an environmentally sensitive and acceptable manner. Presently, concentrates are returned to the feed source away from the intake (be it an ocean, lake, river, etc.); sent to another tributary; deep-well injected away from the potable water aquifer layer; land filled, or evaporated.

Many inland communities do not have large amounts of water available and do not like to consider treatment methods that recover only 70 to 75 percent of the feed water as product. The development of inland desalting facilities is constrained by the availability of environmentally acceptable concentrate disposal options. The primary concern is the contamination of local fresh water, surface water and/or groundwater supplies by the concentrate. Currently, the feasibility and cost of concentrate disposal options remains one of the largest unknowns for inland desalting facilities.

Disposal of this concentrate potentially can create a negative impact and cause irreversible externalities (e.g., environmental/aquatic, human health, soil, etc.). State and federal regulations indicate that the concentrate is, or at best may be, harmful and, thus, onerous concentrate disposal restraints have been imposed. Toxicity information is scarce, and available information is disorganized. It is critical that the issue of concentrate disposal be addressed immediately to maintain the viability of the technology.

In addition to addressing discharge issues, the waste of water inherent in concentrate disposal can be reduced by using the concentrate stream for useful agricultural purposes.

The current criteria for the discharge of concentrate to surface water are based upon the toxicity of shrimp at 300 percent of discharge concentration. This organism may not be the best animal to use for testing due to its sensitivity. Studies should be conducted to identify the best indicator (chemical or biological) that reflects the true ecology of the receiving body. In addition, there is a need for better three-dimensional dispersion models that accurately predict mixing zones.

And, finally, an economic evaluation of the direct and indirect costs of all possible alternatives is necessary for the ranking and comparison under various conditions.

Rationale:

The application of inland desalination will be hindered, and eventually stopped, unless satisfactory ways are developed to deal with concentrates. Disposal of concentrates into the ocean continues to create concerns about environmental impact.

All desalination technologies concentrate the salts into a much smaller volume. Concentrate minimization has two goals:

- Increase the production of potable water.
- Reduce the cost of the ultimate disposal of the concentrate.

The treatment or disposal of this concentrate can be problematic depending on its volume and composition. Many inland locations do not have access to disposal alternatives, such as an ocean outfall. Therefore, these utilities must develop means to further concentrate desalting plant residuals. The cost of concentrating these residuals must be balanced against the cost of ultimate disposal.

Proper disposal of concentrate and waste streams is a consideration when permitting. It will prevent the shutdown of existing plants and will allow the technology to grow and continue to be used. Waste disposal can include cleaning chemicals. Additional knowledge and understanding will expedite the permitting process and improve the economics of any project.

Approach:

<u>Study Items:</u>

- Develop a database of past and newly developed research on the various disposal techniques and the negative impact of concentrate on human health. This work should include studies of salt-tolerant plants and crops that can grow in highly saline water (halophytes).
- Conduct a thorough study of the potential uses of the concentrated salts, beginning with the publication of a thorough literature search.
- Test spent cleaning solutions to determine if they contain hazardous materials requiring special disposal.
- Assess the cost of cleaning solution disposal.
- Evaluate the sensitivity of treatment costs (i.e., concentrating the concentrate) and disposal costs (i.e., building pipelines, deep well injection, etc.).

Action Items:

- Provide funding to municipalities to assess the impact on the environment of various disposal techniques.
- Target the development of concentrate treatment technologies, which are energy efficient and do not produce hazardous waste disposal problems
- Find energy-efficient methods for fully extracting water from the concentrate.
- Find markets for the solids (either mixed or separated) removed or recovered from the concentrate.
- Determine what are the most dominant aquatic species in fresh water, brackish water, and seawater and determine these species' sensitivity to concentrate. These studies would be conducted at the concentrations predicted by a dispersion model, which would predict the mixing of concentrate in the receiving water.
- Find the optimum ion balance for health, and fortify the concentrate (when necessary) so that it will be beneficial to marine organisms, people, and/or crops.
- Fund the investigation of suitable plant species, building on work already done in Arizona, California, and elsewhere. Follow by integrating this work with a paper study of food crop yields and biomass energy production to determine the make-up needs in both activities.

Education Items:

- Create a major educational program aimed mainly at the state regulators and the public to create acceptance of concentrate disposal options.
- Conduct a public campaign to inform the consumers of the results of the work.

Individuals and/or Organizations Best Able to Address and Resolve This Issue:

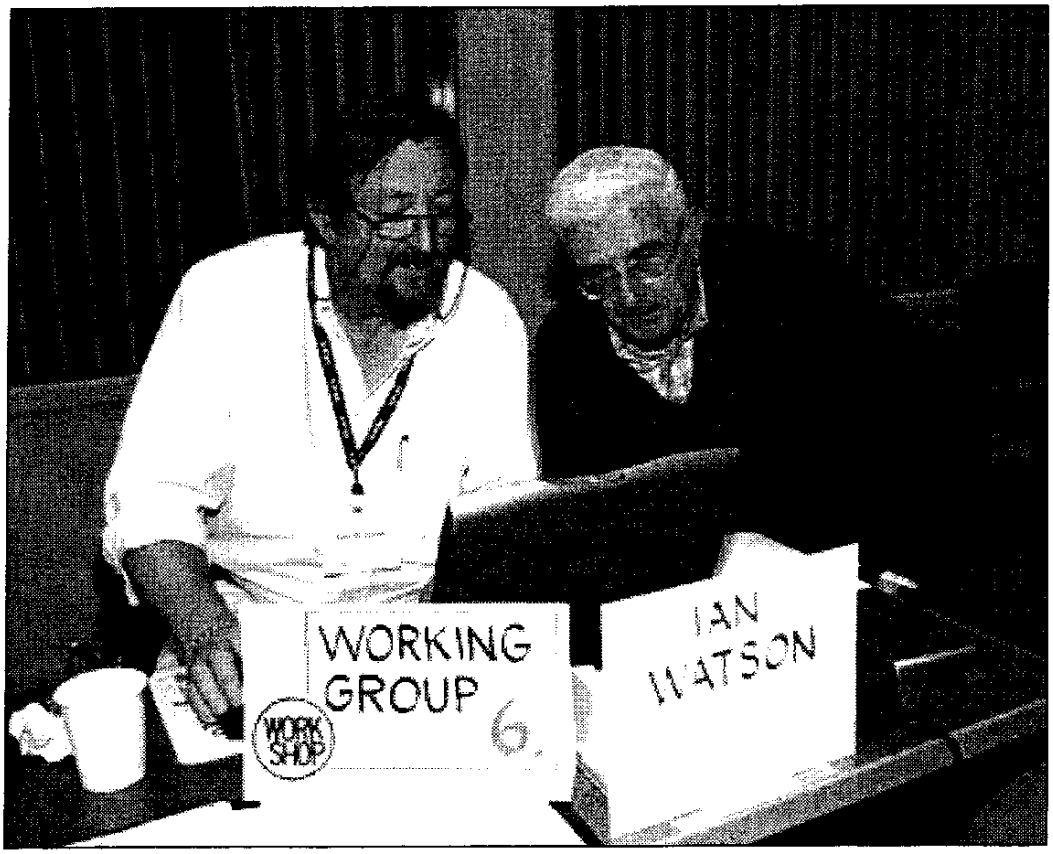
- Prof. John Letcy, University of California, Riverside, CA.
- Mike Mickley, Mickley and Associates, Boulder, CO.
- Dr. Michael Chervinka, Department of Water Resources, Sacramento, CA.
- Prof. Robert Carnahan, University of South Florida, Tampa, FL.

- Dr. Irving Moch, Wilmington, DE.
- Prof. Keith Knapp, University of California, Riverside, CA.
- Prof. Dennis Wichlnes, University of Rhode Island, Providence, RI.

Comments:

"Need to keep environmentally sustainable just to emphasize that the result of the studies will ease regulatory problems." – ***Michelle Chapman Wilbert***

"We should include subjects such as arsenic that, when extracted and concentrated, could become a hazardous waste. How do we dispose of this? Where and in what form?" – ***Jack Jorgensen***



PRIORITY 6

Energy Reduction for Desalination Plants

WORKING GROUP MEMBERS:

Moch and Watson

Issue Description:

Over 75 percent of the energy required for reverse osmosis (RO) desalination is associated with the high-pressure pump. This pressure is required to overcome the concentrate osmotic pressure. Further, plant recoveries have been limited to produce a concentrate quality of about 65,000 mg/L to maintain an acceptable product quality. Sixty to 80 percent of the residual energy in the concentrate can be recovered and reused in the process. Energy consumption for seawater RO and the amortized capital associated with energy recovery equal about 50 percent of the total water cost. Through the improvement of existing technology, or the development of new technology, the potential exists for a significant reduction in the energy costs.

Competing with this intratechnology development is the use of thermal desalination technology for either single or dual-purpose plants. Because of the energy savings inherent in the co-location of RO desalination facilities with power generation facilities, there is a pressing need for federal/state and third party agencies, such as NWRI, to encourage and participate in the development and implementation of efficient water/power facilities. Further, there is an urgent need to reduce the energy costs associated with desalination by RO and to mitigate the energy/water supply problems associated with events such as the current brownouts in California.

Importance:

- With 95+ percent energy recovery, combined with system recovery approaching 60 percent, the total cost of water could be reduced by about 20 percent.

- In seawater RO systems, a 50 psi pressure differential between the applied pressure and the concentrate osmotic pressure would lower the system feed pressure by 25 percent, and the water cost by 10 to 15 percent.

- For smaller RO systems, the efficiency of energy recovery devices is lower than for larger systems, ranging from 40 to 80 percent. If the efficiency of small devices could be improved

to above 85 percent, a significant reduction in water cost for small communities could be realized.

- In military ground-based operations, a major reduction in the energy requirement would significantly reduce the logistics burden involved in supplying the fuel necessary to produce the required energy.

- In the process of licensing new power generation facilities, the feasibility of co-locating desalted water production facilities should be considered from a cost/energy consumption perspective.

Approach:

- Pursue funding by federal, state and private interests for:

  - membrane improvements for flux and ion rejection
  - demonstration of energy recovery devices capable of operating at an efficiency of 95+ percent
  - pumping systems capable of operating at efficiencies in excess of 90%, independent of plant capacity
  - construction of a commercial facility to test and demonstrate the effectiveness of energy reduction developments

- Develop and implement a seminar series on membrane and thermal desalination plants, with associated economics.

- Develop an aggressive public relations campaign, coupled with an open access to the results of research and demonstration of energy reduction projects.

Individuals Best Able to Address and Resolve This Issue:

- Irving Moch
- Ian Watson
- David Furukawa
- Randy Truby
- Leon Awerbuch
- Ron Linsky
- Curt Keifer

- Bob Bergman
- Eli Oklejas
- Robert Oklejas
- Bill Weatherholt
- Chris Martin
- Kurt Frank
- Bill Surattt
- Sherman May

Comments:

"If we are to have a paradigm shift we cannot exclude any energy alternatives. Decrease in energy consumption should mean 'net' energy consumption. Energy recovery, energy generation and energy storage are all part of this problem" – ***Michelle Chapman Wilbert***

"I don't think there are 'paradigm decreases'. There are paradigms shifts and new paradigms, but no 'paradigm decreases', as far as I know. (This is an editing question.)" – ***Mark Clark***

"Chance of title is an improvement. Good Presentation of highly technological issue." – ***Frank Leitz***

PRIORITY 7

Look Outside-the-Box for Innovative Solutions

WORKING GROUP MEMBERS:

Atlas, Furukawa, and Jorgensen

Issue Description:

Technologists are blocked in by rules, guidelines, and regulations that inhibit their ability to develop ideas that are outside the normal realm of current science. To make significant strides in desalting technology, and particularly its cost effectiveness, unorthodox thinking is required – or thinking "outside-the-box." Examples of issue descriptions that entail thinking outside-the-box are given under Priority 7, which can be found in Part 2 of this report.

Rationale:

The desalination technology industry has not spawned out-of-the-box solutions for new and different technologies. Most innovations have been geared toward numerous small incremental changes, which in their totality are significant but, individually, limited in scope and application. If the goal is to take a significant step forward in desalting technology by making it simpler and more cost effective, new technology will have to be developed. Out-of-the-box solutions offer the best opportunity to achieve this goal.

Approach:

- Develop a strategic plan to develop advanced technologies in the long term to ensure that affordable potable water will be available for generations to come. The focus should be on a long-term, not short-term, approach that could entail high risk and potentially high reward.

- Secure significant funding that is a multiple times greater than previous allocations. Sufficient funds must be allocated to sustain this program for 10 years. Stakeholders, public and/or private, should match the funds.

- Establish a national group, such as the NWRI and/or in combination with other associations, to administer and manage the program. Select a team of advisors comprising forward-

thinking individuals who are not bound by convention and are experienced in the art of thinking outside-the-box.

- Create tax incentives to encourage participation by the private sector.

- Encourage the brightest and most capable scientists to work with each other. This could mean addressing the issues of intellectual property ownership to "level the playing field."

- Make the deliverables and milestones tangible – so that a product must be field tested as part of the funding criteria.

- Create a website-based-relational database that would contain summaries organized by technology, inventor, application, economics and performance.

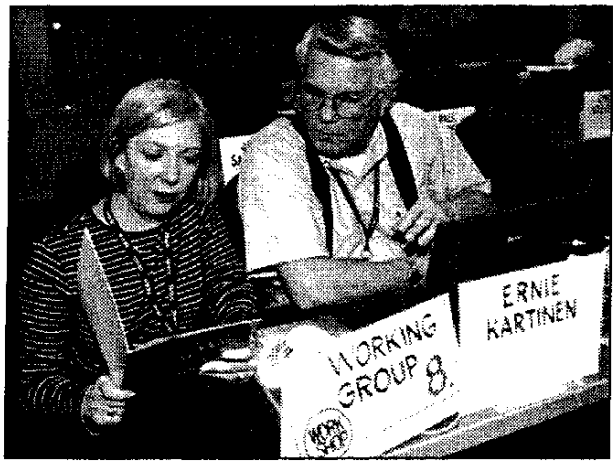
Individuals Best Able to Address and Resolve This Issue:

- Program Managers: Bill Warren, Dave Furukawa

- Innovators: David White, Robert Atlas, Douglas Lloyd, Ron Linsky, Bob Riley

Comments:
"Advanced technologies in developing countries are problematic. Technology there must be sustainable (e.g., field repairs, local materials) to be successful." – ***Brad Coffey***

"Remember the innovative work of C.M. Pleass and Doug Hicks, via the University of Delaware Sea Grant Program. Their work produced a long-stroke, high-pressure (800 psi) piston pump to drive seawater through RO units in remote locations. Their system could be installed in 50 to 100 feet of water by native divers. To avoid the high price of designing a system to stand up during extreme storms, Pleass and Hicks designed a 'weak link' connection between the surface float and the submerged long-stroke pump. The float, which extracted wave energy, was made of bundled coconut logs. The long-stroke, high-pressure pump was made from advanced high-strength plastics developed by the DuPont Company. Dr. Irving Moch is also familiar with Pleass and Hicks' work." – ***William S. Gaither***



PRIORITY 8

Determine the Value of Water for Different Water Uses

WORKING GROUP MEMBERS:

Archibald and Kartinen

Issue Description:

Value is not cost!

We need to develop a better understanding of the current (and future) value of water in its many uses. We should examine the value of water in producing different products in a more disaggregated way than we have in the past (e.g., the value of processed food versus alfalfa). The value of water varies widely across industrial, municipal, and agricultural uses. We have not acknowledged this in the past.

We need to understand that there is uncertainty about water use in the future. How do we model the value of the final products resulting from water availability in the future? Should there be "tiered water rates" so that the cost of water for a particular use is reflected in the value of that use?

Rationale:

Unless we know these values, we could legislate water allocations that lead to economic losses or economic disruption. These implications could affect local, regional, state, national, and/or global economies. The uncertainty regarding value leads to the potential for making poor investments in water projects. That is, we may under-invest in water supplies, including desalination. Including environmental and recreational benefits may make desalination a good investment.

Approach:

All uses of water have a value; however, some uses have more value than others. Consumer education and marketing must take into consideration who and what consumers want and are willing to pay for. Current prices do not reflect the real value of water. The state and federal

governments should support economic research on the uses and values of water. We need to develop "innovative institutions" to establish the value of water for different uses and develop tiered pricing mechanisms. Water markets can be useful allocation mechanisms, but they should include the secondary impacts on the environment and the local economy.

Economists have developed several methodologies for estimating the value of water. This should be a collaborative effort involving, economists, technologists, water purveyors, legislators, and consumers.

Questions that should be answered include:

- How do we incorporate the implicit value of food security?
- What is the value of water reliability?
- How does the value of water vary with quality?
- How much water (per person) do people need to survive – sanitation, cooking, etc.? The quantity of water needed for basic human needs is the "base line" for establishing a pricing system for water. This would be the first "water-pricing tier."
- How much are people willing to pay to wash their cars, water their lawns, fill their swimming pools, and other non-essential uses? These "discretionary" uses will vary by individual preferences and income. We need to know what people are willing to pay for water for these not-essential uses!
- How does the value of water vary by differing commercial and industrial uses (i.e., cost versus value of ultra pure water for the electronics industry)?
- What is the value of water for environmental and recreational uses?

Individuals and/or Organizations Best Able to Address and Resolve This Issue:

The following individuals would look at the value of water for its different uses; design appropriate tiered rate structures; and create rules for fair water trades and/or sales:

- Sandra O. Archibald, Ph.D. – University of Minnesota
  Agricultural water values
- Bill Wade – Foster and Associates, San Francisco
  Economics of industrial water use
- Ernie Kartinen, P.E. – Boyle Engineering, Bakersfield, California
  Cost of water (which is different than the value of water)

- Charles W. Abdalla, Ph.D. – Pennsylvania State University
  Economics of municipal water use

- Richard Bishop, Ph.D. – University of Wisconsin
  Environmental and recreational values of water

- Ariel Dinar, Ph.D. – World Bank
  Expert in water markets and pricing

- Jack Pandol – Agriculturalist, Bakersfield, California
  Agricultural water use and agricultural economics

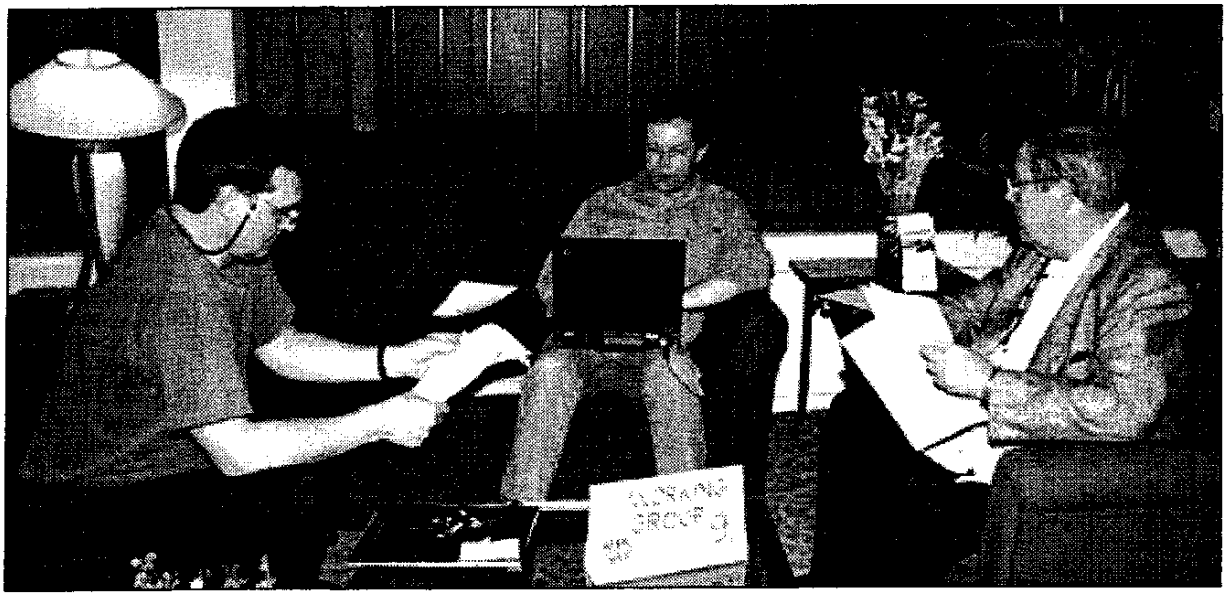
- Brad Coffey, P.E. – Metropolitan Water District of Southern California
  Cost of municipal water supplies

- Ron Linsky – National Water Research Institute

Comments:

"One issue to consider is to value water by prioritizing needs essential to a population (e.g., agricultural use; drinking water use may be valued less than washing a car). As water scarcity increases, how does water value change?" – ***Robert Atlas***

"Any study of the value of water that does not include adequate valuation of environmental water would be seriously flawed. The economic analysis should emphasize the importance to the public of instream flows, which maintain and enhance the aesthetic beauty of the landscape and the health of the ecosystem and which improve the water quality of lakes, rivers, and streams. In addition, it should fairly include the quantifiable commercial benefits that, ultimately, grow from improvements in environmental water supply and water quality." – ***Huali Chai***



PRIORITY 9

Improve the Fundamental Understanding of Membrane Science

WORKING GROUP MEMBERS:

Clark, Lloyd, and Sudak

Issue Description and Rationale:

Technology developed without a thorough comprehension of the underlying fundamental science will not progress at a satisfactory rate and cannot achieve its full potential. All aspects of membrane technology will depend on one or more of the following:

- Polymer materials science (chemical and biological affinity, chemical resistance, thermal stability, processability, etc).
- Transport phenomena (fluid flow and mass transfer within the membrane and within the module).
- Thermodynamics (solution thermodynamics, solute-solvent-surface interactions, etc).
- Chemistry (solution chemistry and surface chemistry).

Without a strong grasp of these subjects, the technological advances proposed in Priority 1 may never be achieved. Without the requisite scientific grounding, it may not be possible to identify and import into membrane technology the advances being made in other areas, as prescribed in Priority 7. Yet, little fundamental scientific research directed towards water treatment is being done in academia, and even less is being done in industry. Unless this situation changes, membrane technology is destined to progress at a slow, laborious, and inefficient pace through a series of incremental improvements based upon Edisonian experimentation and serendipity, rather than rapidly through significant advances. Unless the funding situation for academic membrane research improves, there will be no future generation of fundamentally trained scientists and engineers to advance membrane science and technology.

Approach:

Have NWRI establish a joint academic/industrial/user panel (see Priority 10) to:

- Identify barriers to increase financial involvement in fundamental research by industry, water districts, and agencies.
- Identify fundamental problems of interest to all membrane manufacturers and/or all membrane users.
- Prioritize the problems that have been identified.
- Identify individuals at universities, research institutes, government laboratories, and industrial laboratories that can work together to solve the problems identified above.
- Establish teams to conduct the research (through Call for Proposals).
- Establish a funding consortium with funding from the membrane industry, water districts, and agencies (government and private) to conduct non-proprietary research. The results of the research are to be made available to all of the funding companies and agencies prior to publication in the open literature.

Individuals and/or Organizations Best Able to Address and Resolve This Issue:

- North American Membrane Society
- NWRI
- American Water Works Association
- Membrane industry researchers
- Water district researchers
- Government research labs

PRIORITY 10

Establish a National Advisory Panel for Developing Water Purification Technologies to Increase Water Supplies

WORKING GROUP MEMBERS:

Mills and Price

Issue Description:

Nationally and internationally, additional supplies of water are required to meet population pressures. Current supplies of water have been fully developed, but are impaired, and other non traditional water supply sources need to be developed. These nontraditional sources include wastewater, brackish water, and seawater. In the past, several major federal programs, such as the Office of Saline Water (OSW) and the Office of Water Research & Technology (OWRT), provided ideas and solutions to increase water supplies, but those programs were discontinued many years ago.

Rationale:

The existing water supplies in the United States are under increasing pressure to meet the demands of a growing population, population movement to drier parts of the country, more stringent regulations, and the need to provide supplies for environmental and Native American needs. Meeting these demands requires looking at new water supply sources that have, in the past, been too costly to develop, such as waters of impaired quality, wastewater, and seawater. These supplies have not been cost effectively converted into municipal and industrial supplies due to insufficient knowledge and demonstration of emerging technologies.

What is needed today is a new, dynamic, and highly visible program of research, development, and demonstration projects to develop new sources of water. This effort should involve municipal, industrial, agricultural, environmental, rural, and academic sectors of our economy. Individuals and organizations from all these sectors need to work together to promote solutions to these problems.

Approach:

An advisory panel of 20 to 30 members should be created to review the state-of-the-art and current accomplishments in research conducted to convert impaired water supplies for potable or sub-potable uses. The panel would also discuss and recommend priority areas and topics and suggest how the additional research will be carried out.

Funding for this national effort, including the panel and research and development projects, could be accomplished through existing authorizations (e.g., the Desalination Act of 1996, etc.).

Individuals and/or Organizations Best Able to Address and Resolve This Issue:

Representatives from national agencies and associations involved with water supply management, as well as representatives from environmental groups, regulatory agencies, municipal agencies, manufacturers, architectural and engineering firms, Congress, and concerned citizens include:

- AWWA/AWWARF
- WEF/WERF
- NWRI
- WateReuse Association/Foundation
- AMTA
- National Rural Water Association (NRWA)
- National Water Resource Association
- National Science Foundation

These agencies should be contacted and encouraged to support this program. Because of its broad membership, the NWRI Research Advisory Board, and corporate affiliates, should take the lead.

PART 2

NGT WORKSHOP

INTRODUCTION

In the late 1960's, several University of Wisconsin Professors, led by Andre Delbecq, examined the dynamics of small meetings. Their goal was to design a practical method for a group of individuals to meet and quickly come to consensus on an issue that could not be resolved adequately by one individual. One result of their work was the Nominal Group Technique (NGT) that ensures that (1) the group will begin productive work immediately upon convening, and (2) that each individual's contributions will be heard, respected, and considered equitably by all members of the group

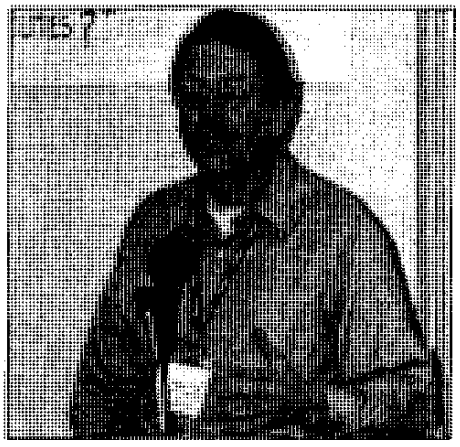
The staff of NWRI, and the U.S. Bureau of Reclamation identified experts in the field of Desalting/Desalination science, technology, economics, environment, and public policy. A list of workshop participants is given in Appendix C.

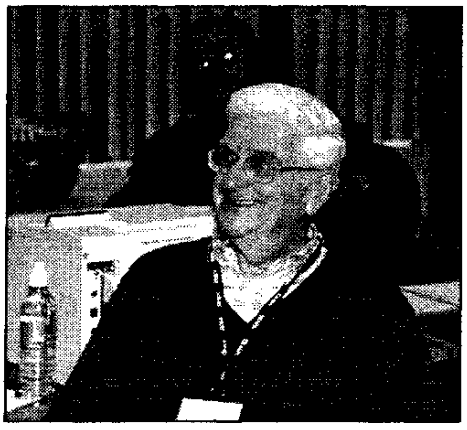
Before coming to the workshop, participants were asked to consider the question: ***What are the highest priority issues (scientific, technological, economic, environmental, and public policy) that need to be addressed now to speed the installation of cost-effective desalting/desalination facilities?*** Participants arrived at the Kellogg West Conference Center on Friday evening. Following dinner, participants took their assigned seats in the workroom. Workshop Guidelines and Procedures were reviewed, working forms discussed, and a detailed schedule of the coming day-and-a-half of work reviewed. Participants then returned to their rooms to prepare for Saturday's NGT session.

On Saturday morning, the NGT workshop began. It comprised three separate steps:

- Identification of priority issues
- Consolidation of issues into major issue areas to minimize overlap between the major issue areas
- Ranking of major issue areas in descending order of importance (individually ranked by each participant)

The 27 participants identified 96 issues during the morning. The workshop secretary and the graphics assistant contributed three of the 96 issues. The title of each issue proposed was hand-lettered on a large sheet of paper, numbered sequentially, the author's name noted, and posted on the workroom wall. After lunch, the participants were guided through a process of grouping each proposed issue into major issues. At the conclusion of this step, 18 major issues remained. Finally, each participant, acting alone, ranked his or her perception of the ten most important major issue areas in descending order of importance. Each participant signed his or her ranking form. Throughout the day, participants edited and approved text of their issue write-ups.





PRIORITY 1

Additional Advancement of Membrane Technology

Originators:

Shoenberger on behalf of himself, Clark, Dusenbury, Lloyd, Lyon, Mills, Moch, Riley, Sudak, Truby, and Yamada

The following issues were consolidated under the above title:

Title: **Additional Advancement of Membrane Technology**

Originator: **Shoenberger**

Issue Description:

The explosion of desalination over the last 10 years is primarily due to the rapid advancement of membrane technology and the development of better rejection, lower pressure, lower fouling, and increased recovery membranes. Further growth in desalination will be greatly enhanced by additional advances.

Importance:

Most desalination facilities produce water on the high side of the cost scale. To lower the cost, which will increase desalination use, additional membrane advances are needed.

How Do You Propose To Address This Issue?

Additional research and development in membrane technology is needed, especially in lower pressure membranes, higher percentage of product water, and low-fouling membranes. Federal and state funds are needed in this area.

Title: **Real-time or On-line Monitoring of Membrane Integrity With Regard to Microbial Removal**

Originator: **Clark**

Issue Description:

How do you know when a membrane has failed? How do you prove when it has fouled?

Importance:

Microbes cause disease.

How Do You Propose to Address This Issue?

Research funding for basic research.

Title: **Develop Technology and Techniques to Reduce Fouling of Membrane Systems**

Originator: **Dusenbury**

Issue Description:

Fouling of the membrane by inorganic, organic, and biological contaminants can reduce water production from a membrane system. This requires cleaning the membranes to restore product flow, which is a costly process and reduces production time, thus reducing the overall output of the system. Fouling eventually becomes so extensive that the membranes will need to be replaced, which is extremely expensive and a time-consuming process.

Importance:

Fouling of reverse osmosis (RO) membranes is the military's single-largest issue during the operation of water purification equipment. This is also a significant concern for commercial and municipal membrane facilities. Fouling reduces system performance and increases operation and maintenance (O&M) costs.

How Do You Propose To Address This Issue?

The Army has funded a significant amount of testing and evaluating methods to reduce fouling through the Operational and Cost Reduction (OCR) Program, including techniques to monitor the extent of fouling, to reduce fouling, and to develop better cleaning methods. The Army and Department of Defense Research Project Agency have also funded research to develop technologies to reduce fouling, including additional monitoring research and new membrane materials.

Title: **Improve the Fundamental Understanding of Membrane Manufacturing**

Originator: **Lloyd**

Issue Description:

The following are examples of issues related to membrane manufacturing, each of which needs a better fundamental understanding:

- Instabilities in hollow-fiber spinning lines lead to an average of 20 percent wastage in time and materials. Even when instabilities are minimized, they lead to variations in fiber dimensions, which cause flow problems within the membrane module and, therefore, inefficiencies. Unfortunately, no fundamental studies of instabilities in follow fiber spinning have been reported.

- Considerable research has gone into understanding the phase inversion or phase separation associated with membrane formation, but that is only the first step in making membranes. The subsequent exchange, extraction, drying, etc. steps have not been studied from a fundamental point of view. Consequently, every time a new membrane is to be developed, an Edisonian approach is taken.

- Many more examples could be listed.

Importance:

Improved understanding will reduce the cost of membranes currently in production and will reduce the start-up/development costs associated with bringing new membranes to the market.

How Do You Propose To Address This Issue?

Establish joint academic/industrial research teams to investigate the fundamental principles related to membrane manufacturing. Joint industrial/agency funding is needed. An interesting byproduct of these programs would be M.S. and Ph.D. researchers with the fundamental knowledge needed to develop new products in the future.

Title: **Implement Bacterial Signaling Compounds and Biofilm Inhibiting Compounds in the Desalination Process**

Originator: **Lyon**

Issue Description:

Bacterial signaling compounds are a recent discovery in the field of Microbial Ecology. The compounds tell or direct the bacteria to form or dissolve a biofilm on a solid surface. Biofilm inhibiting compounds do not kill bacteria, but merely stop the attachment of bacteria to a membrane.

Importance:

Fouling (physical, chemical, or biological) of membranes is one of the major impediments to reverse osmosis and other forms of filtration. Technologies can be implemented to inhibit biofilm formation by sending the signals that tell the bacteria not to aggregate or produce biofilms.

How Do You Propose to Address This Issue?

- Biofilm Research Center – Montana State University
- Water Resources and Technology Department, Orange County Water District, Fountain Valley, California

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Title: **Need for Improved Membranes for Rejecting Low Molecular Weight and Small Organic Compounds**

Originator: **Mills**

Issue Description:

Low molecular weight compounds and organic compounds are of great concern to public health regulators (e.g., nitrosodimethylamine [NDMA]).

Importance:

Without effective removal, additional and costly post-treatment is required, such as ultraviolet (UV), which requires large energy input.

How Do You Propose to Address This Issue?

Need research funding.

Title: **Develop a Chlorine-tolerant Desalination Membrane for Brackish Water and Seawater**

Originator: **Moch**

Issue Description:

Today, only two types of membrane polymers are commercially viable; one is a composite polyamide (CPA), and the second is a blended cellulose acetate (CA). The former has excellent rejection properties and flux, can operate relatively effectively at low applied pressures, and is long lived. The problem is that it is chlorine intolerant. Without chlorine, a most effective biocide, CPA plants cannot prevent the growth of microbes. CA polymers, on the other hand, can cope with low levels of chlorine and as such, when in use, can prevent biological contamination of equipment and water streams. However, CA is subjected to naturally occurring hydrolysis and is, therefore, relatively short lived. In addition, its ion rejections and operating pressures are not as good as that which is available with CPA. A new polymer is required, which has the pluses of CPA with a better degree of chlorine insensitivity than CA. Generally, those polymers being marketed as chlorine tolerant have inadequate ion rejections, flux, and/or stability.

Importance:

- Protects against biological fouling of equipment and water streams.
- Increases process availability.
- Reduces process costs by fewer cleanings and maintenance.
- Biological fouling is the leading cause for noninstitutionalized costs in a membrane desalting plant.

How Do You Propose to Address This Issue?

- Academic research with money funded by private interests and the federal government.
- Establish an independent oversight committee comprising private and government groups.
- Quarterly reports on results versus objectives to be the basis for additional funding.
- Open access to reports and meetings.
- Literature survey, in a data bank, of past research.

Title: **Develop New Feed Spacer Designs to Enhance Reverse Osmosis (RO) Element Efficiencies**

Originator: **Riley**

Issue Description:

The spiral RO element, developed in the 1960's, has greatly improved since. Today, several companies have automated their manufacturing processes. However, the feed spacer has not changed.

Importance:

Both operating experience and computer modeling have identified the inefficiencies of the current feed spacers. These include: poor mixing, dead flow areas, trapping of suspended solids, etc. All of these lead to decreased efficiencies in water production and quality.

How Do You Propose to Address This Issue:

The proposed approach is to use computer modeling to develop new spacer designs. The design selected must be capable of being manufactured at close tolerances.

Title: **Improve Microfiltration (MF) Membranes and Process Operations for RO Pretreatment**

Originator: **Riley**

Issue Description:

Fouling continues to be a major cost factor in RO processes. Large-scale MF has been demonstrated to be cost effective for RO pretreatment to minimize fouling.

Importance:

The development of large-scale MF for pretreatment is relatively new. There are relatively few options in the selection of MF membranes and processes today. The development of new MF membranes and process operations offers opportunity for quantitive improvements.

How Do You Propose to Address This Issue?

Develop new MF membranes and systems that are capable of operating at lower costs.

Title: **Improve the Performance of Reverse Osmosis Membranes With Membrane Pretreatment**

Originator: **Sudak**

Issue Description:

Membrane fouling is a key problem in desalination; with surface water, feed pretreatment is mandatory. Microfiltration has proven to be very effective (technically and economically) as pretreatment for municipal wastewater reclamation. It would appear also to be ideal for seawater pretreatment but has not been demonstrated.

Importance:

Poor pretreatment increases fouling, which increases operating pressures and the frequency of membrane cleaning. These are translated into increased costs for energy, down time, cleaning chemicals, and membrane wear.

How Do You Propose To Address This Issue?

- Develop new membrane for microfiltration of seawater, municipal wastewater, and other surface waters.
- Demonstrate existing membrane concepts on seawater.
- Improve competitiveness of microfiltration/ultrafiltration.

Title: **Increase Recovery of RO Systems by Evaluation and Development of Antiscalants**

Originator: **Sudak**

Issue Description:

Recovery of an RO system is the fraction of feed recovered as product. The lower the recovery, the greater the amount of feed that must be processed, and the greater the amount of concentrate that must be disposed to waste.

Importance:

Low recovery means higher energy requirements, higher pretreatment costs, and large capital costs due to greater feed processing requirements. Low recovery means higher costs for concentrate disposal, particularly in inland plants.

How Do You Propose to Address This Issue?

- Evaluate present-day antiscalants for acceptable limits.
- Encourage research of new antiscalants, particularly for silica precipitation prevention.

Title: **Develop Chemical Additives That Become Part of the Membrane Polymer to Combat Biofouling**

Originator: **Truby**

Issue Description:

Membrane fouling is a major operating cost and economic issue.

Importance:

Fouling causes people to lose confidence in the reliability of membranes.

How Do You Propose to Address This Issue?

Receive research funding from municipalities to create biofouling-resistant membranes.

Title: **Encourage/Accelerate a Move Toward Standardizing MF/UF Membranes**

Originator: **Yamada**

Issue Description:

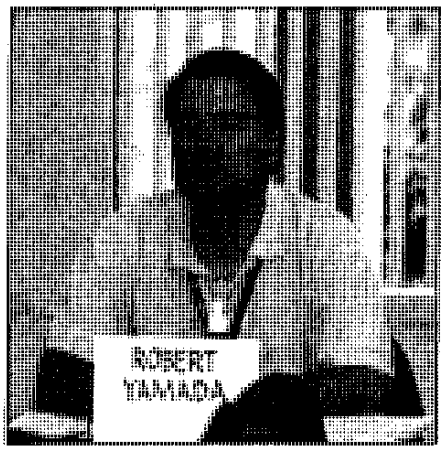
A lack of standards among these membrane types limits their implementation due to concerns over long-term maintenance and replacement.

Importance:

Standardizing these membrane types will encourage the implementation of the most advanced and cost-effective treatment equipment.

How Do You Propose to Address This Issue?

This is a difficult question. Somehow, we must bring competitors together to agree on standards.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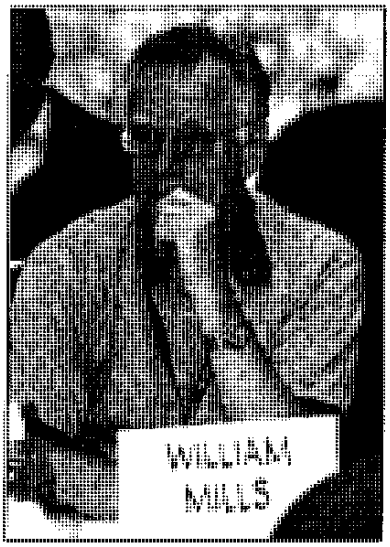
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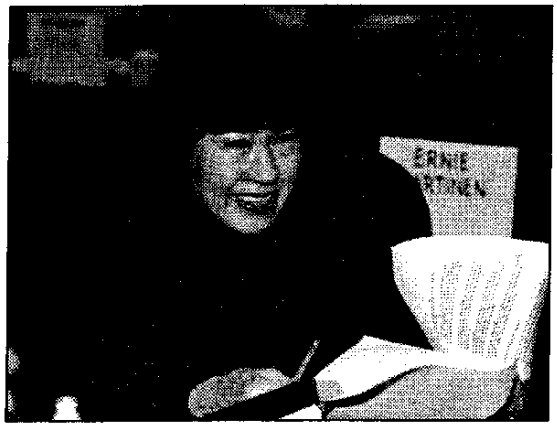
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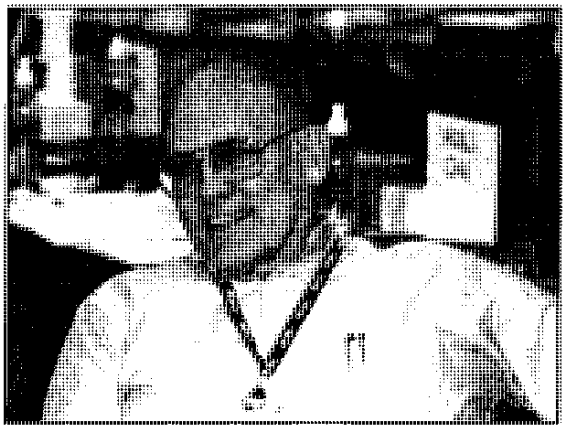


PRIORITY 2

Develop an Education and Public Relations Strategy to Deal With the Implementation of Desalination Projects

Originators:

Yamada on behalf of himself, Archibald, Carnahan, Chai, Clark, Furukawa, Jorgensen, Kartinen, Leitz, Mills, Price, Saphores, Stevens, and Truby

The following issues were consolidated under the above title:

Title: **Develop a Public Relations Strategy for Dealing With the Implementation of Seawater Desalination Projects**

Originator: **Yamada**

Issue Description:

As with the implementation of any new water supply project, there will be issues raised by the public that must be addressed in a credible manner. These issues include water quality, public health, cost compared to other resource options, and reliability.

Importance:

Given the number of proposed desalination facilities, it would seem appropriate to think ahead as to how to approach the public relations issues that will inevitably come up.

How Do You Propose to Address This Issue?

Bring together public relations experts along with potential implementing agencies.

Title: **"Embrace the Political Process"**

Originator: **Archibald**

Issue Description:

Engineers and scientists are not experienced in the political process. They may have some long-term relationships that have been productive, but those may not take us to next levels. Look beyond traditional relationships for new allies. Need to think strategically.

Importance:

Without intervention in the policy process (regulatory, research, funding), delays in adoption/technological change occur.

How Do You Propose to Address This Issue?

Get some training:

- American Association for the Advancement of Science (AAAS) provides seminars for scientists and engineers on science and technology policy, and working with Congress.
- There are courses in conflict reduction.
- Start an on-going dialogue with local, state and federal agencies and elected offices. Invite them to some of these sessions.

Title: **There Is a Need for Sustainable Knowledge of the Membrane Separation Process**

Originator: **Carnahan**

Issue Description:

Currently, there are few young engineers and scientists entering the desalting field. There are few institutions that have programs that permit students to develop knowledge of membrane separation processes.

Importance:

We need knowledgeable young engineers and scientists entering the field.

How Do You Propose to Address This Issue?

Create educational programs that focus on both supplies and basic principles. This can be done through educational programs and research. Provide scholarships for bright students.

Title: **Convince Public of the Safety of Water Treated by Desalination and Other Effective Technology**

Originator: **Chai**

Issue Description:

The press has, through phrases such as "Toilet-to-Tap," created a paranoia about the use of recycled wastewater for various purposes, including groundwater recharge.

Importance:

Public and political opposition could defeat the use of desalination, especially for treatment of recycled water.

How Do You Propose To Address This Issue?

Education about purity and safety of the product.

Title: **Explain Why We Should Speed "Installation of Cost-effective Desalting/Desalination Facilities"**

Originator: **Clark**

Issue Description:

Desalting and desalination are often applied to waters of marginal quality, sometimes in environmentally sensitive areas. Will speeding development of desalting/desalination speed environmental degradation?

Importance:

There is probably a significant psychological and ethical opposition to developing areas with marginal water quality; hence, there may be similar opposition to the speedy development of desalting/desalination.

How Do You Propose To Address This Issue?

Consider the ethical and environmental impact of water development in environmentally sensitive areas.

Title: **Portable Demonstration Project to Show Consumers How Desalting Works and How It Improves Taste**

Originator: **Clark**

Issue Description:

People that are used to poor-tasting water might be surprised at how advanced technologies can improve taste.

Importance:

Help consumers to accept new technologies!

How Do You Propose to Address This Issue?

Develop a portable demonstration facility and associated education programs.

Title: **Education: Dispel the Myths and Improve the Perception of Desalination**

Originator: **Furukawa**

Issue Description:

Educate the media, public, Congress, municipalities, and regulators of the real facts describing the desalination technologies. The propagation of myths and lack of facts reflect negatively on desalination.

Importance:

The public will not embrace desalination as a viable alternate source of water unless properly informed. The media is probably the single most offending segment.

How Do You Propose to Address This Issue?

Institute a national desalination education program.

Title: **Introduce and Define the Use of Desalting Technology for Extraction of Undesirable or Objectionable Substances Such As Extraction Technology as Opposed to Desalting Technology**

Originator: **Jorgensen**

Issue Description:

In areas of the United States where additional water supply is not a problem, but water-quality items are, it is difficult to obtain recognition and acceptance in discussing the solutions by using the term "desalting" when you are discussing an extraction problem as opposed to a water-production problem.

Importance:

The use of this technology for extractions is and will continue to grow.

How Do You Propose to Address This Issue?

Use terms as they apply to the actual use rather than as generic terms for applicable technology developed over the years.

Title: **Value Versus Cost of Water**

Originator: **Kartinen**

Issue Description:

Water is essential; therefore, it is priceless. Convince the government/public that seawater desalting is worth the cost.

Importance:

Without desalting, there will be economic and demographic disruptions.

How Do You Propose to Address This Issue?

An education program.

Title: **Public Acceptance**

Originator: **Leitz**

Issue Description:

There needs to be acceptance by the public of two major factors:

- High-quality potable water is a valuable commodity.
- The desalination processes now in use generate high-quality water.

Importance:

This is important because if there is no public acceptance of desalination, regardless of how one chooses to define that term, there is little chance that a facility that is apparently expensive to build and expensive to run will make it through the political process.

How Do You Propose To Address This Issue?

This is a matter of public education. The most effective channels of communication are the local television stations and newspapers. Unfortunately, this issue does not have the headline appeal of a massacre at the local K-Mart.

Title: **Develop Effective Public Education Programs to Educate the Public of the Safety of Indirect Potable Recycling Projects Using RO**

Originator: **Mills**

Issue Description:

The public has become increasingly concerned about the safety of ingesting foods and water, and are particularly concerned about "water from sewage" (Toilet-to-Tap); sewage to beverage.

- Northern California
- San Diego
- Los Angeles

Importance:

Indirect potable recycling projects have become difficult to implement due to public opposition (perhaps, generated by political concerns).

How Do You Propose to Address This Issue?

Public information programs include:

- Public relations people.
- A step-by-step program, perhaps with the WateReuse Association.

Title: **Improve Access to Desalination Information**

Originator: **Price**

Issue Description:

Many people are investigating desalination as a way to increase water supplies. Finding useful literature takes time if done without consultation with desalting experts.

Importance:

Decisions are quickly being made that are not based upon full information.

How Do You Propose to Address This Issue?

- Centralize abstracts of desalination literature.
- Develop a series of articles/lectures of lessons learned, starting with experiences of the desalination brethren/mafia.
- Develop list of spin-offs from desalination research (e.g., kidney dialysis, gas separations).
- Provide a list and full text of the 20 most important papers in desalination.

Title: **Survey the Importance of Water Public Opinion Polls**

Originator: **Price**

Issue Description:

The largest growth in beverages is bottled water. Is this only a matter of convenience or it is a symptom of the public's health concerns? In Canada, clean water is the public's priority issue over crime, etc. Are the issues of public health and water of greater significance than the water professionals believe?

Importance:

The public's perception/priority of clean water drives the market and should drive policy.

How Do You Propose to Address This Issue?

- Conduct surveys.
- If the public sees clean water as a top priority, hire a sociologist to study the phenomena.
- Use the results to assist in resolving the public's concerns.

Title: **Understand Public Health Risks and Risk Perceptions for Various Fresh Water Supplies**

Originator: **Saphores**

Issue Description:

There is a growing concern about the reliability of public fresh water supplies. This can be seen by the number of water stories in the newspapers, or by the rise of bottled water consumption, either in developed or developing countries (e.g., India). Different water supplies may have different health risks; for example, the risks of pollution from agriculture, municipal, or industrial sources are often higher for surface water and shallow groundwater. This has led the USEPA to require the construction of water filtration plants (or to study their construction as in New York City). Those costs are often not incorporated in the comparisons between various fresh water supply options. This could lead to incorrect decisions.

Importance:

This is very important for implementing an effective water policy.

How Do You Propose to Address This Need?

Assess the various health risks (i.e., probability of occurrence, number of people potentially affected) associated with various sources of fresh water, then cost out those risks based on costs of diseases or deaths. In addition, conduct a meta-analysis of surveys of public perceptions of the water supply.

Title: **Increase Training and Education of the Public, Regulators, Owners, Engineers, and Plant Operators**

Originator: **Stevens**

Issue Description:

Owners are hesitant to build. Regulators and politicians are hesitant to permit. These hesitations are reflected in public perception. I contend that mass education and training would produce acceptance by the regulators, politicians, owners, and the public. However, training will ultimately rely upon the engineering and daily operations.

Importance:

Radioactive waste is what the public fears most. The operating costs, or the perception of cost, seem to be another fear. The operating staff can "buy in" to reduce cost of daily operations and provide public education if they truly understand the concept. Engineers should be provided "hands on" training as part of their formal education, so they can build a better "mouse trap."

How Do You Propose to Address This Issue?

- Design educational programs for regulators and politicians. Outline the process. I think so many times we "expect" that regulators and politicians understand the process when they do not, and they will not ask questions for fear of appearing ignorant.
- Teach conservation at the youngest age in our schools.
- Train the facilities' operators after the dust settles. After all, they are the ones that can make or break a project.

Title: **Bolster Public Confidence in the Reliability of Seawater Desalination Plants Using Membranes**

Originator: **Truby**

Issue Description:

Most seawater reverse osmosis installations are located outside the United States. Misinformation or miscommunication about the reliability of these plants has resulted in low public confidence. There has also been miscommunication about water quality, costs, energy

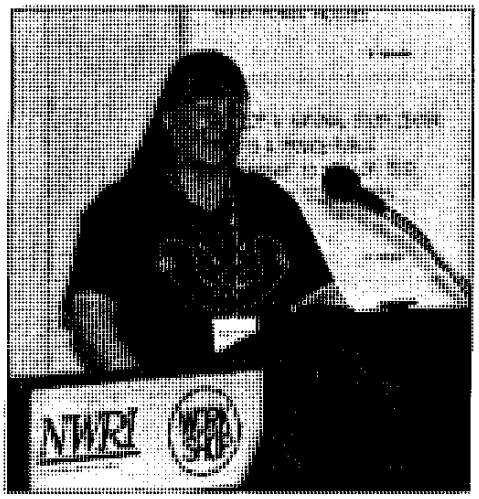
consumption, and environmental impact. Accurate information needs to be gathered and analyzed, and demonstration plants or facilities need to be built.

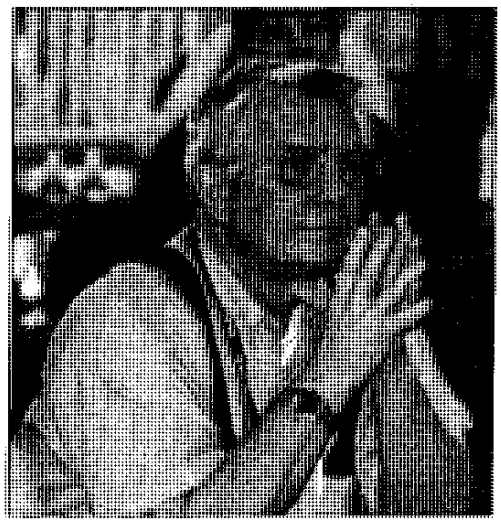
Importance:

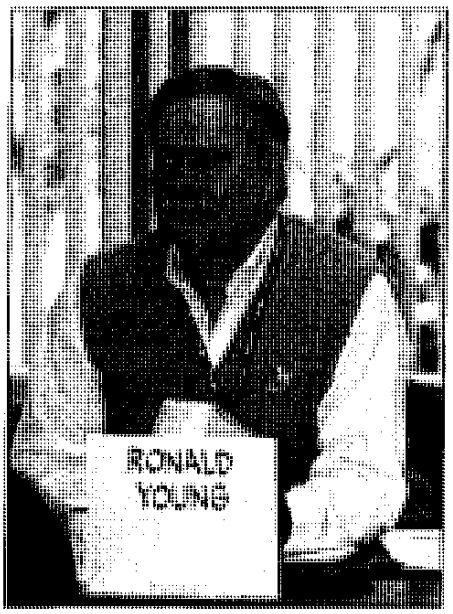
Seawater is the only source of new water. All other efforts revolve around conservation and reclamation. These programs must continue, but are finite. Seawater desalting adds to the water supply.

How Do You Propose To Address This Issue?

- Parametric studies of existing seawater reverse osmosis plants (outside the United States).
- Analysis of information with commentary on costs and reliability.
- Side-by-side testing/demonstration of reliable techniques and designs.



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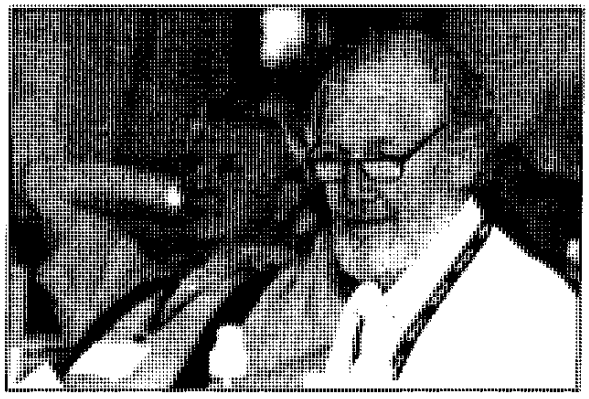


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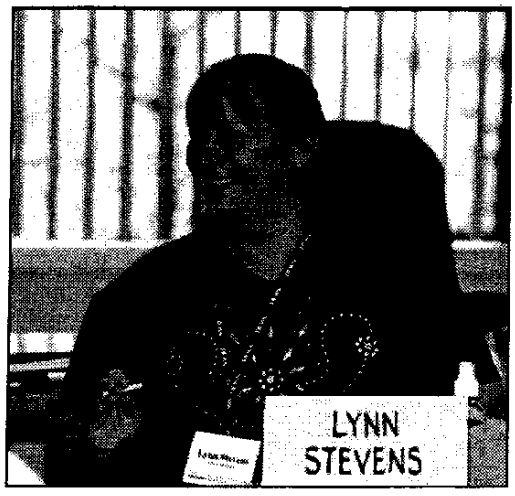
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PRIORITY 3

National Desalting and Water Quality Improvement Act

Originators:

Young on behalf of himself, Atwater, Chai, Kartinen, Leitz, Shoenberger, and Stevens

The following issues were consolidated under the above title:

Title: **Develop a National Desalination Act**

Originator: **Young**

Issue Description:

The Act can be used to establish a national water policy, streamline regulations for development, and provide funds for construction and research.

Importance:

The policy can set a national mandate while streamlined regulations can help with permits for brine disposal to speed-up project implementation.

How Do You Propose to Address This Issue?

Lobby the Congress with support from all water, wastewater, desalination, and membrane professional organizations. Also include environmental groups and both public and federal research agencies.

Title: **Federal Financial Support for Desalination Research and Development, Demonstration Projects, and Grants**

Originator: **Atwater**

Issue Description:

We need a federal clearinghouse for desalination technology with adequate financial support to leverage other funding (e.g., WateReuse Foundation, Southern California Desalination Research Investigation Participation [DRIP]).

Importance:

Need a federal research center and clearinghouse on research and development, training, and the application of desalination technology.

How Do You Propose Addressing This Issue:

- Congressional authorization recommendation: $25 million per year ($125 million for 5 years).
- Prototype example: U.S. Department of Energy and General Electric research partnership developing micro turbines.

Title: **Convince Water Policy Decision Makers That Desalination Technology Has Practical Potential to Solve Both Water Quality and Water Supply Problems**

Originator: **Chai**

Issue Description:

At present, government funds are inadequate to stimulate widespread research, testing, and the implementation of desalination and, further, the federal government has made the cost of water artificially low, thereby discouraging the development and use of new treatment technologies, such as desalination.

Importance:

In many regions, including the western states, it is apparent that problems of overtapped surface and groundwater supplies and deteriorating water quality cannot, in the long-term, be solved by traditional approaches. Desalination would increase the water supply by allowing the use of impaired sources and would improve water quality by decreasing salinity and disinfectant byproducts and other constituent loads.

How Do You Propose To Address This Issue?

The federal government should, through its national water policy and in its regional water planning efforts, provide significant additional funding for desalination research, pilot projects, and incentives to local agencies that incorporate desalination into their treatment regimens.

Title: **The Need for a State/National Water Policy**

Originator: **Kartinen**

Issue Description:

- Insufficient water:
  - contrived?
  - present – yes
  - future – worse
- Local concerns versus state/national concerns.
- Define "cost-effective" (Do subsidies really reduce cost?).

Importance:

Without adequate water:

- Economy declines.
- Negative health effects.
- Political unrest.

How Do You Propose to Address This Issue?

Need a state/nation water policy to:

- Maximize water supplies over planning area.
- Spread costs over planning area.
- Encourage seawater desalting by spreading costs.
- Overcome political/social concerns over reclaimed wastewater.

Title: **National Research and Development Program**

Originator: **Leitz**

Issue Description:

There are a number of scientific and technical problems in desalination. Resolution of these problems would benefit a large number of people, from manufacturers to operators to users. It would appear to be an appropriate use of federal funds to support cooperative research and development on these problems. We may also benefit from development/research on new processes.

Importance:

The failure to solve, or at least address, these problems would result in long-term excessive costs or the failure to install a plant in the first place. I foresee major requirements for additional water supplies. Progress is better and cheaper by long-term, low-cost efforts than by waiting for a crisis to occur and then searching for a solution, regardless of the cost.

How Do You Propose to Address This Issue?

Establish a long-term government program that will provide partial support for research, applications, and demonstrations in desalination. Only partial support should be provided to ensure that the organization proposing and performing the research has fully bought into the project and will make full use of the results.

Title: **Construct a National Seawater Demonstration Project**

Originator: **Shoenberger**

Issue Description:

Surface-, brackish-, and recycled-water desalination are all being implemented. The next source to be desalinated is seawater. I believe that the technology is available and that public and political support can be galvanized with a highly visible seawater demonstration project.

Importance:

Seawater desalination is still viewed as a futuristic technology and, therefore, is not attracting the political, public, and financial support that it should. Seawater desalination is our next water source, and efforts to develop it should commence.

How Do You Propose to Address This Issue?

A National Center for Water Treatment Technology should be set up that includes a seawater desalination plant. In southern California, the West and Central Basin Municipal Water District, Long Beach, and the Municipal Water District of Orange County may have interest in such a facility.

Title: **Develop a National Standard of Permitting for Desalters to Aid, Not Hinder, the Installation**

Originator: **Stevens**

Issue Description:

Each region of the USEPA, DEP, and/or HRS agencies interprets and applies numerous rules in different ways. The USEPA in one area of the country may be more understanding and open to permitting concentrate discharges than another region. Government agencies seem to slow the permit process for years in some cases. More often than not, desalting plants are on the verge of start-up before discharge permits are received.

Importance:

Without a discharge permit, these plants cannot start. In addition, many potential owners of desalters need relief immediately and cannot afford to gamble with time and money to build a facility prior to obtaining permits.

How Do You Propose to Address This Issue?

Further revise federal requirements for concentrate discharges; provide grant money to coastal communities to encourage seawater desalting. Just as the water industry meets the current standards, government raises the bar. The bar should be the same across the country.

Title: **Develop a National Technology Center That Is a Private-Public Partnership to Develop, Test, and Certify Technologies**

Originator: **Young**

Issue Description:

As an example of research topics, the center could analyze methods and materials that are operator friendly, long lasting (match life of the membrane), and resistant to the chemicals used for cleaning or disinfecting membranes.

Importance:

Better joints will prevent leakage that could contaminate the end product, degrading high-quality water.

How Do You Propose to Address This Issue?

Congress should fund a National Technology Center to be managed by a private-sector research institute with cofunding from manufacturing and multiple agency sources.

PRIORITY 4

Develop a Roadmap to Simplify the Decision-making Process for Potential Desal Users; A Living Document Revised As R&D, or Practice Develops New Answers

Originators:

Furukawa on behalf of himself, Archibald, Atwater, Chapman Wilbert, Coffey, Dinar, Kartinen, Mills, Saphores, Shoenberger, and Yamada

The following issues were consolidated under the above title:

Title: **Develop a Roadmap to Simplify the Decision-making Process for Potential Desal Users; A Living Document Revised As R&D, or Practice Develops New Answers**

Originator: **Furukawa**

Issue Description:

User agencies are largely unaware of the steps and the procedures required to develop a project that will ensure a successful desalination plant. As a result, significant time and funds are required to find the answers.

Importance:

Time is money, and funds are usually required to investigate and find the right answers. Both must be minimized to reduce the cost of state-of-the-art desalting projects.

How Do You Propose To Address This Issue?

- Develop a roadmap of decisions and investigations essential for successful projects.
- Develop "standardized" guidelines (specifications) for hardware, including materials.
- Develop guidelines for process selection (e.g., thermal membrane, others) for different feeds.
- Develop strategies for solving environmental sensitivities, permitting (streamline), evaluating risk/reward for options, establishing wastewater plans, and economic evaluations.

Title: **Frameworks in Which to Make Decisions Regarding Desalination**

Originator: **Archibald**

Issue Description:

There are different decision frameworks that can be used to guide public investment decisions. A cost-effectiveness framework implies that a goal is selected – to deliver a given quantity of water of a specified quality – and the least costly option of achieving it adopted. If, indeed, desalination is the least costly option, it will be selected. This framework is useful when benefits are difficult to quantify or when achievement of a given quality standard is mandated. Economists prefer, for public investment decisions, a benefit-cost framework in which benefits are weighed against costs of alternative supply options. Benefits should include environmental benefits (e.g., avoided treatment costs), and environmental damages should be included as social costs.

Importance:

Deciding on a decision framework is critical if progress on implementation is desired and is also critical to guide research. If a benefit-cost framework is employed, information on the value (measured by willingness to pay, for example) of water of a given quality in alternative uses is necessary. In both cases, estimates of environmental damages are needed.

How Do You Propose To Address This Issue?

The federal government should support research to develop an appropriate decision framework and to fund development of subsequent needed information and guidelines to implement it.

Title: **Use Integrated Water Resources Planning Techniques to Evaluate Desalination Alternatives to Other Water Supply Options (Regional, Statewide, River Basin)**

Originator: **Atwater**

Issue Description:

Evaluations of cost-effectiveness, cost-benefits, and other decision-making metrics need to be comprehensively considered, including nonmonetary factors (i.e., environmental externalities, societal values).

Importance:

- Consider the relative cost of building desalination treatment plants for new water supply.
- Consider all costs and benefits in a comprehensive manner.

How Do You Propose to Address This Issue?

Develop planning guidebooks of potential benefits and costs of desalination versus other water supply options.

Title: **Define Economic Boundaries of Water Treatment Processes**

Originator: **Chapman Wilbert**

Issue Description:

We cannot compare or optimize water treatment processes if they do not include all components of the process.

Importance:

The key to expanding the use of desalination is to make it the most cost-effective alternative.

How Do You Propose To Address This Issue?

- Define boundary to include intakes, distribution, power generation, treatment, waste processing, quality monitoring, and administration.
- Use the new boundary to optimize the size and number of desalting plants in a region.

Title: **Developing Cost Metrics for Decision Makers to Evaluate Desalination Economics**

Originator: **Coffey**

Issue Description:

High salinity (over 500 mg/L of TDS — the USEPA's nonhealth-based secondary standard) causes significant economic impacts for homeowners by corrosion and scaling of plumbing fixtures and appliances, as well as for agriculture, commercial, and industrial processes. Recent studies have shown that salinity inside the southern California region is increasing due in part to importing relatively high TDS Colorado River water with a TDS of 600 to 750 mg/L. It is estimated that for every 100 mg/L TDS over 500 mg/L, coastal southern California incurs $95 million per year in damages to the public and private sectors. However, because this is a societal cost not borne exclusively by water agencies, the monetary benefit of TDS reduction is often not included in cost-benefit analyses.

Importance:

It is important that policy and decision makers can more holistically evaluate the potential benefits of desalination.

How Do You Propose To Address This Issue?

This study must be completed under the direction of economists who are experienced with the implementation of cost-benefit analyses. Technical experts must be used to evaluate both the costs of desalting and the economic damages associated with increasing salinity.

Title: **Improve Economies-of-Scale for Large Membrane Desalting Facilities**

Originator: **Coffey**

Issue Description:

Large-scale desalting facilities do not benefit from the same economies-of-scale as do other water treatment processes, such as coagulation, filtration, or ozonation. By increasing the size of the RO element and module, economies-of-scale could be improved through the reduction of mechanical equipment, seals, piping, and valves. Capital costs and, perhaps, operating costs may be reduced.

Importance:

Typical RO plants are built with "building blocks" consisting of RO elements bundled into 1 to 3 million gallons per day (mgd) modules. If the RO module size were increased by a factor of 5 to 10, economy-of-scale savings would be achieved for plants of 50 to 200 mgd capacities. This breakthrough would make RO technology more economically viable for large-scale use.

How Do You Propose to Address This Issue:

This issue requires close partnerships between large water suppliers and membrane manufacturers. The economies-of-scale need to be addressed in different water qualities and at realistic recovery rates.

Title: **Develop a Holistic Framework for Evaluating Desalination in Comparison with Other Options, Including Non-structural Ones**

Originator: **Dinar**

Issue Description:

Determine whether desalination is needed; do not take a need for granted. The proposed framework will address the following issues:

- Social versus private.
- Intersectional.

- Externalities.
- Water resources master plan.

Importance:

- Partial versus comprehensive framework.
- Long- versus short-term.

How Do You Propose To Address This Issue??

Blueprint of guidelines and principles for conducting economic/engineering research programs.

Title: **Value Versus Cost of Water**

Originator: **Kartinen**

Issue Description:

Water is essential; therefore, it is priceless. Convince the government/public that seawater desalting is worth the cost.

Importance:

Without desalting, there will be economic and demographic disruptions.

How Do You Propose to Address This Issue?

An education program.

Title: **Develop a Standard Method for Evaluating True Costs and Benefits of Alternative Water Supplies**

Originator: **Mills**

Issue Description:

Decisions are based on cost comparisons, but the playing field is not level, and external benefits are not given much weight. Cost comparisons are based on melded supply costs; agricultural water costs have federal subsidies; and water transportation costs are related to long-term energy contracts or market prices. Water-quality benefits are not well defined. Environmental benefits must also be quantified.

Importance:

Desalting projects often have the highest cost in comparison to other supply sources; much is due to the incomplete evaluation of costs (on a comparable basis) and benefits.

How Do You Propose to Address This Issue?

NWRI should conduct a research project to develop the standard evaluation methodology.

Title: **Assess the Environmental Costs of Desalination**

Originator: **Saphores**

Issue Description:

In order to compare fairly the costs and benefits of various options for new supplies of fresh water, it is important to better quantify the environmental costs of desalination. These include:

- Costs of withdrawing water from ecosystems.
- Costs of discharging solid residues into the environment.
- External energy costs of operating a desalination plant.

Importance:

This is a fundamental issue in the context of the increasing complexity of the permitting processes. A better understanding of the environmental impacts of desalination would also help in gaining the public's acceptance.

How Do You Propose To Address This Issue?

Look at various methodologies, including the costs of mitigating damages or contingent valuation to quantify damages to ecosystems. Also, address the issue of transferring research findings between various sites.

Title: **Optimal Timing of Adopting Desalination Under Uncertainty**

Originator: **Saphores**

Issue Description:

It is well known in the finance literature that in the presence of irreversibility and uncertainty, a standard cost-benefit analysis for investing in a risky project tends to lead to erroneous decisions. This result is particularly relevant when it comes to building a desalination plant, because closing this plant would lead to unrecoverable losses, and because there is substantial uncertainty in the following areas:

- Permitting system.
- Future energy costs (often a key ingredient in variable costs).
- Cost of other water supply options.
- Future water demand.

Importance:

Understanding the impact of uncertainty and irreversibility on the decision to invest in desalination technology is essential for wisely using public funds.

How Do You Propose to Address This Issue??

Use the theory of real options, from finance; it allows explicitly to take into account irreversibility and uncertainty in key decision variables. A good starting point is Dixit and Pindyck (1994).

Title: **Understand Public Health Risks and Risk Perceptions for Various Fresh Water Supplies**

Originator: **Saphores**

Issue Description:

There is a growing concern about the reliability of public fresh water supplies. This can be seen by the number of water stories in the newspapers, or by the rise of bottled water consumption, either in developed or developing countries (e.g., India). Different water supplies may have different health risks; for example, the risks of pollution from agriculture, municipal, or industrial sources are often higher for surface water and shallow groundwater. This has led the USEPA to require the construction of water filtration plants (or to study their construction as in New York City). Those costs are often not incorporated in the comparisons between various fresh water supply options. This could lead to incorrect decisions.

Importance:

This is very important for implementing an effective water policy.

How Do You Propose to Address This Need?

Assess the various health risks (i.e., probability of occurrence, number of people potentially affected) associated with various sources of fresh water, then cost out those risks based on costs of diseases or deaths. In addition, conduct a meta-analysis of surveys of public perceptions of the water supply.

Title: **Determine the True Value of Developing Local Supplies of Water**

Originator: **Shoenberger**

Issue Description:

Go beyond the cost of an individual project. Determine the value of developing local sources of water and compare the value versus the true cost of alternative supplies.

Importance:

The cost of desalination projects tends to be fairly high; however, most desalination projects are for local supply. These projects have many secondary benefits (e.g., environmental benefits, available costs, increased quality, benefits, economics, and health) that are not captured in the project cost.

How Do You Propose to Address This Issue?

Develop a framework by which the value of new local projects can be accurately determined.

Title: **Develop a Probabilistic Methodology/Model to Evaluate the Cost and Reliability of Desalination Versus Other Resource and Facility Options**

Originator: **Yamada**

Issue Description:

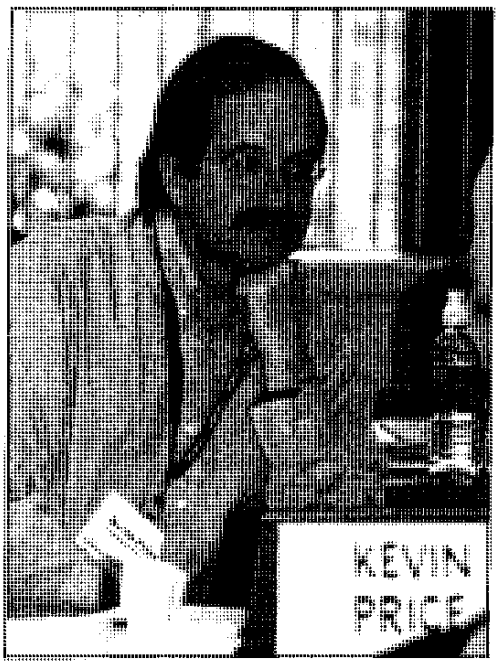
This methodology/model will utilize a probabilistic approach to quantify the uncertainty of future supplies and demands and test the cost, reliability, and facility impacts of existing and potential resource options.

Importance:

The issue has a high level of importance given that the decision to develop a new desalination facility must be considered in the context of other existing and potential water resources.

How Do You Propose To Address This Issue?

Bring together economists and resource planners to develop this methodology.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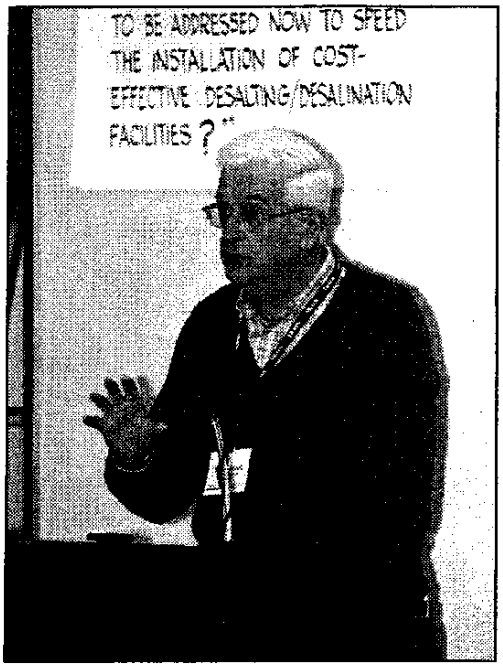
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NWRA

PRIORITY 5

Environmentally Sustainable Concentrate and Waste Management

Originators:

Dinar on behalf of himself, Carnahan, Chapman Wilbert, Coffey, Moch, Price, Stevens, Watson, and Young

The following issues were consolidated under the above title:

Title: **Environmentally Sustainable Disposal of Brine**

Originator: **Dinar**

Issue Description:

- Desalinization will become a major source of supply in certain regions.
- The process of desalinization produces concentrated brine.
- Disposal of this brine may create negative impacts and may cause irreversible externalities (environmental/aquatic, human health, soil, etc.).

Importance:

Disposal of brine will not only reduce the social benefits/cost ratio of desalinization, but it will create opposition by segments of civil society.

How Do You Propose to Address This Issue?

- Research possible brine-derivative products and markets.
- Research safe land and sea disposal techniques.
- Public campaign.
- Prof. John Letcy, University of California, Riverside.

Title: **Develop Criteria Based Upon Sound Scientific, Engineering and Economic Principles to Permit the Discharge of Concentrate From Membrane Facilities**

Originator: **Carnahan**

Issue Description:

The current criteria for the discharge of concentrate to surface water are based upon the toxicity of shrimp at 300 percent of discharge concentration. This organism may not be the best animal to use for testing due to its sensitivity. Studies should be conducted to identify the best indicator organism that reflects the true ecology of the receiving body.

There is a need for better three-dimensional dispersion models that accurately predict mixing zones.

Importance:

This will expedite the permitting process and, ultimately, have an economic impact on the project.

How Do You Propose to Address This Issue?

Conduct studies to determine what is the most dominant aquatic species in fresh water, brackish water, and seawater and determine this species' sensitivity to concentrate. These studies would be conducted at the concentrations predicted by the model.

Title: **Zero Discharge**

Originator: **Chapman Wilbert**

Issue Description:

Membrane processes are inefficient at 80 to 50 percent conversions of natural resources to product.

Many inland communities do not have large amounts of water available and do not like to consider treatment methods that are so wasteful.

Importance:

We (as a nation) are asking the industry to process their waste streams and work towards zero discharge. Membrane processes are often used in this endeavor yet, in water treatment, we try to dispose of 20 to 50 percent of our process stream.

How Do You Propose to Address This Issue?

- Find energy-efficient methods for fully extracting water from the concentrate.
- Find markets for the solids, either mixed or separated.
- Find the optimum ion balance for health and fortify the concentrate (when necessary) to be beneficial to marine organisms, people, and/or crops.

Title: **Economic Evaluation of Near-Inland Brine Disposal Options**

Originator: **Coffey**

Issue Description:

The development of inland desalting facilities is constrained by the availability of environmentally acceptable brine disposal options. The primary concern is the contamination of local fresh surface water and/or groundwater supplies by the brine. Currently, the feasibility and cost of brine disposal options remains one of the largest unknowns for inland desalting facilities. Near-inland facilities (less than ~50 miles from the ocean) also have the option of regional interceptor systems (parallel network of sewage lines for high-salinity waste).

Importance:

All desalination technologies concentrate the salts to a much smaller volume. Brine minimization has two goals: (1) increase the production of potable water; and (2) reduce the cost of the ultimate disposal of the brine. The treatment or disposal of this brine can be problematic depending on its volume and composition. Many inland locations do not have access to disposal alternatives, such as ocean outfall. Therefore, these utilities must develop means to further concentrate desalting plant residuals. The cost of concentrating these residual must be balanced against the cost of ultimate disposal.

How Do You Propose to Address This Issue?

This project will investigate this issue by evaluating the sensitivity of treatment costs (concentrating the brine) and disposal costs (building pipelines, deep well injection, etc.). Recommendations will be offered regarding the relative value of these options.

Title: **Develop Brine Concentration Technologies**

Originator: **Coffey**

Issue Description:

Treatment and disposal of the brine stream often limits the successful application of desalting technology. Current technologies for recovering water from a brine stream are limited. Two leading technologies are evaporation ponds and thermal evaporation processes. The former requires significant land and may contaminate the site with concentrated heavy metals, while the latter is energy intensive and economically unattractive.

Importance:

The most feasible methods to improve brine disposal involve concentrate minimization. Concentrate minimization increases the available water supply and reduces the energy costs of importing water. For a large-scale treatment plant in southern California, water savings with improvements in brine technology would result in the recovery of 12.5 mgd of water — enough to serve 28,000 households. This improvement equates to energy savings of 40,000 kilowatts hour per day (kWh/day).

How Do You Propose to Address This Issue?

This project should target the development of brine treatment technologies, which are energy efficient and do not produce hazardous waste disposal problems. The goal of the new technology would be to increase the recovery from 85 to 95 percent (i.e., on a water with a TDS of 750 mg/L).

Title: **Develop a Convincing Databank of Information on the Effects That Current Brine Disposal Methods Have on the Environment**

Originator: **Moch**

Issue Description:

The concentrate effluent from a membrane desalting plant must be discarded in an environmentally acceptable manner. This stream, for brackish water, represents, generally, about a four times the feed TDS; in seawater, it is somewhat less than double the feed salinity.

What to do, environmentally, with this concentrated brine is a concern. Presently, it is returned to the feed source away from the intake (be it an ocean, lake, river, etc.), sent to another tributary, deep well injected away from the potable water aquifer layer, land filled, etc.

In each of these scenarios, the question is whether the brine is harmful to the ecosystem. State and federal regulations state that brine is, or at best may be, harmful, and, thus, onerous brine disposal restraints have been imposed on operations.

Toxicity information is scarce, and available information is disorganized. It is critical that the issue of brine disposal be addressed immediately to maintain the viability of the technology.

Importance:

- Continue the viability of the technology to prevent the shutdown of existing plants and to allow the technology to grow.

- Is disposal of the brine today being accomplished in an environmentally sound manner? If not, major costs are to be incurred in rerouting this stream.

How Do You Propose to Address This Issue?

- Provide funding to municipalities to assess the impact on the environment of various disposal techniques.
- Develop an environmental databank of past and newly developed research on the various disposal techniques.
- Create major education programs aimed mainly at the states and the public to discuss the pros and con's of this issue.
- Create a "truth" squad who would immediately respond to any adverse articles.

Title: **Concentrate Disposal**

Originator: **Price**

Issue Description:

When dissolved and suspended materials are removed form water, they are generally left in a concentrated solution. This solution must be disposed. Along the coast, the current state-of-the-art practice is to dispose the solution into the sea. Inland, the problem becomes more difficult and expensive. Neither problem has satisfactory solutions.

Importance:

The application of inland desalination will be hindered, and, eventually, stopped, unless satisfactory ways are developed to dispose of concentrates. Disposal of concentrates into the ocean continues to create concerns about environmental impacts.

How Do You Propose To Address This Issue?

- Conduct a thorough study of the potential uses of the concentrated salts, beginning with the publication of a thorough literature search.
- Take the most promising top two ideas for use of the salts and test the market.
- Advertise a large joint project ($400K) for inland concentrate disposal. Fund the best proposal that makes sense.

Title: **Investigate Spent Cleaning Solution Disposal and Its Impact on the Environment**

Originator: **Stevens**

Issue Description:

All plants must clean their membranes at some point. The type of cleaner used and its disposal method could incur considerable expenses.

Importance:

Disposal of waste products is always a consideration when permitting. Waste disposal includes cleaning chemicals. Further information may ease the public's concern of environmental impacts.

How Do You Propose to Address This Issue?

- Test spent cleaning solutions.
- Address the cost of cleaning solution disposal before use.

Title: **Concentrate is a Resource, Not a Wastewater**

Originator: **Watson**

Issue Description:

In addition to addressing discharge issues, the waste of water inherent in concentrate disposal can be reduced by using the concentrate stream for useful agricultural purposes.

Importance:

In developing countries where both water and food is scarce, desalination plants can be used to produce potable water and the concentrate can be used for growing salt-tolerant food crops, then using the biomass to produce energy.

How Do You Propose to Address This Issue?

Persuade USBR to fund the investigation of suitable plant species, building on work already done in Arizona and elsewhere. Follow by integrating this work with a paper study of food crop yields and biomass energy production to determine make-up needs in both activities.

Title: **Develop a Watershed Model for Brine Disposal Supported by Federal Agencies**

Originator: **Young**

Issue Description:

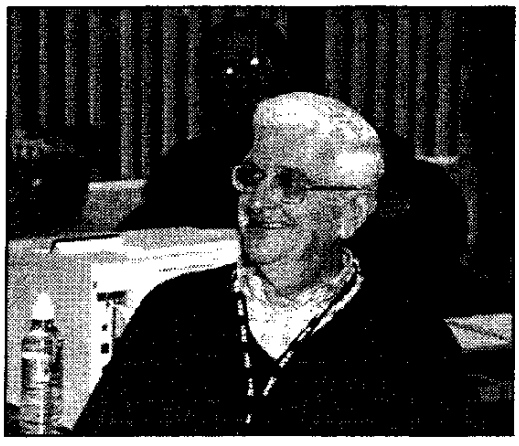
Provide the brine disposal method used for ocean disposal to facilitate inland desalting projects. Finance projects with federal funds because of the long planning horizon needed for development and trans-basin/interstate/international economic benefits.

Importance:

Inland desalting costs for brine disposal can prohibit project development.

How Do You Propose To Address This Issue?

Use the watershed management approach, coupled with national purpose, to plan developments outside the coastal areas.



PRIORITY 6

Innovate a Paradigm Decrease in the Energy Consumption of a Seawater Membrane Desalting Plant

Originators:

Moch on behalf of himself, Chai, Dusenbury, Truby, Watson, and Yamada

The following issues were consolidated under the above title:

Title: **Innovating a Paradigm Decrease in the Energy Consumption of a Seawater Membrane Desalting Plant**

Originator: **Moch**

Issue Description:

Over 75 percent of the energy required for seawater desalination is associated with the high-pressure pump. This pressure is required to overcome the brine osmotic pressure plus provide the process driving force so that the number of membranes used and the product quality are acceptable. This driving force normally is about 300 pounds per square inch (psi) whereas, with brackish water, the pressure differential can be as low as 10 psi. Further, plant recoveries have been limited to a brine TDS of 65K mg/L to maintain acceptable product quality. A better limitation would be about 90K mg/L, the point where calcium sulfate ($CaSO_4$) would precipitate. Over 80 percent of the brine pressure/energy is reused, employing an energy recovery device (ERD). Energy consumption and the amortized capital associated with it equals about 50 percent of the total cost of water. If the driving force could be reduced to more reasonable levels and, if the system recoveries and/or ERD efficiencies could be significantly increased, a major reduction in the total cost of operating a plant would result.

Importance:

- With 95+ percent energy recovery and/or system recovery approaching 60 percent, the total cost of water would be reduced by about 20 percent.

- A 50 psi pressure differential between the applied pressure and brine osmotic pressure would lower system feed pressure by 25 percent and water costs another 10 to 15 percent.

- A new economic balance of variables among applied pressure, system recovery, and general equipment sizing would result with the success of the above two items.

How Do You Propose To Address This Issue?

- Attain funds from private interests and federal government for:
  - membrane improvements for flux and ion rejection
  - energy recovery devices operating at 95+ percent efficiency for large-scale plants
  - high-pressure centrifugal pumps with 90+ percent efficiency or alternatively high-capacity, high-efficiency positive displacement pumps, all at reasonable capital costs

- A commercial facility to test developments.

- Routine reports and open access to all research developments.

Title: **Promote Desalination; Need to Contend With the Interrelationships Between California's Recent Energy Cost/Supply Problems and Water Cost/Supply Problems**

Originator: **Chai**

Issue Description:

The rotating blackouts of the past few days and the California state legislature's agreement to expend substantial taxpayer funds to purchase electricity raise the questions of how we can best obtain energy for desalination and advocate desalination in this new atmosphere of public and political concern over the supply and expense of energy.

Importance:

Depending upon how much more tax money and consumer ratepayer money will be expended to purchase electrical power, we may confront a reluctance to adopt energy-hungry treatments, such as desalination.

How Do You Propose to Address This Issue?

Innovative and alternative means of obtaining energy and persuasive economic analysis will be vital to convince people that desalination is affordable.

Title: **Develop New or Improved Technology to Reduce the Power Required for Desalination**

Originator: **Dusenbury**

Issue Description:

Producing potable water from source water with high TDS using traditional technologies requires a significant amount of energy. Improvements to membrane processes or alternative technologies are needed that are more energy efficient and able to produce potable water with a fraction of the current energy requirements.

Importance:

For fixed facilities, the power required to operate traditional desalination systems is a large cost driver for the final cost of the water produced. In military ground-based applications, the large energy requirements create a significant logistics burden through the requirement to supply these systems with fuel to produce the required energy. The large power requirements also lead to larger overall systems.

How Do You Propose to Address This Issue?

The Army, Marine Corps, and the Defense Advanced Research Project Agency are funding a number of research projects to investigate technology to reduce the power requirements of membrane systems, including topics such as pulsed reverse osmosis, advanced spacer design, forward osmosis, and alternate technologies such as capacitive deionization. Additional research is needed to expand the investigation into lower energy techniques for desalination.

Title: **NWRI Should Conduct a Seminar on Dual-Purpose Power/Desalination Plants**

Originator: **Truby**

Issue Description:

Electric energy and water are in short supply as the result of population growth. A serious analysis and evaluation of the cost-benefit ratio and reliability need to be conducted.

Importance:

New energy plants are needed. Desalination can be coupled with the new plants to offset costs.

How Do You Propose to Address This Issue?

Educate via seminars to show the public and users how dual water/power plants work outside the United States and its economics.

Title: **Improve Efficiency of Small Energy Recovery Devices for Small-scale Seawater RO Systems**

Originator: **Watson**

Issue Description:

The energy recovery devices available today cover a range of efficiencies and capacities. The Pelton wheel approach is used primarily for large installations; turbo is used for mid-sized and small systems, together with reverse-running turbines and work exchangers.

Importance:

Energy recovery device efficiencies range from 40 to 80 percent. This range represents a significant difference in energy needs. There may be a significant benefit to the distribution of small systems for environmental and other reasons.

How Do You Propose to Address This Issue?

Research time and funds need to be focused on improving the efficiency of small energy-recovery devices to bring them to the same or similar level as large Pelton Wheel devices.

Title: **Develop State and Federal Funding Incentives to Encourage the Development and Implementation of Efficient Co-located Water/Power Facilities**

Originator: **Yamada**

Issue Description:

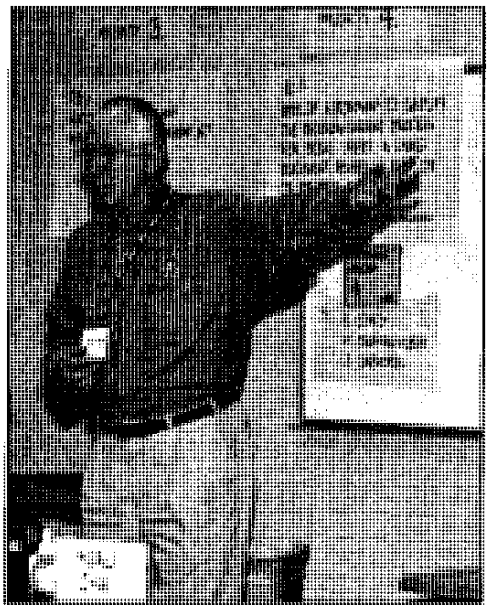
Given the anticipated construction of new power generation facilities, more work is needed to investigate and develop efficient ways to interconnect combined-cycle power plants with reverse osmosis facilities, as well as to work through the institutional issues associated with such interconnections.

Importance:

A high level of importance should be given to this issue, recognizing the current energy and water situations.

How Do You Propose to Address This Issue?

Cooperative partnership with the U.S. Department of Energy (DOE), Electric Power Research Institute (EPRI), and private energy companies, as well as reverse osmosis equipment manufacturers.




FRANK
LEITZ

PRIORITY 7

Look Outside the Box for Innovative Solutions

Originators:

Furukawa on behalf of himself, Atlas, Leitz, Linsky, Lloyd, Moch, and Saphores

The following issues were consolidated under the above title:

Title: **Look Outside the Box**

Originator: **Furukawa**

Issue Description:

Requirements for justifying research and development often inhibit or eliminate ideas that are not within the realm of current science.

Importance:

Existing processes are improving, but in small increments. A look from outside the box is needed.

How Do You Propose to Address This Issue?

Additional research funding is needed to seek innovative, radically new processes and solutions.

Title: **How to Bring New Desalting Technology to the Market in 5 Years or Less for the Purpose of Purifying Water for Supply or Wastewater Reuse**

Originator: **Atlas**

Issue Description:

- Need sufficient research funding.
- Require development funds for:
  - scale-up quantities
  - significant flow-size beta testing
  - creating a manufacturing process
- Conduct educational programs to expose the world to new technology.
- Minimize the threat of intellectual property (IP) being stolen so technologists can collaborate together.
- Provide the incentives for corporations in the water treatment industry to invest again in research and development (R&D).

Importance:

- General: If the costs to produce water need to be halved, this can only be accomplished with new technology. A small percentage of improvements to existing technology will not get it done.
- More probably, a small entrepreneur operating out of his garage will fund innovation, then will be funded by a large corporation.
- Funding. It provides the time for initial R&D ideas to develop, and then it speeds up the time necessary to take a commercially developed product to market. Government can provide the initial research funding, and corporations can form joint ventures to speed development.
- If investments in new technology are to be made, then these investments will come from outside the industry, unless it is a company that has assets and value... and then, it will be purchased and all development money stripped from its core.
- IP is not threatened by teamwork — rather, it is strengthened. This would empower all the brilliant technologists to work together.

- Education: Our technology will be purchased only by leading-edge companies seeking leading-edge solutions. The masses will still purchase RO or de-ionization (DI), and still only a fraction of the world will know that there is an alternative technology.

- Corporations have to get out of the death spiral – diminishing profit margins with no product differentiation. We need a bold pioneer spirit again. This has been lost.

- Government can make a difference, but more funding is needed.

How Do You Propose To Address This Issue?

- Seek $1 billion annually in government funding.

- Create tax credits for new technology for water purification.

- Create a development fund with matching funding, including commercialization, beta testing, and manufacturing processes.

- Make the deliverables and milestones tangible – so a product must be field-tested – as part of the funding criteria.

- Create incubators where IP is not threatened from those trying to steal it. Get bright minds to work with each other.

- Look for corporate investments outside the industry and make the search global.

Title: **How to Develop New Technology to Speed Cost-effective Solutions for Desalting All Water Sources by Optimizing Resource Availability**

Originator: **Atlas**

Issue Description:

Since much of the world seems to look at technology that originates in the United States first, it is incumbent of the United States government to optimize the use of all resources available, so that a cost-effective desalting technology can be developed.

Importance:

Technologists seem to be myopically focused on existing technology. Who is working on the next "flying automobile that uses water as fuel?" In our development laboratory, we state, "If one falls in love with their own design, then all the possibilities for improvement are removed." Thus, it is imperative to use all resources: people, government funding, and corporate funding. One must challenge technology solutions by removing the boundaries for classifying the problems and solutions.

How Do You Propose To Address This Issue?

- Secure $1 billion annually in government funding.
- Create tax credits for new technology for water purification.
- Create a development fund, with matching funds to include commercialization, beta testing, and manufacturing processes.
- Make the deliverables and milestones tangible – so that a product must be field-tested – as part of the funding criteria.
- Create incubators where intellectual property is not threatened from those trying to steal it. Get bright minds to work with each other.
- Look for corporate investments outside the industry and search globally.

Title: **How to Empower People Using New Technology to Desalt Their Own Water and Stop Governments From Invading Their Lives**

Originator: **Atlas**

Issue Description:

The average citizen in the United States does not think there is a water shortage problem, but other parts of the world are living the problem. Perhaps, we are thinking about too large a solution; think smaller in size and more globally in scope. Since two-thirds of the world lives in economies with a Gross Domestic Product (GDP) that is one-fifth of the United States, we need to provide cheap (under $100) consumer technology (under 50 gpd), so that water can be purified for potable use without the use of any infrastructure, such as electricity, water supply, and sewers. Is this too idealistic? (Hint: a hand-cranked generator will generate power under low voltage, but it is not feasible with RO.)

Importance:

I am not familiar with any company that is considering the development of new technology— for the third-world countries – that both desalts and sterilizes water without municipally generated electricity. This idea would have no batteries, disposable filters, changeable media, or membranes. It would be wonderful if someone living in Africa, or in a remote village in India, could have available a countertop water purifier that could desalt and sterilize water. The governments' role would be to act only as a channel of distribution. Philanthropy would be used to purchase the units, and agencies, such as the Red Cross, UNICEF, United Nations, etc., would distribute this new gizmo.

Foundations currently provide funding for food, medicine and bottled water. Why not this?

How Do You Propose to Address This Issue?

- Approach foundations for development funds.
- Procure philanthropic money for manufacturing and purchases.
- Empower and involve agencies to assist governments with distribution.
- Contact us for the technology.

Title: **Develop Dead-cheap Water Treatment Systems**

Originator: **Leitz**

Issue Description:

A little over a hundred years ago, a major improvement in public heath was introduced: filtration. This seems such an obvious step that we frequently forget that there are people on the bottom of the economic scale that have not even had this much treatment.

Importance:

Poor water is one of the major contributors to bad public health among the extremely economically challenged people.

How Do You Propose to Address This Issue?

Develop and test a single-family unit, which could be as simple as a bucket of sand. It would seem that a country as rich as the United States could finance this development. The Peace Corps or the United Nations could disseminate the technology.

Title: **Shareholder Utility: A Possible Solution to Acceptance**

Originator: **Linsky**

Issue Description:

Consumers (i.e., the public) are not "linked" to utilities, or the water factories, because the pipes are hidden, water remains a mystery, and they only receive the monthly bills. They do not feel, or share, a sense of ownership.

Importance:

Facilities are assets of the district; if the "rate payers" are the owners, they will have an economic stake in the facility and an opportunity to share in the benefits.

The owners would have an incentive to accept new technologies if they see themselves as a beneficiary of improved water quality and quantity.

How Do You Propose to Address This Issue?

Investigate a new mutual utility model (or a shareholder model) that would provide real ownership into not only the facility, but also in any problems and, therefore, acceptance of technical and economic solutions.

Title: **Re-evaluate Technologies**

Originator: **Lloyd**

Issue Description:

Some membrane materials and membrane technologies that were rejected in the early days of desalination may now be feasible due to improvements in our understanding of transport, module design, and membrane materials. Examples: piezodialysis and membrane distillation.

Importance:

Provide alternative technologies not currently available.

How Do You Propose to Address This Issue?

Re-read earlier literature, especially Office of Saline Water reports, with an open mind and an up-to-date knowledge base. Are these reports available in print?

Title: **Simplify the Desalination Manufacturing Process As a Mechanism Towards Significantly Lowering the Total Cost of Product Water**

Originator: **Moch**

Issue Description:

It is today's public perception that desalting water is expensive. This concept is based on the idea held by many that the technology is too complicated and that there are too many process steps in desalination. Compared to drawing potable water from a river or a well, desalination is a more costly alternative. Perhaps, it will always be valid that the more complicated a technology is, the more expensive it is to commercialize. However, processing costs, historically, have receded as the degree of manufacturing complexity has decreased.

Membrane desalination is over 30 years old, and it certainly appears now that, with the present application techniques, it will be possible to make only minor improvements in water production costs. A paradigm shift in the thinking on how to deliver the saline water to the customer as something fit to drink is required to significantly alter desalting economics.

Importance:

- Further acceptance of desalting technology by the public and decision makers.
- Significant reduction in the cost of manufacturing.
- Probable conservation of resources – water, materials, and labor.

How Do You Propose to Address This Issue?

- Create a "think tank" to develop and evaluate ideas for a paradigm shift in processing techniques for converting saline water to drinking water.

- Develop a databank of information that is open to the pubic and its representatives.'

Title: **Desalination Solutions for Developing Countries**

Originator: **Saphores**

Issue Description:

In a 1961 speech, President Kennedy said that producing cheap fresh water from saltwater would be in the long-range interest of humanity and would dwarf any other scientific accomplishment.

Solutions thought inadequate for providing fresh water in developed countries may be adequate for some developing countries because they face different input costs. In addition, energy costs are a large part of the variable costs of desalinating water, and imported oil or gas for desalination requires hard currency. Many developing countries are only left with expensive options for new supplies.

I thus suggest exploring how current desalination technologies could be adapted to conditions found in developing countries and exploring how desalination technologies could be coupled with recent advances in solar power.

Importance:

Finding a rugged, cost-effective system to desalinate water in developing countries would represent major progress for humankind.

How Do You Propose to Address This Issue?

Analyze input costs for desalinating water in a group of selected developing countries and for various technologies that could use solar energy. Give out small seed grants to develop new technologies combining desalination and advances in solar energy.

PRIORITY 8

Develop a Better Understanding of the Current and Future Value of Water of Different Qualities in Alternative Uses

Originators:

Archibald on behalf of herself, Kartinen, Leitz, Linsky, and Shoenberger

The following issues were consolidated under the above title:

Title: **Develop a Better Understanding of the Current and Future Value of Water of Different Qualities in Alternative Uses**

Originator: **Archibald**

Issue Description:

Because water has not been traded in markets but is largely provided through subsided public institutions, we have little information on consumers' willingness to pay for water. What quantities would be demanded at different prices? Subsidized prices do not reflect the value of water to consumers leading to under-investment and overuse. Until recently, we have not been able to measure monetarily the nonmarket value of water (e.g., for fish and wildlife). Historically, the nonmarket value has been ignored, but, more recently, we may have over-valued some of these uses.

Importance:

The lack of information on the total (market and nonmarket uses) value of water deters investment in desalination facilities. The uncertainty regarding value leads to uncertainty regarding the level of demand for the product at the price it can be developed.

How Do You Propose To Address This Issue?

- Encourage the development of tiered pricing mechanisms and water markets, including options and futures markets.
- Support economic research on water's nonmarket uses and values.

Title: **Value Versus Cost of Water**

Originator: **Kartinen**

Issue Description:

Water is essential; therefore, it is priceless. Convince the government/public that seawater desalting is worth the cost.

Importance:

Without desalting, there will be economic and demographic disruptions.

How Do You Propose to Address This Issue?

An education program.

Title: **We Need to Have a Current Value of New Water**

Originator: **Leitz**

Issue Description:

Water prices vary all over the map. It was not too long ago that a farmer in Yuma, Arizona, with a long-term contract could get an acre-foot of water for 5 to 10 cents, while a customer at the grocery store would pay 25 cents for a gallon at vending machine where he supplied his own gallon bottle. The top end of the price scale is the "frou-frou" water that sells for dollars per gallon.

Importance:

This would get around certain misunderstandings in selling desalination. Here is a characteristic dialog that attends the potential sale of a desalination plant:

Buyer – I need an increase in my water supply.

Seller – My plants desalinate water for $1.25 per thousand gallons.

Buyer – I'm only paying 30 cents for water from my current supplier.

Seller – Why don't you buy from him?

Buyer – He doesn't have any more.

How Do You Propose to Address This Issue?

This would be an interesting subject for a study.

Title: **Discover and Characterize the Consumers of Desalinated Water**

Originator: **Linsky**

Need Description:

Desalting/desalination is too often viewed as a private technology of those who understand its complexities.

Importance:

The public, composed of investors, taxpayers, and ratepayers, are the consumers.

How Do You Propose Addressing This Need?

Consumer education and marketing must take into consideration who the consumers are, what they want, and how much they are willing to pay.

Marketing. Ask the question, what do you want? Keep the consumer informed on a regular basis of attempts to satisfy their needs.

Title: **Determine the True Value of Developing Local Supplies of Water**

Originator: **Shoenberger**

Issue Description:

Go beyond the cost of an individual project. Determine the value of developing local sources of water and compare the value versus the true cost of alternative supplies.

Importance:

The cost of desalination projects tends to be fairly high; however, most desalination projects are for local supply. These projects have many secondary benefits (e.g., environmental benefits, available costs, increased quality, benefits, economics, and health) that are not captured in the project cost.

How Do You Propose to Address This Issue?

Develop a framework by which the value of new local projects can be accurately determined.

PRIORITY 9

Improve the Fundamental Understanding of Membrane Science

Originators:

Lloyd on behalf of himself and Mills

The following issues were consolidated under the above title:

Title: **Improve the Fundamental Understanding of Membrane Transport**

Originator: **Lloyd**

Issue Description:

Virtually all transport models applied to desalination assume monovalent ions and single salts in solution. These are the models that design engineers use to specify operation parameters. However, all feed streams contain more than one salt – many of which are multi-valent – as well as organic compounds.

Importance:

- A better transport model will help in setting operation parameters for desalination plants.
- A better transport model will facilitate the selection of membrane materials for treating streams not previously treated properly with membranes.

How Do You Propose to Address This Issue?

Establish joint academic/industrial research teams with joint industrial/agency funding to develop transport models leading to the improved operation of desalination plants and membrane materials selection.

Title: **Need for Improved Membranes for Rejecting Low Molecular Weight and Small Organic Compounds**

Originator: **Mills**

Issue Description:

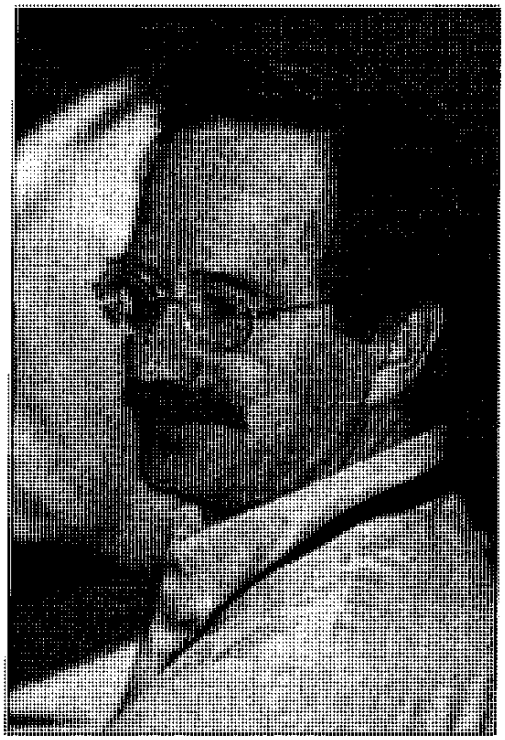
Low molecular weight compounds and organic compounds are of great concern to public health regulators (e.g., nitrosodimethylamine [NDMA]).

Importance:

Without effective removal, additional and costly post-treatment is required, such as ultraviolet (UV), which requires large energy input.

How Do You Propose to Address This Issue?

Need research funding.



PRIORITY 10

Develop a National Advisory Panel for Advanced Water Treatment Tchnologies

Originator:

Price

Issue Description:

A National Advisory Panel for Advanced Water Treatment Technologies would:

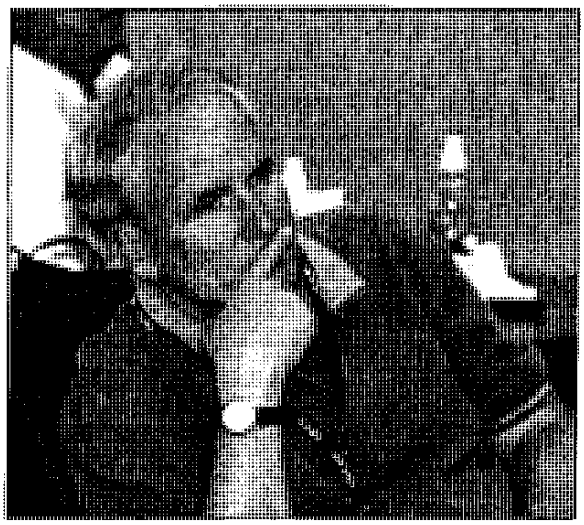
- Provide visibility throughout government.
- Be tasked with goals to reduce cost, lower environmental impacts, increase supply, reliability, and public health.
- Promote coordination among federal, state, and municipal agencies.
- Promote advocacy for public policy, recommended projects, etc.

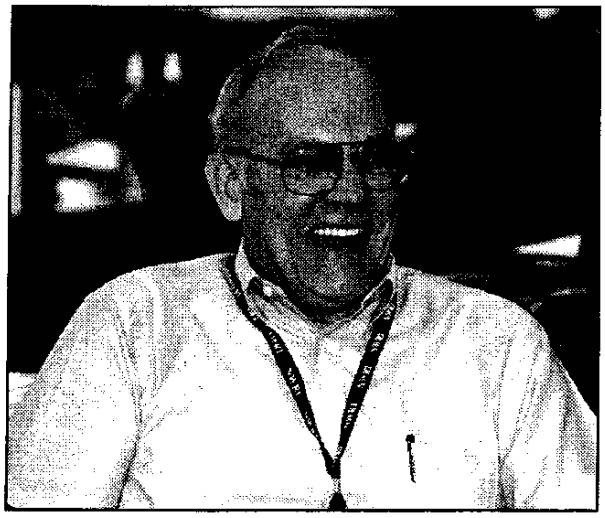
Importance:

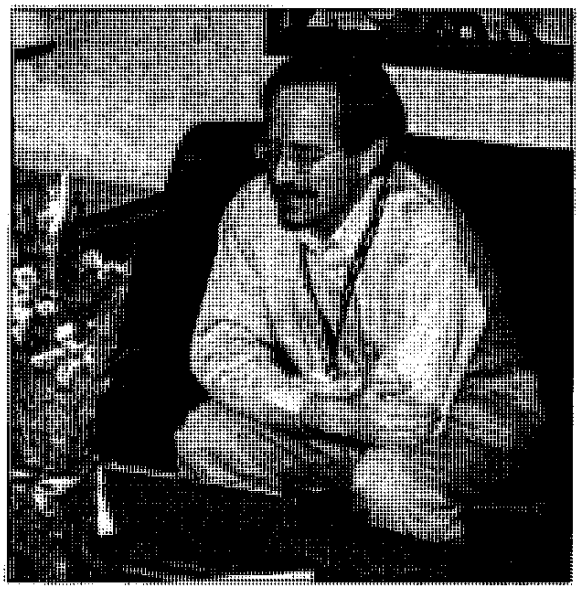
A broad coalition of concerned entities would have influence with policy makers.

How Do You Propose To Address This Issue?

On a regular basis, bring together a diverse group of concerned entities to discuss advanced water treatment needs. Use the results to recommend appropriate public policy and actions.







PRIORITY 11

Desalination Technology Clearinghouse

Originators:

Atwater on behalf of himself, Carnahan, and Price

The following issues were consolidated under the above title:

Title: **Desalination Technology Clearinghouse**

Originator: **Atwater**

Issue Description:

The U.S. Bureau of Reclamation (USBR) should put together an information center, library, and web page that include a desalination database on all projects, pilot plants, research, operating data, etc.

Importance:

There is available a wide range of data and operating experience, but there is no easily retrievable source of information on desalination technologies.

How Do You Propose To Address This Issue?

The USBR (or possibly NWRI) should organize at the Engineering and Research Center, a clearinghouse, library, and web page for a comprehensive database on desalination information. Estimated an annual budget of $1.5 million.

Title: **Survey Practitioners As to Process Needs to Provide a Cost-effective System**

Originator: **Carnahan**

Issue Description:

Research should focus on the need for application. This may be pretreatment methods as well as system configurations or it can be development of new membranes.

Importance:

This will focus the effort on true needs.

How Do You Propose To Address This Issue?

Conduct a survey of practitioners as to their needs. Develop a road map for a directed research program.

Title: **Improve Access to Desalination Information**

Originator: **Price**

Issue Description:

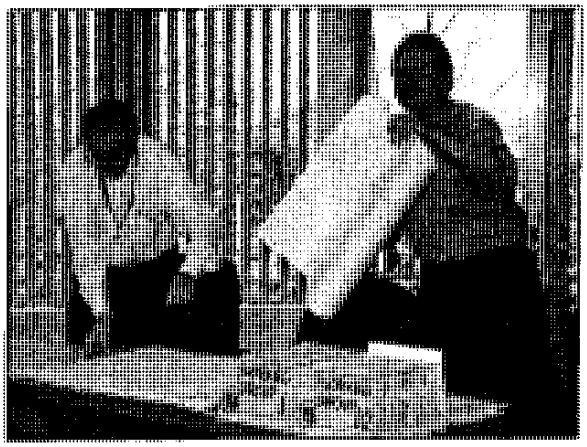
Many people are investigating desalination as a way to increase water supplies. Finding useful literature takes time if done without consultation with desalting experts.

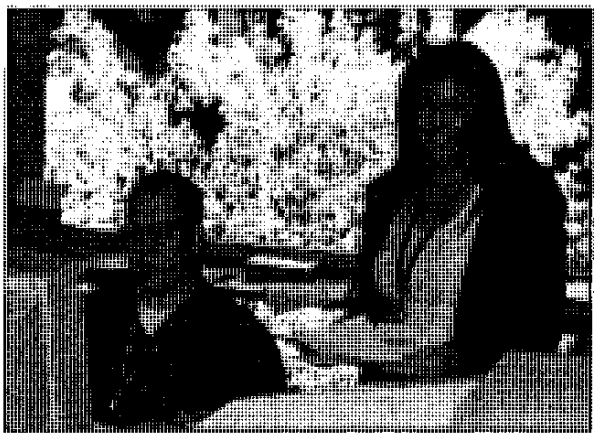
Importance:

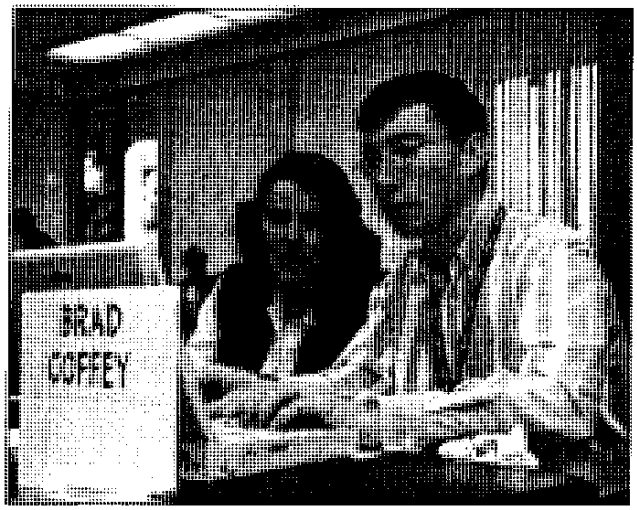
Decisions are quickly being made that are not based upon full information.

How Do You Propose to Address This Issue?

- Centralize abstracts of desalination literature.
- Develop a series of articles/lectures of lessons learned, starting with experiences of the desalination brethren/mafia.
- Develop list of spin-offs from desalination research (e.g., kidney dialysis, gas separations).
- Provide a list and full text of the 20 most important papers in desalination.



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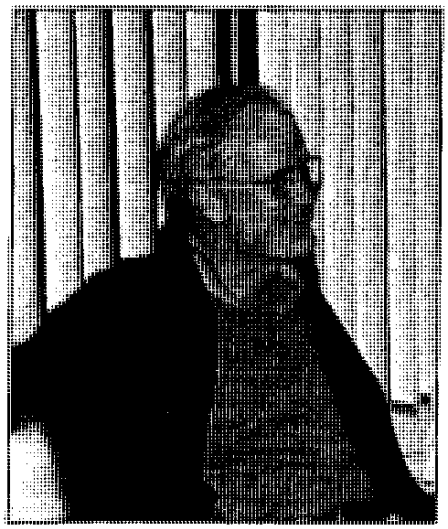
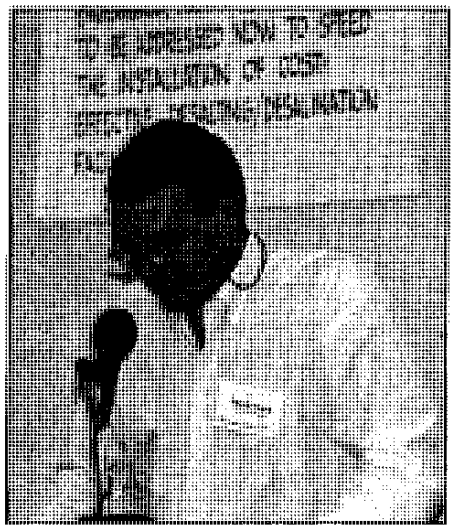




PRIORITY 12

Separate Water Distribution Systems

Originators:

Chapman Wilbert on behalf of herself, Atwater, Clark, Coffey, and Watson

The following issues were consolidated under the above title:

Title: **Separate Water Distribution Systems**

Originator: **Chapman Wilbert**

Issue Description:

We do not need all of our water treated to drinking water standards.

Importance:

People use about 70 gallons a day and drink only 1 gallon.

How Do You Propose to Address This Issue?

- We need to upgrade distribution systems and put in parallel systems for drinking (very small) and other uses (washing, watering).
- Cities could install point-of-use systems instead of a central treatment system.
- Establish drinking water supply services controlled by the government rather than the private sector.

Title: **Use Integrated Water Resources Planning Techniques to Evaluate Desalination Alternatives to Other Water Supply Options (Regional, Statewide, River Basin)**

Originator: **Atwater**

Issue Description:

Evaluations of cost-effectiveness, cost-benefits, and other decision-making metrics need to be comprehensively considered, including nonmonetary factors (i.e., environmental externalities, societal values).

Importance:

- Consider the relative cost of building desalination treatment plants for new water supply.
- Consider all costs and benefits in a comprehensive manner.

How Do You Propose to Address This Issue?

Develop planning guidebooks of potential benefits and costs of desalination versus other water supply options.

Title: **What Would Be the Most Economic Partnership Between Municipal Water Providers and Home-treaters?**

Originator: **Clark**

Issue Description:

What is the minimum municipal tap water quality that could be used for bathing, laundry, lawn watering, toilet flushing, and feed for home treatment units?

Importance:

- Reduce total costs.
- Minimize environmental impacts of residuals.

How Do You Propose to Address This Issue?

Research is needed on water-quality requirements of:

- Lawn watering
- Bathing
- Toilet flushing
- Feed for home RO units

Title: **Preserve the Quality of Desalted Water in the Distribution System**

Originator: **Coffey**

Issue Description:

Historically, utilities are challenged when changing the chemistry of the water quality in aged distribution systems (e.g., Tucson, Arizona). Some ongoing studies are evaluating the quality of the distribution system as water resource mix varies (e.g., the tailored collaboration project in Tampa, Florida, managed by the University of Central Florida).

Importance:

The public's perception of desalted water will, in large measure, result from the appearance and taste at the tap. Well-managed RO water quality may be acceptable at the effluent from the treatment plant, but how will it appear 3 days later? Poor public perception after treatment changes may greatly harm public support for the technology. Major change to the distribution system may not be feasible, however, as utilities typically have ten times greater investment in distribution systems as they do in treatment.

How Do You Propose to Address This Issue?

Perform both controlled, lab-scale and in-case studies.

Title: **Reduce the Use of Expensive Potable Water for Non-potable Uses**

Originator: **Watson**

Issue Description:

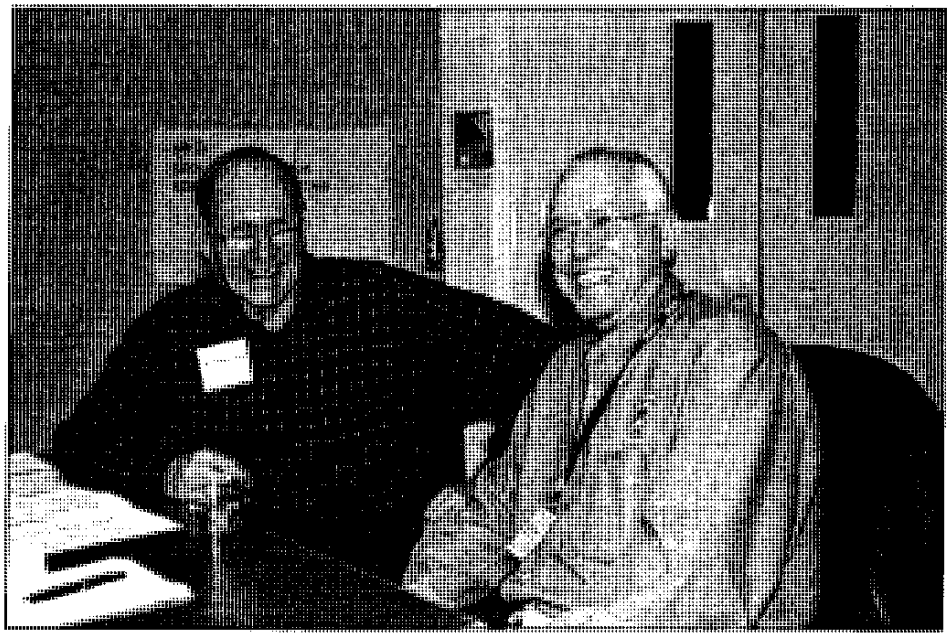
In many areas of the country, potable water is being used for non-potable uses, mainly industrial and agricultural.

Importance:

When shortages occur, the typical scenario is that the individual users of the water supply are restricted, resulting in personal loss in terms of landscaping, etc.

How Do You Propose to Address This Issue?

Develop and implement a national program for wastewater reuse in industry and agriculture, include internal industrial recycling, and make the program mandatory, with a phase-in period.



PRIORITY 13

Simplify, but Improve the Ability to Control RO Systems Through Use of Modern Telecommunications Technology and Improved Monitoring Equipment

Originators:

Watson on behalf of himself, Carnahan, and Clark

The following issues were consolidated under the above title:

Title: **Simplify, but Improve the Ability to Control RO Systems Through Use of Modern Telecommunications Technology and Improved Monitoring Equipment**

Originator: **Watson**

Issue Description:

Although the use of control systems based on Instrumentation and Control (I&C) hardware is widespread, the adoption of new technologies, such as "field bus," is slow. Accuracy and reliability of I&C components (i.e., specific ion monitors, TOC analyzers, color, etc.) are proportional to cost. Lower cost equipment is needed and could be based on a wireless system.

Importance:

Improved I&C hardware allows operators to improve plant efficiency by operating closer to theoretical design limits – more bang for the buck.

How Do You Propose to Address This Issue?

- Conduct comprehensive reviews of available hardware and software.
- Evaluate points for improvement.
- Evaluate and test wireless approaches, such as "Blue Tooth." Blue Tooth is a short-range wireless technology for control functions transmitted from personal computers to remote components. Intel, Nokia, IBM, Qualcomm Microsoft, and others are funding the research and development.
- Identify opportunities and encourage the private sector to address the issues.

Title: **Economical and Reliable Real-time Monitoring Instrument for Microbial and Chemical Foulants Needs to Be Developed**

Originator: **Carnahan**

Issue Description:

Currently, the time required to identify a microorganism, or in some cases the chemical contaminant, does not permit corrective action on the operator's part. This requirement is essential due to the potential for direct contamination from urban runoff or terrorist action.

Importance:

Better real-time instrumentation would provide greater reliability.

How Do You Propose To Address This Issue?

- Determine the types of potential contaminants and their chemical characteristics.
- Survey the instrumentation market and determine types of instruments that may be used.
- Develop a research plan for instrument development for those contaminants that cannot be detected in real time.

Title: **Real-time or On-line Monitoring of Membrane Integrity With Regard to Microbial Removal**

Originator: **Clark**

***Issue Description*:**

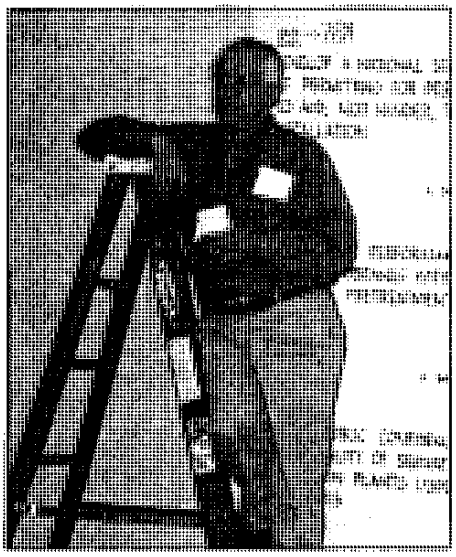
How do you know when a membrane has failed? How do you prove when it has fouled?

Importance:

Microbes cause disease.

How Do You Propose to Address This Issue?

Research funding for basic research.



PRIORITY 14

Establish and Get Public Acceptance of Criteria for Healthful, Good-tasting Drinking Water

Originators:

Leitz on behalf of himself, Chapman Wilbert, and Linsky

The following issues were consolidated under the above title:

Title: **Public Recognition That an Existing Water Supply May Be of Questionable Quality**

Originator: **Leitz**

Issue Description:

Many public water supplies do not meet even the simplest water-quality criterion (i.e., 500 ppm or less of TDS).

Importance:

The principal hindrance is the attitude, "It's always tasted like that." The issue of water quality is important because the water supply essentially affects every consumer every day.

How Do You Propose To Address This Issue?

First, we need reliable quality criteria, which I am not sure that we have.

Second, we need reliable, accurate means of monitoring quality, which is a rapidly improving field.

Finally, we need to sell this concept of water quality to the consumers.

Title: **What Is in the Most Healthful, Tasty Water?**

Originator: **Chapman Wilbert**

Issue Description:

A reverse osmosis product is not healthy water. We need to put something back to make the water healthy for people (not necessarily just pipes). What is it?

Importance:

Water that tastes good (due to supplies of trace elements and minerals) could be sold for a higher price with very little increase in production cost.

How Do You Propose to Address This Issue?

- Recruit nutritionists to determine what concentration and combination of minerals are needed by humans for optimum health.
- Put these minerals back into membrane product water.
- Tailor membrane rejection to leave those minerals in the product water.

Title: **Discover and Characterize the Consumers of Desalinated Water**

Originator: **Linsky**

Need Description:

Desalting/desalination is too often viewed as a private technology of those who understand its complexities.

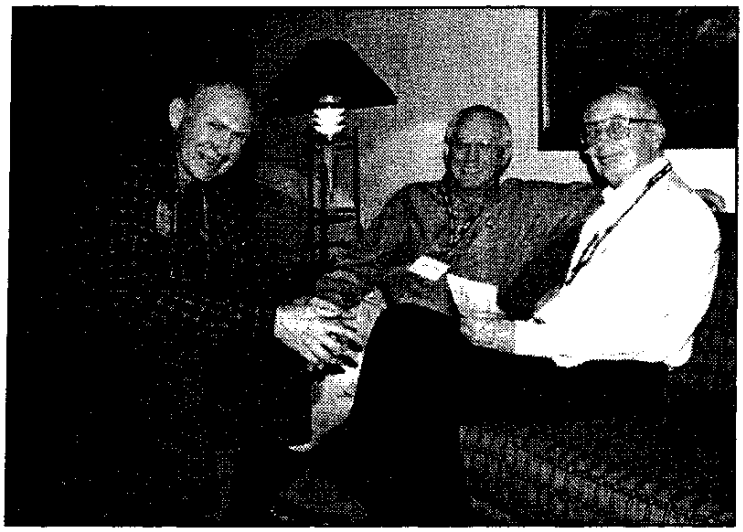
Importance:

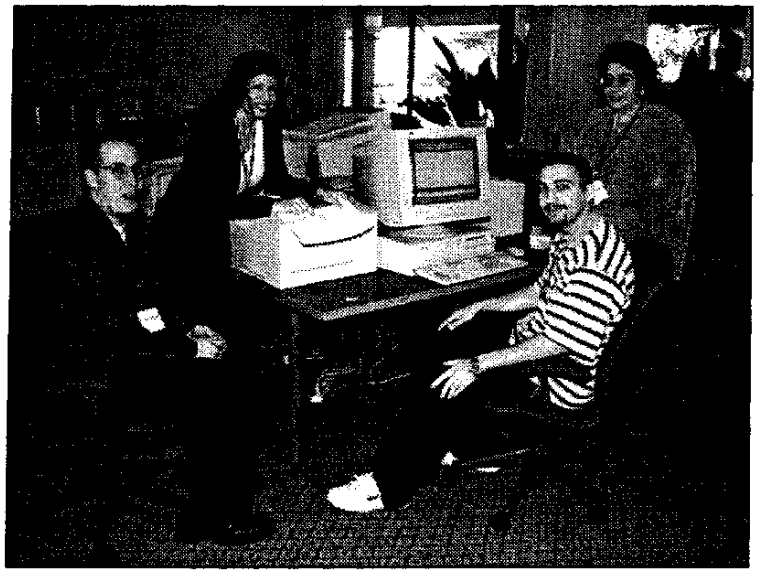
The public, composed of investors, taxpayers, and ratepayers, are the consumers.

How Do You Propose Addressing This Need?

Consumer education and marketing must take into consideration who the consumers are, what they want, and how much they are willing to pay.

Marketing. Ask the question: What do you want? Keep the consumer informed on a regular basis of attempts to satisfy their needs.





PRIORITY 15

Expand the Cake: Outreach and Involvement

Originators:

Dinar on behalf of himself, Archibald, and Price

The following issues were consolidated under the above title:

Title: **Expand the Cake: Outreach and Involvement**

Originator: **Dinar**

Issue Description:

Involve all interested/disinterested parties in the debate.

Importance:

If knowledge remains in-house, potential support dissipates.

How Do You Propose to Address This Issue?

- Fund the preparation of a handbook on desalinization and water management.
- Encourage policy-related papers in policy journals.
- Fund international conferences to share experiences in technology, economics, and the politics of desalinization.
- Approach policy makers at local, state, and national levels.

Title: **Develop More Consumer- and Environmentally Friendly Technology**

Originator: **Archibald**

Issue Description:

Desalination technology is too technical and not descriptive in an appealing sense.

Importance:

It is difficult to communicate to broader audiences.

How Do You Propose to Address This Issue?

Modernize and standardize desalination technology.

Title: **Develop Environmental Support of Desalination Technologies**

Originator: **Price**

Issue Description:

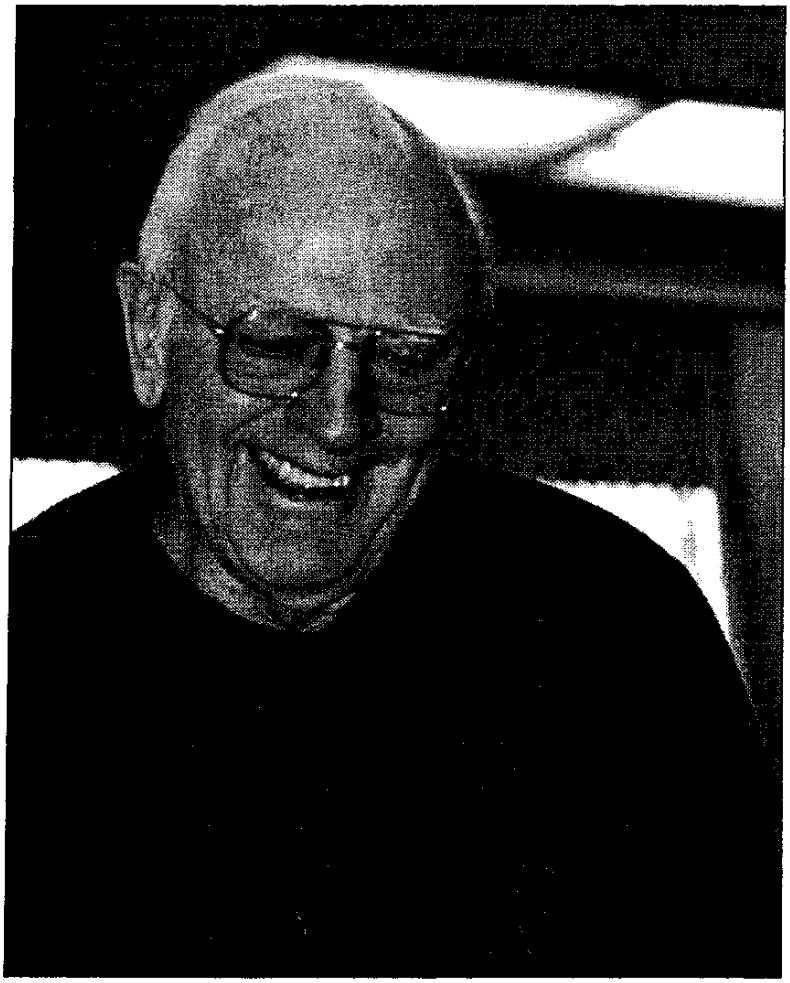
Various speakers claim that 70 percent of the United States' population lives within 50 miles of the coast. Yet, many of the costal communities are dependent upon the distribution of water from inland sources. In the western United States, this has become a problem since environmental and Native American water needs have to compete for a supply that has already been allocated. Low-cost desalination of brackish water and seawater could free-up demands on inland supplies.

Importance:

The application of desalination needs to be supported by a wider constituency to receive the attention of policy makers.

How Do You Propose to Address This Issue?

- Meet with three national environmental groups to test the idea.
- Hold an NGT workshop to study the issues surrounding the use of technology to meet environmental needs.
- Develop a joint-position paper to present to the environmental, water treatment, and political communities.



PRIORITY 16

Viability of Using RO or ED As a Solution for Arsenic Removal in Small-community Water Systems

Originator:

Jorgensen

Issue Description:

The USEPA has proposed to establish the maximum contaminant level (MCL) for arsenic to be lowered from the present standard of 50 parts per billion (ppb) to 5 ppb. The rule was to become effective on January 1, 2001, but has been delayed by an act of Congress until July 2001. A review of the USEPA document reveals that the data used to determine sensitivity to arsenic were based on studies performed in Taiwan during the 1960's and is considered by experts to be dated and inadequate. The field lab personnel used by small-community water systems are not prepared to give accurate results on field samples to a value of less than 10 ppb, and, furthermore, the equipment suppliers do not make a field laboratory instrument that reads accurately to less than 10 ppb.

The USEPA lists RO as a solution with an estimated cost of $85 per household per year as a cost for those served by small systems. A documented case shows this to be at least half the average cost for a system serving 700 customers and probably several times that amount for units with as few a 10 customers or less. A critical cost not recognized by these figures is the concentrate disposal problem. Field conditions limit the conventional solutions, and the designation of the product as a Hazardous Waste would further complicate the problem.

Importance:

The proposal raises serious financial problems for the thousands of small-community water systems across the country, both privately and publicly owned. In many large and small systems, the available underground storage capacity is being integrated with surface water storage and, by doing so, could contaminate the resulting product when extracted. The problem could extend far beyond the USEPA's forecast and is proposed to be accomplished, in some cases, within 2 years.

How Do You Propose to Address This Issue?

Several groups have expressed interest in researching the arsenic issue, including: the American Water Works Association (AWWA), National Sanitation Foundation (NSF), and National Rural Water Association (NWRA). Each will have their priorities and primary interests.

A primary-interest knowledge group should supervise the desalting aspects but, at the same time, all of the related problem subject areas described above, and perhaps others, should also be subjects for some concurrent research.

Establish coordinating group and have the NWRI/USBR proceed with the desalting alternative aspects of the joint study. Field tests should be a part of the proposal.

PRIORITY 17

Increase Incomes in Developing Countries to Make Desalting Affordable

Originator:

Kartinen

Issue Description:

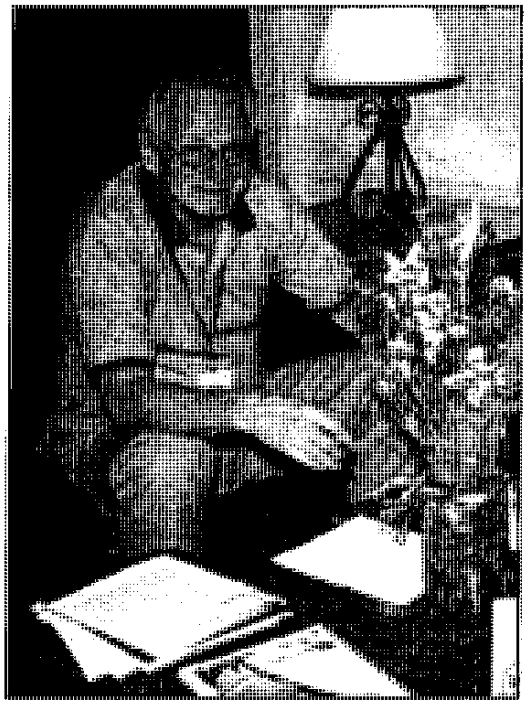
Water shortages and poor-quality water impact the health and economy of developing nations. If poor nations had money, they could develop additional water supplies, including desalting.

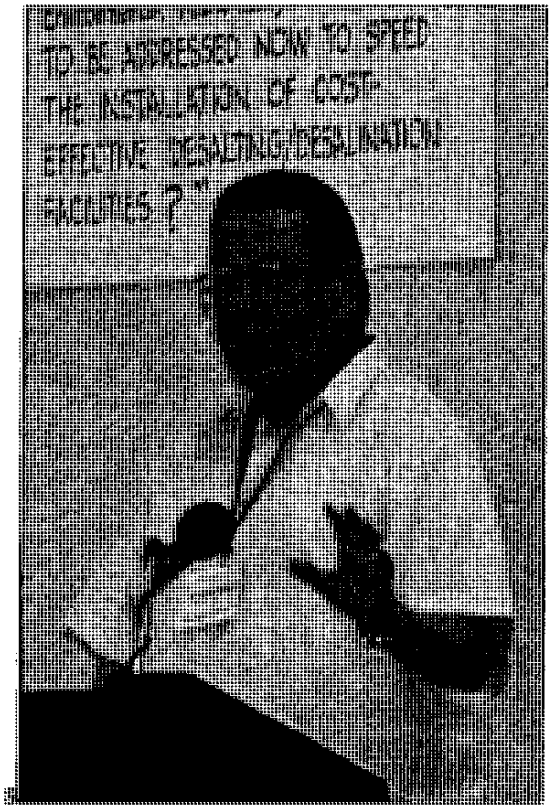
Importance:

- Avoids political unrest.
- Humanitarianism.

How Do You Propose to Address This Issue?

Improve the economies of developing countries. How?




TO BE ADDRESSED NOW TO SPEED
THE INSTALLATION OF COST-
EFFECTIVE DESALTING/DESALINATION
FACILITIES ?

PRIORITY 18

Time Is Running Out for Developing Membrane Water Purification Systems

Originators:

Mills on behalf of himself and Sudak

The following issues were consolidated in the above title:

Title: **Time Is Running Out for Developing Membrane Water Purification Systems**

Originator: **Mills**

Issue Description:

Federal water-quality standards are generated at a faster rate than the ability to comply and seek cost-effective remedies, thereby raising the cost of the water supply. Cost-effective desalting technologies could meet this need.

Importance:

Very little water that is delivered to a residence is ingested. Why then is it necessary to treat all water to remove minute concentrations of exotic constituents? Alternative delivery systems may well be developed (i.e., bottled water, home treatment devices, etc.), thus precluding the need to develop large-scale, cost-effective desalting facilities.

How Do You Propose to Address This Issue?

Expedite research and development of desalting processes to rapidly lower desalting costs to treat an entire domestic supply.

Title: **Assess the True Cost of Regulating Contaminant Concentrations**

Originator: **Sudak**

Issue Description:

Regulation usually increases the cost of the overall desalination process.

Importance:

Regulation adds layers of cost that may sink projects unnecessarily.

How Do You Propose to Address This Issue?

Independently (other than the Department of Health Services) assess the cost of new regulations versus the benefits.

STRENGTH OF FEELING ANALYSIS

The following six Strength-of-Feeling tables provide a quantitative sense of the degree of agreement, or disagreement, among participants about the importance of the 18 major issues identified at the conclusion of the NGT Workshop. Table 1 shows how all-27 participants ranked the 18 major issues they created during the consolidation process. Tables 2 through 6 show the priority ranking and the relative level of agreement among the five subgroups of participants. The subgroups of participants whose Strength of Feeling were analyzed included: business representatives, consultants, economists, researchers, and utility representatives.

Each table lists, in descending order of importance, the major issues they regarded as significant in the context of the question asked of the NGT Workshop participants. Beside each issue title is the number of times it was picked, the total number of points it received from all participants who selected the issue, and finally, the Strength of Feeling expressed as a percentage. The times picked is a straightforward count of the number of ranking sheets on which that issue appeared. The points column shows the total number of points that a particular issue received. For example, if all 27 participants ranked a category last on their voting sheet, it would show a total of 27 points (one point per participant because each ranked it tenth). On the other hand, if each of the 27 participants ranked a category first it would have 270 points (ten points assigned by each participant).

The Strength of Feeling expressed as a percentage is the total number of points a major issue received divided by the maximum number of points it could have received if every participant had ranked it first. For example, look at the first issue in Table 1. It was voted for by 25 of the 27 participants. If all had ranked it first it would have received 270 points. However, it received a total of only 170 points so its Strength of Feeling was 170/270 x 100 = 63.0 percent, relatively low.

Examination of subgroup rankings is important because sometimes, stark disagreements among groups are masked in the overall ranking (Table 1) but are revealed in the subgroups (Tables 2 through 6). For example, the highest priority major issue selected by all participants was not selected as the highest priority by any subgroup. It was, however selected as second most important by the seven research participants (Table 5) and the six utility participants (Table 6). The second place votes of these 13 individuals gave it enough points to be ranked number one by all participants. This may seem anomalous but notice that all 27 participants were very divided about the highest-priority major issue, giving it only a 63.0 percent Strength of Feeling. By contrast, the three economists (Table 4) all voted for the same highest priority major issue thus giving it a 100.0 percent Strength of Feeling.

TABLE 1

Issues (18) Ranked by all Participants (27)

Rank	Title	Times Picked/Pts	Strength of Feeling
1.	Additional Advancement of Membrane Technology	25/170	63.0%
2.	Develop an Education and Public Relations Strategy to Deal With the Implementation of Desalination Projects	26/170	63.0%
3.	National Desalting and Water Quality Improvement Act	25/167	61.9%
4.	Develop a Roadmap to Simplify the Decision-making Process for Desal Users; a Living Document Revised As R&D, or Practice Develops New Answers	24/162	60.0%
5.	Environmentally Sustainable Concentrate and Waste Management	24/158	58.5%
6.	Innovate a Paradigm Decrease in the Energy Consumption of a Seawater Membrane Desalting Plant	22/125	46.3%
7.	Look Outside the Box for Innovative Solutions	22/114	42.2%
8.	Develop a Better Understanding of the Current and Future Value of Water of Different Qualities in Alternative Uses	17/95	35.2%
9.	Improve the Fundamental Understanding of Membrane Science	17/69	25.6%
10.	Develop a National Advisory Panel for Advanced Water Treatment Technologies	15/67	24.8%
11.	Desalination Technology Clearinghouse	16/54	20.0%
12.	Separate Water Distribution Systems	12/42	15.6%

Rank	Title	Times Picked/Pts	Strength of Feeling
13.	Simplify, But Improve, the Ability to Control RO Systems Through Use of Modern Telecommunications Technology and Improved Monitoring Equipment	8/28	10.4%
14.	Establish and Get Public Acceptance of Criteria for Healthful, Good-tasting Drinking Water	8/27	10.0%
15.	Expand the Cake: Outreach and Involvement	4/15	5.6%
16.	Viability of Using Reverse Osmosis or Electrodialysis As a Solution for Arsenic Removal in Small-community Water Systems	3/14	5.2%
17.	Increase Incomes in Developing Countries to Make Desalting Affordable	1/4	1.5%
18.	Time Is Running Out for Developing Membrane Water Purification Systems	1.4	1.5%

TABLE 2

Issues (18) Ranked by Business Participants (2)

Rank	Title	Times Picked/Pts	Strength of Feeling
1.	National Desalting and Water Quality Improvement Act	2/15	75.0%
2.	Develop an Education and Public Relations Strategy to Deal With the Implementation of Desalination Projects	2/15	75.0%
3.	Environmentally Sustainable Concentrate and Waste Management	2/14	70.0%
4.	Look Outside the Box for Innovative Solutions	2/14	70.0%
5.	Develop a Roadmap to Simplify the Decision-making Process for Desal Users; a Living Document Revised As R&D, or Practice Develops New Answers	2/13	65.0%
6.	Innovate a Paradigm Decrease in the Energy Consumption of a Seawater Membrane Desalting Plant	2/9	45.0%
7.	Develop a Better Understanding of the Current and Future Value of Water of Different Qualities in Alternative Uses	1/9	45.0%
8.	Additional Advancement of Membrane Technology	2/8	40.0%
9.	Separate Water Distribution Systems	1/4	20.0%
10.	Improve the Fundamental Understanding of Membrane Science	1/3	15.0%
11.	Develop a National Advisory Panel for Advanced Water Treatment Technologies	1/3	15.0%
12.	Desalination Technology Clearinghouse	1/2	10.0%
13.	Expand the Cake: Outreach and Involvement	1/1	5.0%

TABLE 3

Issues (18) Ranked by Consulting Participants (9)

Rank	Title	Times Picked/Pts	Strength of Feeling
1.	Environmentally Sustainable Concentrate and Waste Management	9/66	73.3%
2.	Innovate a Paradigm Decrease in the Energy Consumption of a Seawater Membrane Desalting Plant	8/52	57.8%
3.	Additional Advancement of Membrane Technology	8/52	57.8%
4.	Develop an Education and Public Relations Strategy to Deal With the Implementation of Desalination Projects	9/51	56.7%
5.	National Desalting and Water Quality Improvement Act	9/50	55.6%
6.	Develop a Roadmap to Simplify the Decision-making Process for Desal Users; a Living Document Revised As R&D, or Practice Develops New Answers	7/46	51.1%
7.	Look Outside the Box for Innovative Solutions	8/44	48.9%
8.	Develop a Better Understanding of the Current and Future Value of Water of Different Qualities in Alternative Uses	5/28	31.1%
9.	Improve the Fundamental Understanding of Membrane Science	6/26	28.9%
10.	Develop a National Advisory Panel for Advanced Water Treatment Technologies	6/25	27.8%
11.	Desalination Technology Clearinghouse	4/14	15.6%
12.	Viability of Using Reverse Osmosis or Electrodialysis As a Solution for Arsenic Removal in Small-community Water Systems	2/11	12.2%

Rank	Title	Times Picked/Pts	Strength of Feeling
13.	Separate Water Distribution Systems	3/11	12.2%
14.	Establish and Get Public Acceptance of Criteria for Healthful, Good-tasting Drinking Water	2/7	7.8%
15.	Simplify, But Improve, the Ability to Control RO Systems Through Use of Modern Telecommunications Technology and Improved Monitoring Equipment	2/6	6.7%
16.	Time Is Running Out for Developing Membrane Water Purification Systems	1/4	4.4%
17.	Expand the Cake: Outreach and Involvement	1/2	2.2%

TABLE 4

Issues (18) Ranked by Economist Participants (3)

Rank	Title	Times Picked/Pts	Strength of Feeling
1.	Develop a Roadmap to Simplify the Decision-making Process for Desal Users; a Living Document Revised As R&D, or Practice Develops New Answers	3/30	100.0%
2.	Innovate a Paradigm Decrease in the Energy Consumption of a Seawater Membrane Desalting Plant	3/22	73.3%
3.	Look Outside the Box for Innovative Solutions	3/20	66.7%
4.	Develop a Better Understanding of the Current and Future Value of Water of Different Qualities in Alternative Uses	3/19	63.3%
5.	Additional Advancement of Membrane Technology	3/15	50.0%
6.	Develop a National Advisory Panel for Advanced Water Treatment Technologies	3/13	43.3%
7.	National Desalting and Water Quality Improvement Act	2/11	36.7%
8.	Desalination Technology Clearinghouse	2/8	26.7%
9.	Improve the Fundamental Understanding of Membrane Science	1/8	26.7%
10.	Develop an Education and Public Relations Strategy to Deal With the Implementation of Desalination Projects	2/8	26.7%
11.	Expand the Cake: Outreach and Involvement	1/4	13.3%
12.	Separate Water Distribution Systems	1/3	10.0%
13.	Environmentally Sustainable Concentrate and Waste Management	1/2	6.7%

Rank	Title	Times Picked/Pts	Strength of Feeling
14.	Establish and Get Public Acceptance of Criteria for Healthful, Good-tasting Drinking Water	1/1	3.3%
15.	Simplify, But Improve, the Ability to Control RO Systems Through Use of Modern Telecommunications Technology and Improved Monitoring Equipment	1/1	3.3%

TABLE 5

Issues (18) Ranked by Researcher Participants (7)

Rank	Title	Times Picked/Pts	Strength of Feeling
1.	Develop an Education and Public Relations Strategy to Deal With the Implementation of Desalination Projects	7/52	4.3%
2.	Additional Advancement of Membrane Technology	6/48	68.6%
3.	Environmentally Sustainable Concentrate and Waste Management	6/41	58.6%
4.	Develop a Roadmap to Simplify the Decision-making Process for Desal Users; a Living Document Revised As R&D, or Practice Develops New Answers	7/39	55.7%
5.	National Desalting and Water Quality Improvement Act	6/35	50.0%
6.	Improve the Fundamental Understanding of Membrane Science	7/25	35.7%
7.	Look Outside the Box for Innovative Solutions	6/24	34.3%
8.	Innovate a Paradigm Decrease in the Energy Consumption of a Seawater Membrane Desalting Plant	4/18	25.7%
9.	Desalination Technology Clearinghouse	3/18	25.7%
10.	Develop a National Advisory Panel for Advanced Water Treatment Technologies	3/18	25.7%
11.	Separate Water Distribution Systems	4/15	21.4%
12.	Develop a Better Understanding of the Current and Future Value of Water of Different Qualities in Alternative Uses	3/14	20.0%
13.	Establish and Get Public Acceptance of Criteria for Healthful, Good-tasting Drinking Water	3/13	18.6%

Rank	Title	Times Picked/Pts	Strength of Feeling
14.	Simplify, But Improve, the Ability to Control RO Systems Through Use of Modern Telecommunications Technology and Improved Monitoring Equipment	3/13	18.6%
15.	Expand the Cake: Outreach and Involvement	1/8	11.4%
16.	Increase Incomes in Developing Countries to Make Desalting Affordable	1/4	5.7%

TABLE 6

Issues (18) Ranked by Utility Participants (6)

Rank	Title	Times Picked/Pts	Strength of Feeling
1.	National Desalting and Water Quality Improvement Act	6/56	93.3%
2.	Additional Advancement of Membrane Technology	6/47	78.3%
3.	Develop an Education and Public Relations Strategy to Deal With the Implementation of Desalination Projects	6/44	73.3%
4.	Environmentally Sustainable Concentrate and Waste Management	6/35	58.3%
5.	Develop a Roadmap to Simplify the Decision-making Process for Desal Users; a Living Document Revised As R&D, or Practice Develops New Answers	5/34	56.7%
6.	Develop a Better Understanding of the Current and Future Value of Water of Different Qualities in Alternative Uses	5/25	41.7%
7.	Innovate a Paradigm Decrease in the Energy Consumption of a Seawater Membrane Desalting Plant	5/24	40.0%
8.	Desalination Technology Clearinghouse	6/12	20.0%
9.	Look Outside the Box for Innovative Solutions	3/12	20.0%
10.	Separate Water Distribution Systems	3/9	15.0%
11.	Simplify, But Improve, the Ability to Control RO Systems Through Use of Modern Telecommunications Technology and Improved Monitoring Equipment	2/8	13.3%
12.	Develop a National Advisory Panel for Advanced Water Treatment Technologies	2/8	13.3%

Rank	Title	Times Picked/Pts	Strength of Feeling
13.	Improve the Fundamental Understanding of Membrane Science	2/7	11.7%
14.	Establish and Get Public Acceptance of Criteria for Healthful, Good-tasting Drinking Water	2/6	10.0%
15.	Viability of Using Reverse Osmosis or Electrodialysis As a Solution for Arsenic Removal in Small-community Water Systems	1/3	5.0%

APPENDICES

APPENDIX A

ACRONYMS

AAAS	American Association for the Advancement of Science
ADA	American Desalting Association (Renamed American Membrane Technology Association)
AMTA	American Membrane Technology Association
ASTA	American Society for Testing and Materials
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
CA	cellulose acetate
$CaSO_4$	calcium sulfate
CPA	composite polyamide
DARPA	Defense Advance Research Projects Agency
DEP	(U.S.) Department of Environmental Protection
DHS	Department of Health Services (State of California)
DI	de-ionization
DOE	(U.S.) Department of Energy
DRIP	Desalination Research Investigation Participation
DWR	Department of Water Resources (State of California)
ED	electrodialysis
EPRI	Electric Power Research Institute
ERD	energy recovery device

GDP	Gross Domestic Project
GE	General Electric
gpd	gallons per day
HRS	(U.S. Department of) Health and Rehabilitative Services
I&C	instrumentation and control
IDA	International Desalination Association
IP	intellectual property
kwh/day	kilowatts hour/day
MCL	maximum contaminant level
MF	microfilitration
mgd	million gallons per day
mg/L	milligrams per liter
NCDT	National Centers for Desalination Technology
NDMA	nitrosidemethylamine
NF	nanofiltration
NIH	National Institute of Health
NOM	natural organic molecules
NRWA	National Rural Water Association
NSF	National Sanitation Foundation
NWRI	National Water Research Institute

O&M	operation and maintenance
OCR	operational and cost reduction
OCWD	Orange County Water District
OSW	Office of Saline Water
OWRDT	Office of Water Research and Desalination Technology
OWRT	Office of Water Research & Technology
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
RO	reverse osmosis
R&D	research and development
SEDA	Southeast Desalting Association
TDS	total dissolved solids
THM	trihalomethane
UF	ultrafiltration
USBR	U.S. Bureau of Reclamation
USEPA	U. S. Environmental Protection Agency
UV	ultraviolet
WERF	Water Environment Research Foundation
WRD	WateReuse Research Foundation

APPENDIX B

PREVIOUS NGT WORKSHOPS CONDUCTED BY NWRI

Knowledge Management. Report of a workshop sponsored by NWRI. Kellogg West Conference Center/Hotel, California State Polytechnic University, Pomona, CA January, 5-7, 2001. 169p.

Oxygenate Contamination. Report of a workshop sponsored by NWRI in cooperation with the United States Bureau of Reclamation. Kellogg West Conference Center/Hotel, California State Polytechnic University, Pomona, CA, September 15-17, 2000: 258p.

Utility Leadership. Report of a workshop sponsored by NWRI in cooperation with Malcolm Pirnie, Inc., the University of Southern California, and the University of South Florida. Kellogg West Conference Center/Hotel, California State Polytechnic University, Pomona, CA, October 24-26, 1999: 154p.

Non-potable Water Recycling. Report of a workshop sponsored by NWRI in cooperation with Irvine Ranch Water District and the Orange County Water District. Kellogg West Conference Center/Hotel, California State Polytechnic University, Pomona, CA, May 23-25, 1999: 174p.

Conjunctive Use Water Management Program. Report of a workshop jointly sponsored by NWRI, Association of Ground Water Agencies, and the Metropolitan Water District of Southern California. Kellogg West Conference Center/Hotel, California State Polytechnic University, Pomona, CA, May 27-29, 1998: 157p.

Barriers to Providing Safe Drinking Water Through Small Systems. Report of a workshop jointly sponsored by NWRI, Pan American Health Organization, and NSF International/WHO Collaborative Center. Pan American Health Organization Headquarters, Washington, D.C., May 13-15, 1998: English report: 175p., Spanish report: 188p. (Bound in a single volume.)

Barriers to Harvesting Stormwater. Report of a workshop jointly sponsored by NWRI, Los Angeles County Department of Public Works, County of Orange Public Facilities & Resources Department, Southern California Coastal Water Project, and the American Oceans Campaign. Kellogg West Conference Center/Hotel, California State Polytechnic University, Pomona, CA, September 22-24, 1997: 159p.

Groundwater Disinfection Regulations Benefits Conference. Report of a conference sponsored by NWRI. Arnold and Mabel Beckman Center, National Academies of Sciences and Engineering, Irvine, CA, March 17, 1997: 75p.

Groundwater Disinfection Regulation. Report of a workshop jointly sponsored by NWRI and the USEPA. Arnold and Mabel Beckman Center, National Academies of Sciences and Engineering, Irvine, CA, January 6-8, 1997: 209p.

Membrane Biofouling. Report of a workshop jointly sponsored by NWRI, UNESCO Centre for Membrane Science and Technology, and CRC for Waste Management and Pollution Control, LTD. UNSW Institute of Administration, Sydney, Australia, November 15-17, 1996: 176p.

The Santa Ana River Watershed. Report of a workshop jointly sponsored NWRI and the Santa Ana Watershed Project Authority. Co-sponsors included: City of San Bernardino Water Department, City of Riverside, Western Municipal Water District, and Orange County Water District. Kellogg West Conference Center/Hotel, California State Polytechnic University, Pomona, CA, August 23-25, 1995: 182p.

The New River. Report of a workshop jointly sponsored by NWRI and the County of Imperial, California. Barbara Worth Country Club, Holtville, CA, May 19-21, 1995: English report: 134p., Spanish report: 134p. (Bound in a single volume)

Establishment of The Middle-East Water and Energy Research and Technology Centre. Report of a workshop jointly sponsored by NWRI and the Sultanate of Oman through the Worldwide Desalination Research and Technology Survey. Muscat, Oman: September 21, 1994: 29p.

Risk Reduction in Drinking Water Distribution Systems. Report of a workshop jointly sponsored by NWRI and the Environmental Criteria and Assessment Office of the USEPA. Arnold and Mabel Beckman Center, National Academies of Sciences and Engineering, Irvine, CA, February 27-28, 1994: 142p.

Fouling and Module Design. Report of a workshop jointly sponsored by NWRI and the National Science Foundation (NSF). Virden Conference Center of the University of Delaware, Lewes, DE, October 30 – November 1, 1993: 115p.

Groundwater Disinfection Rule. Report of a workshop jointly sponsored by NWRI and the USEPA in collaboration with the Weston Institute. Virden Conference Center of the University of Delaware, Lewes, DE. June 7-8, 1992: 103p

APPENDIX C

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APPENDIX D

PARTICIPANTS' BIOGRAPHICAL SKETCHES

Sandra O. Archibald, Ph.D.
Associate Dean for Resident Instruction
H.H. Humphrey Institute of Public Affairs
University of Minnesota

Sandy Archibald has taught economics at the University of Minnesota since 1992. At the university, she also has full faculty membership in both the Water Resources Science and Conservation Biology programs. Within the last year, she has taught courses on Environmental and Resource Economics in Romania and Italy, and she was a member of a Blue Ribbon Panel to help the Municipal Water District of Orange County determine if the construction of a seawater desalination plant would benefit the district. Archibald received a B.A in History and M.A. in Public Administration from the University of California, Berkeley, and an M.S. and Ph.D. in Agricultural and Resource Economics from the University of California, Davis.

Robert Atlas
President
Sabrex of Texas, Inc.

For the past 10 years, Bob Atlas has been involved in the purification and recycling of industrial wastewater, and has spent the last 5 years developing flow through capacitor technology and applying it to all types of water and wastewater purification processes, including the desalination of ocean water. As a result, Atlas is one of three principal investigators on a new 3-year Defense Advance Research Projects Agency (DARPA) research contract to further develop the flow through capacitor technology to generate drinking water from the ocean and other polluted waters. In addition, his company, Sabrex of Texas, Inc., is one of the primary developers of a new emerging technology called the electronic water purifier. Atlas received a B.S. in Chemistry from the State University of New York at New Paltz and a M.S. in Chemical Engineering from Stevens Institute of Technology.

Richard W. Atwater
CEO/General Manager
The Inland Empire Utilities Agency

Rich Atwater has over 20 years experience in water resources management in the western United States. He has pioneered award-winning projects and implemented numerous innovative water resources management programs. He has been CEO/General Manager of the Inland Empire Utilities Agency – which distributes imported water, provides industrial/municipal wastewater collection and treatment services, and other utility services in San Bernardino County

(California) – since 1999. In addition, he was the former General Manager of the West and Central Basin Municipal Water Districts and also managed the Resources Division for the Metropolitan Water District of Southern California. Atwater received a B.S. in Geology and Environmental Science from Stanford University and an M.S. in Urban and Regional Planning from the University of Southern California.

Robert P. Carnahan, Ph.D.
Associate Dean of Research, College of Engineering
University of South Florida (USF)

Bob Carnahan has been Associate Dean for Research at USF since 1993. His research interests include the application of membrane filtration in water treatment, wastewater treatment and industrial waste treatment, and biological and physical/chemical treatment of wastewaters and industrial waste. He is also interested in the application of innovative technology for the recycling and reuse of wastewaters to be used toward the treatment and disposal of hazardous materials. In addition, Carnahan was elected to the American Desalting Association's Hall of Fame in 1998. He received a B.C.E. in Civil Engineering from the University of Florida, an M.S. in Sanitary Engineering from the University of North Carolina, and a Ph.D. in Environmental Systems Engineering from Clemson University.

Huali G. Chai, Esq.
Attorney
Law Offices of Huali G. Chai

Huali Chai is a practicing attorney who conducts a civil litigation practice in both San Francisco and San Jose, California, and acts as a court-appointed arbitrator. She is a Board Member of The Bay Institute of San Francisco; a Member of the CALFED Bay Delta Program's Delta Drinking Water Council; and a Member of the President's Western Water Policy Review Advisory Commission, which published the report, "Water in the West: The Challenge for the Next Century." Chai received her B.S. in Chemistry from Wellesley College and has conducted research in biochemistry under grants from the National Science Foundation. She has a Juris Doctorate degree from George Washington University National Law Center.

Michelle J. Chapman Wilbert
Research Physical Scientist
Water Treatment Engineering and Research Technical Service Center
U.S. Bureau of Reclamation

Michelle Chapman Wilbert has 11 years experience working with research projects to reduce the cost of membrane processes for desalting and water treatment systems to make them more affordable for providing potable water to people all over the world. Past work at the Bureau of Reclamation includes developing a cost estimation program for water treatment processes, membrane characterization, and standards for membrane system operations. Chapman Wilbert

received a B.S. in Physical Geography at the University of Oregon and an M.S. in Technology & Human Affairs at Washington University. She also has course work in Engineering Physics and Chemistry at the Colorado School of Mines.

Mark M. Clark, Ph.D.
Professor of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign (UIUC)

Mark Clark has taught engineering at the University of Illinois at Urbana-Champaign since 1987. His research interests include the surface properties of membranes, membrane filtration of natural water, and the modeling of mass transport in membranes, among many others. In addition, he has consulted on a membrane technology projects for Malcolm Pirnie, Inc., NSF International, the U.S. Army Construction Engineering Research Laboratory, and the Savannah River Technology Center in South Carolina. Clark received a B.S. in Civil Engineering from the University of Missouri, Columbia, M.S. in Environmental Engineering from the University of Missouri, Columbia, and Ph.D. in Environmental Engineering from The Johns Hopkins University.

Bradley M. Coffey, P.E.
Senior Engineer
Metropolitan Water District of Southern California (MWD)

As Senior Engineer for MWD, Brad Coffey assists in the development of water treatment process design criteria. He manages an applied research team that investigates processes like particulate removal, ozone and ultraviolet disinfection, and salinity removal. He has been with MWD for 10 years working on projects such as investigating the impacts of ozonation on biological filtration and biological re-growth in a distribution system, and developing experimental plans for a 5.5 million gallons per day (mgd) water treatment research facility. Coffey received a B.S and M.S. in Mechanical Engineering as well as an M.S. in Environmental Engineering from Virginia Tech.

Ariel Dinar, Ph.D.
Lead Economist
Rural Development Department, Agricultural Policy Division
The World Bank

Since 1993, Ariel Dinar has worked in the Agricultural Policy Division of the World Bank on projects such as the Sub-Saharan Africa Water Strategy, the Mexico Water Resources Management Project, the Morocco Second Large-scale Irrigation Project, and the Bangladesh Flood Action Plan, just to name a few. He specializes in resource and environmental economics, water resource economics, and production economics as well as in operation research and extension. He also teaches a graduate level course entitled "Water: Conflict, Negotiation, and Cooperation" in the School of Advanced International Studies at the Johns Hopkins University.

Dinar received a Bs.C, Ms.C., and Ph.D. in Agricultural Economics from the Hebrew University in Jerusalem.

James S. Dusenbury, Ph.D.
Research Engineer, Water & Wastewater Treatment Team
U.S. Army Tank Automotive Research, Development & Engineering Center

As a Research Engineer on the Water & Wastewater Research Team, Jay Dusenbury is responsible for advancing the U.S. Army's tactical water and wastewater treatment program through research, development, and engineering. He has also been the Project Manager of multiple Army projects to develop novel water purification and generation systems as well as water treatment and quality monitoring instruments. Dusenbury received a B.S. in Chemical Engineering from Worcester Polytechnic Institute in Massachusetts, and both an M.S. and Ph.D. in Environmental Engineering from Pennsylvania State University.

David H. Furukawa, P.E.
President
Separation Consultants, Inc.

David Furukawa has over 40 years of desalination technology experience in both public and private sectors. Since 1988, his company, Separation Consultants, Inc., has provided technical, management, and strategic assistance to institutions, communities, municipalities, nations, and private companies. In addition, he was past President and Director of the International Desalination Association, past President of the American Desalting Association, and Vice-moderator on the Research Advisory Council for the Middle East Desalination Research Center. Recently, he chaired a Blue Ribbon Panel to help the Municipal Water District of Orange County determine if the construction of a seawater desalination plant would benefit the district. Furukawa received a B.S. in Chemical Engineering from the University of Colorado.

Ernest O. Kartinen, Jr., P.E.
Vice President
Boyle Engineering

Ernie Kartinen, who specializes in water treatment and economic feasibility studies, has been with Boyle Engineering since 1968. He is experienced in the planning, design, and construction administration of public works projects, including water treatment transmission, pumping, storage, and distribution facilities; wastewater collection, treatment, and disposal; drainage improvements; and road and street improvements. He has been the Project Engineer/Manager for many reverse osmosis treatment plant or desalination plant projects in California, Nebraska, Colorado, and Texas, just to name a few. In addition, he is a member of the American Desalting Association and International Desalination Association. Kartinen received both a B.S. and M.S. in Civil Engineering from California State University Long Beach.

Jack C. Jorgensen
President and Systems Manager
Beaches Water Company

Jack Jorgensen has spent more than 50 years researching, planning, designing, and constructing water resources projects and programs. In 1972, as the Assistant Director for Technology Transfer in the Office of Water Research and Technology, he pioneered the application of desalting technologies within the U.S. by undertaking efforts to develop the desalting industry. For his efforts, he was named as the American Desalting Association (ADA) Man of the Year in 1994 and, later, was elected to the ADA Hall of Fame. He was also the primary author of the desalting bill that became the "Simon Bill" – and, later, the Water Desalination Act of 1996 – under the sponsorship of former U.S. Senator Paul Simon (Illinois). Jorgensen received his B.S. in Civil Engineering, specializing in Water and Hydrology, from the University of Washington in Seattle.

Frank B. Leitz
Chemical Engineer
Water Treatment Engineering and Research Group
U.S. Bureau of Reclamation

Overall, Frank Leitz has over 39 years experience in the field of desalination and water treatment, specializing in reverse osmosis and electrodialysis. He has worked with a major manufacturer of desalination equipment, with the federal government in the design and operation of Yuma Desalting Plant (Arizona) and other desalination plants, and with the Saudi Arabian government on establishing a Desalination Research, Development, and Training Center in Al Jubail. In addition, he has served as a 10-year member on the Editorial Board of *Desalination* and has four patents on membranes and electrochemical cells. Leitz received a B.S in Chemical Engineering, M.S. in Chemical Engineering Practice, and Degree, The Chemical Engineer, from the Massachusetts Institute of Technology.

Douglas R. Lloyd, Ph.D.
Associate Chair, Department of Chemical Engineering
The University of Texas at Austin

Doug Lloyd has taught at the University of Texas at Austin since 1981. He became Dean of the College of Engineering at UT Austin in 1989 and was invited to be Associate Chair in 1997. He is the author of more than 115 publications and three books, and he is on the Editorial Board of the *Journal of Porous Materials*. Recently, he was Conference Chairman of the International Congress on Membranes in 1999. In addition, he served as a Board of Director and past President of the North American Membrane Society, which he co-founded in 1985. Lloyd received a B.A.Sc., M.A.Sc., and Ph.D. in Chemical Engineering from the University of Waterloo in Ontario, Canada.

William R. Mills, Jr., P.E., P.G.
General Manager
Orange County Water District (OCWD)

Bill Mills was appointed as General Manager of OCWD in 1987. Among his duties, he is responsible for developing a long-range plan aimed at decreasing OCWD's dependence on imported supplies and improving the quality of surface and groundwater supplies. Currently, he serves as Chair of the Association of Groundwater Agencies and as Chair of Association of California's Water Agency's Water Quality Committee. In addition, he was awarded as Outstanding Member (1994) and the Presidential Award for Distinguished Service (1996) from the American Desalting Association. Mills is a graduate Geological Engineer from the Colorado School of Mines and has an M.S. degree in Civil/Environmental Engineering from Loyola University in Los Angeles.

Irving Moch, Jr., Ph.D.
President
I. Moch & Associates, Inc.

Irving Moch has over 23-years experience in water treatment, particularly in reverse osmosis. He founded I. Moch & Associates, Inc., in 1996, which is a consulting firm that specializes in project scopes, plant design and troubleshooting, and personnel training for membrane separation systems. Moch is a Director and past Editor of the International Desalination Association and a Director and the International Liaison Committee Chair of the American Membrane Technology Association (AMTA). As Chairman of the American Society for Testing and Materials (ASTM) D19 Task Force on membrane filtration, he is leading the effort for writing standards for the U.S. industry. He is also on the editorial board of the *International Desalination and Water Reuse Quarterly*. Moch received an A.B. in Liberal Arts as well as a B.S., M.S., and Ph.D. in Chemical Engineering from Columbia University.

M. Kevin Price
Manager
Water Treatment Engineering and Research Group
U.S. Bureau of Reclamation

Besides managing the Water Treatment and Engineering Group, Kevin Price also oversees the Desalination and Water Purification Research and Development Program, Advanced Water Treatment Research Program, and the Water Reuse Research Program at the Bureau of Reclamation. In addition, he has also worked on desalination projects in the Middle East as well as with the European Union, Korea, and Japan. For instance, he was the U.S. Technical Representative (through the U.S. Department of State) to the Middle East Desalination Research Center in Muscat, Oman, and served as the Center's first Research Director. Price received a B.S. in Zoology from Albertson College of Idaho, M.S. in Chemical Engineering from Columbia University, and MBA in Finance from the University of Denver.

Robert L. Riley
President
Separation Systems Technology, Inc.

Bob Riley has over 35 years experience in the development of synthetic polymeric membranes, separation devices, equipment and processes for water desalination, water purification, and membrane filtration. In addition to being President of Separations Systems Technology, Inc., he also maintains a private consulting firm, Separation Systems International in La Jolla, California. He is a member of the Editorial Board of *Desalination* and the *Journal of Membrane Science*, and the author/co-author of numerous publications and patents in the area of polymers, synthetic membranes, and separation processes. Riley received a B.S. in Chemistry from Regis College in Denver, Colorado, and continued his graduate studies at Texas Christian University, San Diego State University, and the University of California, Los Angeles.

Jean-Daniel Saphores, Ph.D.
Assistant Professor, Urban and Regional Planning, School of Social Ecology
University of California, Irvine (UCI)

Jean-Daniel Saphores has been an Assistant Professor with UCI since July 2000; previously, he had taught in the Department of Economics at the Université Laval in Quebec since completing his Ph.D. in 1997. His current research interests include investing in new supplies versus conservation options under uncertainty and investing to protect water quality using real options. Saphores studied Civil Engineering (with a Minor in Applied Mathematics) at the Ecole Nationale des Ponts et Chaussées in Paris, France, and received an M.S. in Geotechnical Engineering at the University of Colorado, Boulder as well as an M.S. in Environmental Systems Engineering, M.A. in Economics, and Ph.D. in Agricultural Economics at Cornell University

Paul E. Shoenberger
Chief of Engineering and Operations
West and Central Basin Municipal Water Districts

For 6 years, Paul Shoenberger has been an engineer for West and Central Basin Municipal Water Districts, a member agency of the Metropolitan Water District of Southern California that serves 2.2 million residents. As Chief of Engineering and Operations, he manages the design, construction, and inspection of the districts' Capital Improvement Projects; manages the operations of district facilities, including recycled water treatment plants, pump stations, and storage and distribution systems; and manages regional and local planning for the districts. Shoenberger received a B.S. in Civil Engineering from the University of California, Davis, and an M.S. in Water Resources Planning and Management from Colorado State University.

Evelyn Stevens
Water Production Foreman
City of Dunedin (Florida)

Lynn Stevens has been Water Production Foreman for the City of Dunedin since 1991. Among her duties, she is responsible for the daily operation of a reverse osmosis-nanofiltration plant, provides on-site instruction and training to plant operators, oversees operational and capital improvement expenditures, and acts as a liaison to all regulatory agencies. In addition, she was a Charter Member, former Director, and former President of the Southeast Desalting Association; currently, she is the Vice President. Stevens received an A.A. in General Studies (Emphasis on Chemistry, Geology, and Management) from St. Petersburg Junior College in Florida.

Richard G. Sudak
President
Separation Processes, Inc.

Dick Sudak has over 30 years experience in the field of membrane research and development. His early work included the design of reverse osmosis systems with spiral wound elements at General Atomic (ROGA), which later became Fluid Systems. In 1980, he founded Separation Processes, Inc., a consulting engineering firm that specializes in the application of membrane separations. He has since remained President of Separation Processes. Presently, he is involved in one of the largest desalting projects in the southwestern United States. Sudak received a B.S. in Chemical Engineering from Gonzaga University and an M.S. in Chemical Engineering from Ohio State University.

Randolph L. Truby
Vice President, Sales and Marketing Water Applications
Koch Membrane Systems

During his 31-year career, Randy Truby has authored over 35 technical papers on reverse osmosis and membrane technology. He was involved in the development of reverse osmosis membranes for brackish water and seawater desalination, and was instrumental in the sale of the first large reverse osmosis system for saltwater desalting in 1977. He was also a key participant in a number of landmark brackish water installations, such as the 5 mgd reverse osmosis system at the Orange County Water District (California) and the 54 mgd Yuma Desalination Project (Arizona). At Koch, he is in charge of the global marketing of Koch's entire product line for water applications and membrane products sold for industrial and municipal use. He is a past President of the International Desalination Association and currently serves as Vice President of the American Membrane Technology Association (AMTA). Truby received a B.S. in Biology from San Diego State University.

Ian C. Watson, P.E.
President
RosTek Associates, Inc.

Ian Watson has over 35 years of experience in the field of desalination and membrane application technology. Among his many projects, he has helped develop a brackish water reverse osmosis plant in Florida, served as a technical advisor for four wellhead reverse osmosis plants to reduce radionuclides in Maryland, and helped design a membrane water treatment plant for removing color from deep well water in southern California. He was also the Project Manager for revising and updating "Desalting Handbook for Planners," published by the U.S. Bureau of Reclamation. In addition, he has been a member of the Board of Directors for the International Desalination Association (IDA) since 1993. Watson completed the Institute of Chemical Engineers' requirements for Chartered Engineer Status at Neath College of Technology in South Wales, Great Britain.

Robert R. Yamada, P.E.
Senior Civil Engineer
San Diego County Water Authority

Currently, Bob Yamada manages the Project Development Section for the Water Resource Department at the San Diego County Water Authority and is involved in the Authority's efforts to plan and facilitate the development of the region's available water resources, including surface water, groundwater, recycled water, and seawater. In addition, he also coordinates the Authority's seawater desalination activities and served as Project Manager for the Authority's South Bay Seawater Desalination Project Study. Yamada received both a B.S. and M.S. in Civil Engineering from San Diego State University, and has over 17 years experience in civil engineering and water resources planning, design, and construction.

Ronald Young, P.E., DEE
Senior Associate
Malcolm Pirnie, Inc.

Ron Young is involved in several desalination projects in California. He is a Design Team Member for brackish water desalination for the Santa Ana Watershed Project Authority, Procurement Team Member for the San Juan Capistrano brackish water desalination Design-Build-Operate-Finance project, and a Consultant Team Member for the Municipal Water District of Orange County for a saltwater desalination plant reliability and economic study. Young received a B.S. in Civil Engineering from Colorado State University and an M.S. in Environmental Engineering from Loyola Marymount University.

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Published January 26, 2001

By

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National Water Research Institute Report Number NWRI-01-02