F I E L D R E P O R T

TECHNICAL ASSISTANCE PROGRAM FOR THE MINISTRY OF WATER RESOURCES SULTANATE OF OMAN

TASK 5: WATER MANAGEMENT
TASK 6: TECHNOLOGY DEVELOPMENT

INTRODUCTION AND BACKGROUND
Parts 1 & 2

WASH Field Report No. 353
December 1991

Sponsored by the U.S. Agency for International Development
Operated by CDM and Associates

WATER AND SANITATION
FOR HEALTH PROJECT
Operated by CDM and Associates

Sponsored by the U.S. Agency
for International Development

WASH Operation Center
1611 N. Kent St., Room 1001
Arlington, Virginia 22209-2111 USA

Telephone (703) 243-8200
Telex No. WUI 64552
Cable Address: WASHAID
FAX No. (703) 243-9004

19 October 1992

TAS 254 and 255

Dear Colleague:

On behalf of the WASH Project, I am pleased to provide you with WASH Field Report Number 353: *Task 5 Water Management and Task 6 Technology Development*, by Steve Luxton, Mitchell Heineman, Jonathan Hodgkin, Patrick Lang, Frederick Meyer, Ronald Miner, Peter Schwartzman, and Kendrick Taylor. This report was produced under WASH Tasks 254 and 255 as part of a Technical Assistance Program For the Ministry of Water Resources, Sultanate of Oman. The overall objectives of the technical assistance were to assist the Ministry of Water Resources to: 1) strengthen all aspects of its operations, 2) establish a strong technical base, and 3) develop policy and procedures.

If you have any questions or comments about the findings or recommendations contained in this report, we will be happy to discuss them. Please contact Phil Roark at the WASH Operations Center. Please let us know if you would like additional copies.

Sincerely,

J. Ellis Turner
WASH Project Director

WASH Field Report No. 353

Parts 1 & 2

INTRODUCTION AND BACKGROUND

Prepared for the Omani-American Joint Commission
under WASH Tasks Nos. 254 and 255

by
Steve S. Luxton
Mitchell C. Heineman
Jonathan P. Hodgkin
Patrick T. Lang
Frederick W. Meyer
Ronald Miner
Peter N. Schwartzman
and
Dr. Kendrick C. Taylor

December 1991

Water and Sanitation for Health Project
Contract No. DPE-5973-Z-00-8081-00, Project No. 936-5973
is sponsored by the Office of Health, Bureau for Research and Development
U.S. Agency for International Development
Washington, DC 20523

RELATED REPORTS

Evaluation of Alternatives for Interim Treatment and Disposal of Trucked Wastewater in Salalah Town, Sultanate of Oman. WASH Field Report No. 243. By Leo A. St. Michel and Albert B. Pincince. July 1988.

Proposed Hydrological Monitoring and Evaluation Unit for the Ministry of Agriculture and Fisheries Aquifer Recharge Program (Oman). WASH Field Report No. 285. By Charles E. Fuller and John Kent Kane III. February 1990.

Technical Assistance Program for the Ministry of Water Resources, Sultanate of Oman. Task 3: Surface Water Data Collection. Task 4: Groundwater Data Collection and Management. WASH Field Report No. 332. By Steven S. Luxton et al. July 1991.

CONTENTS

PARTS 1 & 2

PART 3

FIGURES

TABLES

PART 4

FIGURES

TABLES

PART 5

FIGURES

TABLES

PART 6

FIGURES

TABLES

PART 7

FIGURES

TABLES

PART 8

FIGURES

TABLES

ACKNOWLEDGMENTS

The authors wish to thank the staff of the Ministry of Water Resources who spent much time sharing their thoughts and perspectives on the issues facing the new Ministry. Without their enthusiastic cooperation, this report would not have been possible.

We also wish to thank the officers and Managing Director of the Omani-American Joint Commission who assisted us and made our work here possible.

Other persons and agencies who deserve thanks are too numerous to mention here, but their cooperation and support helped to make our work more complete.

During our stay here we made friends with many Omanis who welcomed us and gave us their friendship. We hope that our work may add to the efforts of the Ministry of Water Resources to create a better future for Oman.

ABOUT THE AUTHORS

Mitchell C. Heineman is a water resources engineer with Camp, Dresser & McKee of Cambridge, Massachusetts. Mr. Heineman has developed database management systems and computer models for groundwater and other water resources applications. He holds a B.S. in geology and an M.S. in water resources engineering.

Jonathan P. Hodgkin is an engineer with Associates in Rural Development, Inc. in Burlington, Vermont. Mr. Hodgkin has extensive international engineering experience with water supply related issues. He has had broad experience working in rural villages in Yemen, Sudan, Somalia, Chad and Djibouti. Mr. Hodgkin holds a B.S.C.E. and is an M.S.C.E. candidate.

Patrick T. Lang is a water resources engineer with Camp, Dresser & McKee International of Cambridge, Massachusetts. Mr. Lang's experience includes ground and surface water hydrology, ocean circulation, dilution analysis, and water distribution systems. He holds a B.S. in civil engineering.

Steve S. Luxton is a hydrologist and registered civil engineer with Camp, Dresser & McKee International's Cambridge office. Mr. Luxton has extensive experience in practical applications of hydrology and hydrogeology. Mr. Luxton has worked in Oman for over six years in water resources and rural development. He served as team leader on this and the previous WASH assignments to Oman. Mr. Luxton holds a B.S. in civil engineering and an M.S. in hydrology and hydrogeology.

Frederick W. Meyer is accomplished in all aspects of geology, hydrology, and environmental science. During his 37-year career, he has acted as a special consultant to the United States Environmental Protection Agency and the Florida Department of Environmental Regulation and has authored over 50 publications. Prior to joining Camp, Dresser and McKee's Florida office in 1990, Mr. Meyer spent 30 years with the United States Geological Survey. He is a leading authority on the hydrology of deep, saline-water aquifer systems in South Florida. Mr. Meyer is a registered professional geologist.

Ronald Miner is a registered professional engineer with 15 years of experience in water resources engineering. His experience includes evaluation and analysis of groundwater systems, analysis of water distribution networks, and much work on geographical information systems. Mr. Miner holds a B.S. in civil engineering and an M.S. in water resources engineering.

Peter N. Schwartzman is a hydrogeologist with Pacific Groundwater Group in Seattle, Washington. Mr. Schwartzman's specialties include regional water resources assessment,

stream aquifer interactions, aquifer mechanics, and the design and installation of production and monitoring wells. He holds a B.S. in geology and an M.S. in hydrology.

Dr. Kendrick C. Taylor is associate research professor at the Water Resources Center, Desert Research Institute, University of Nevada System in Reno, Nevada. He is interested in and instructs on the application of geophysical techniques to hydrogeologic issues, including groundwater detection, determination of groundwater quality and hydraulic properties of the subsurface, and definition of hydrostratigraphy. Dr. Taylor holds a B.S. and an M.S. in geophysics and a Ph.D. in hydrogeology.

ACRONYMS

ASR	aquifer storage and recovery
cm	centimeter
CSR	center sampling rotary
EC	electrical conductivity
FAO	United Nations Food and Agriculture Organization
GIS	geographic information system
GPS	ground positioning system
H.E.	His Excellency
H.H.	His Highness
H.M.	His Majesty
in	inch(es)
JICA	Japanese International Cooperation Agency
km	kilometer(s)
l	liter(s)
l/s	liters per second
L.S.	lump sum
m	meter(s)
m^2/d	square meters per day
m^3/d	cubic meters per day
m^3	cubic meters

MAF	Ministry of Agriculture and Fisheries
mcm	million cubic meters
mcm/yr	million cubic meters per year
MEW	Ministry of Electricity and Water
mm	millimeter
MM/WH	Mott MacDonald International, Limited in association with Watson Hawksley
MMP	Sir Mott MacDonald and Partners, Limited
MOC	Ministry of Communications
MOD	Ministry of Defense
MOH	Ministry of Housing
MOI	Ministry of Interior
MSS	multispectral scanner sensor
MWR	Ministry of Water Resources
NASA	National Aeronautics and Space Administration
NSA	National Survey Authority
OAJC	Omani-American Joint Commission for Economic and Technical Cooperation
pop	population
PAWR	Public Authority for Water Resources
PVC	polyvinyl chloride
R.O.	Omani Rials
SCTP	Supreme Committee for Town Planning

SFWMD	South Florida Water Management District
tm	trademark
TEM	transient electromagnetics
TM	thematic mapper sensor
TPM	team planning meeting
uS/cm	micro Siemens per centimeter
USAID	United States Agency for International Development
UTM	universal transverse mercator
WASH	Water and Sanitation for Health Project

EXECUTIVE SUMMARY

The Omani-American Joint Commission (OAJC) and the newly established Ministry of Water Resources (MWR) of the Sultanate of Oman have a common interest in the water resources of the nation. Early in 1990, OAJC requested the Water and Sanitation for Health Project (WASH) to assist the fledgling Ministry in:

- Strengthening all aspects of its operations
- Establishing a strong technical base
- Developing policy and procedures

The WASH team worked in Oman and in the United States from May through August 1991 to complete Tasks 5 and 6 of the scope of work and also work under Tasks 3 and 4 that was interrupted by the Gulf War.

Following Parts 1 and 2, which provide a general introduction and background, each of the six parts of the report on Tasks 5 and 6 covers a different area of study and contains a summary of conclusions and recommendations to which the reader can refer for a quick review.

MAJOR FINDINGS AND RECOMMENDATIONS

Part 3 ... Wadi Gauging Network Rationalization and Upgrade

More surface water gauging stations are needed in MWR's wadi gauging network to provide information on the process of groundwater recharge and the effectiveness of recharge enhancement schemes. But the expansion of the network should not delay the processing and publication of the large volume of data already in hand.

Surface water data collection is limited by various physical and practical constraints, and all users of these data would greatly benefit from an understanding of these limitations and of the methods employed by the Surface Water Department.

The department's effective relations with other agencies and private sector groups interested in surface water and floods should be cited as a model for other MWR departments.

Part 4 ... Salt Water Intrusion Monitoring and Remediation

MWR faces a serious problem of saline intrusion and upconing in the Batinah coast region. Past efforts at control have lacked a focus and a defined policy. Emphasis must now change from observation of the advancing intrusion to a detailed program designed to find a solution. This can begin with concentrated efforts to protect municipal and public water supply systems from upconing and lateral intrusion in areas where severe impacts and economic dislocations are expected.

MWR should set up a section to undertake this work urgently after reviewing and, if necessary, modifying the policy and goals recommended. Unless this is done, the saline intrusion program will continue to lack direction and purpose.

Part 5 ... Alternative Well Technologies for Use in Saline Groundwater Systems

The WASH team investigated several alternative well technologies to pump fresh water from saline aquifers. The separation of fresh water from saline groundwater is called skimming by some hydrologists. Of the methods investigated, three show the most promise in Oman:

- Conventional low-drawdown wellfields
- Scavenger wells
- Water collection galleries

Existing conventional wells with high drawdowns are prone to upconing and sea water intrusion, whereas low-drawdown wells can extract a similar amount of water without inducing salt upconing. MWR should enhance its capacity to advise others on the use of this technology.

Scavenger wells separate salt water and fresh water into two discharge streams. More work needs to be done to define their potential for specific sites in Oman.

Collection galleries may find some application in coastal areas to provide agricultural or potable water supplies. They must be operated with care and, to be most effective, should be pumped continuously at very low drawdowns.

MWR should work on these methods to provide a leadership role in their use. There are many opportunities for applying them as part of a broad regional water management strategy rather than to improve water quality in a few wells while the regional groundwater system deteriorates.

Part 6 ... Small Basin Management

The WASH team quickly discovered that the inhabitants of the upper basins and small catchments have a thorough understanding of the water resources that sustain them. Much of this knowledge has neither been recorded nor considered of any value in water resources management in these areas.

MWR should set up a Small Basins Reconnaissance Section to draw upon this knowledge in a collaborative plan for water resources development that would take the villagers' ideas into account.

Cultural, political, and human considerations are no less important than technical concerns in the planning and implementation of water related work. Although the guidelines provided relate to small basins, they can be profitably applied to many other MWR projects.

Part 7 ... Applications of Geophysics

There are several methods of geophysical exploration that could help MWR in its assessment work. However, many of these are expensive and, experience suggests, could lead to poor results unless they are properly utilized. Recommendations are offered on staff organization to develop the necessary skills and on appropriate training, equipment, and computer software.

The author of this part, Dr. Kendrick Taylor of the University of Nevada, is willing to sponsor one or more Omani students for graduate studies in the application of geophysics in Oman. The OAJC would finance these studies.

Part 8 ... Applications of Remote Sensing

Remote sensing has many useful applications but its products are expensive and MWR must be sure that they would advance its work. The range of available products, their costs, and their uses are dicussed. A pilot project to test the technology in defining water use along the Batinah coast and an incremental process that moves ahead as useful results are obtained are suggested.

Working Paper ... Discussion Paper for a Staff Orientation Document

The WASH team worked with almost the entire MWR staff from August 1990 to August 1991. Although it noted much progress in that short time, it also observed that many new staff members knew very little about Oman and its water resources and had poorly formed ideas about the nature of MWR's work. In spite of the fact that most policies and

goals have been defined, the information has not yet filtered down to the rank and file of the organization. Given its rapid growth this is not surprising.

The discussion paper is an attempt to summarize important information that senior staff members should have as they begin their work. It reviews MWR's policies and approaches and explains what the Ministry is and why it was formed, what they should know about working in Oman, and how they can help the Ministry to reach the important goals ahead.

The paper is intended to fill an immediate need and should be followed by a similar document that is enlarged and refined as MWR gains knowledge and experience.

In Conclusion

To assist decision makers, the report on Tasks 5 and 6 provides the approximate capital and recurrent costs of the programs recommended. The earlier reports on Tasks 1 through 4 contain similar data.

OAJC and WASH hope that the information provided here will be useful to MWR in its important work in Oman. The OAJC staff and its managing director, H.E. Hamoud Halil al Habsi, are anxious to be of continuing support.

Chapter 1

INTRODUCTION

1.1 Project Introduction

In 1989, the Omani-American Joint Commission requested the Water and Sanitation for Health Project (WASH) to carry out a three-phase project of technical assistance to the newly established Ministry of Water Resources (MWR), which had been given responsibility for managing the water resources of the Sultanate of Oman. The project was executed in 1990 and 1991, part of it during the war in the Persian Gulf. This report presents the results of the third phase: Task 5, Water Management, and Task 6, Technology Development, and also the results of work originally scheduled for the second phase which was interrupted by military action in the region.

1.2 Objectives of the Third Phase

The third phase had the following objectives:

WATER MANAGEMENT

Wadi Gauging Network

- Establish a plan for rationalizing the existing network, including its equipment and its monitoring procedures

Saline Water Intrusion Monitoring and Remediation

- Establish programs for monitoring salinity intrusion in the Batinah and Salalah and assist MWR in developing a solution to the problem in the Sultanate as a whole

Alternative Well Technologies for Saline Aquifers

- Provide pre-feasibility data and cost analysis for alternative wells that might be used to skim fresh water from aquifers that produce saline water in deeper wells

Upper Basin Management

- Introduce suitable small-scale water management and conservation projects in upper basin villages, taking into account community concerns and the contribution of local labor to the degree possible

Regional Assessment

- Assist MWR in assessing the water resources of the country and identifying problems needing remedial action

TECHNOLOGY DEVELOPMENT

Geophysics

- Assist MWR in the organization and development of a capacity to undertake appropriate geophysical work

Remote Sensing

- Assess opportunities for MWR to use remote sensing in its work and provide guidance for the purchase and use of such data

1.3 Preparation for the Assignment

The scope of work was prepared by Robert Thomas of Camp, Dresser & McKee, International, who interviewed numerous MWR personnel in February 1990 to identify the key areas in which they needed assistance.

During a team planning meeting in Washington, D.C. from May 15-17, 1991, the team reviewed the scope of work, considered comments and suggestions from United States Agency for International Development (USAID) personnel, outlined a tentative work plan, and identified elements of technical support required from the Camp, Dresser & McKee offices in the United States.

1.4 Scope of Work

The scope of work for each assistance area is presented in the appropriate part of this report.

1.5 Conduct of the Study

Most of the team members began work in Oman on May 21, 1991, and remained there until early in August. The team included personnel who completed work on Tasks 3 and 4 that had been interrupted by the Gulf War.

The team met weekly with OAJC to give an account of progress and to raise any problems that needed resolution. Interviews with personnel and officials of various Omani government agencies provided valuable information that helped in the preparation of this report.

The team prepared a preliminary draft of its findings late in July 1991, incorporating the comments and suggestions of key personnel in the OAJC and MWR. Formal presentations were made to the OAJC and MWR staffs and to MWR before the team's departure. After these presentations, some follow-up work to assist in implementation was carried out.

1.6 Report Contents

This report on the results of Tasks 5 and 6 has eight parts: an introduction (Part 1) and general background on Oman (Part 2); measures to expand and rationalize the existing surface water gauging network (Part 3); a program for salt water intrusion monitoring and remediation (Part 4); a summary of the alternative technologies available to draw fresh water from aquifers that have been invaded by saline groundwater (Part 5); a discussion of the opportunities for MWR to do useful work in the smaller basins and upper catchments of Oman (Part 6); an outline of some of the best geophysical techniques that MWR might use (Part 7); and information on the uses of remote sensing (Part 8). The report also offers a discussion paper to assist MWR in defining its goals and general policies that could serve to orient new staff.

Parts 3 and 4 are supplements to the report on Tasks 3 and 4 that could not be included in the earlier volume because of the interruption by war in the Middle East.

Chapter 2

BACKGROUND

2.1 General Background and Information

The Sultanate of Oman is highly dependent on groundwater for its domestic, agricultural, and industrial needs. Precipitation averages less than 100 mm per year in most areas of the country. For hundreds of years communities and villages have relied on dug wells to intercept shallow groundwater that is then transported through an extensive network of subsurface and above-ground aqueducts, or aflaj, to supply both potable water and the means to support a traditional and productive agricultural base.

This system has generally been in balance, with the demand not exceeding the supply naturally replenished by rainfall. However, rapid expansion of agriculture and a rising population during the last two decades have placed great pressure on the country's water resources. Explosive growth in the use of mechanical pumps and drilled wells to withdraw large quantities of groundwater from greater depths has compounded the problem. Some of the increased demand has been met by the construction of desalination plants. But these are capital-intensive and expensive to operate and maintain. The pressure on groundwater resources has caused serious decreases in water levels and the degradation of water quality in many areas. The water resources of many communities have been depleted, and many localities have declined as agricultural and population centers.

2.2 Physiography and Regional Geology

The geology of Oman consists of an almost featureless desert foreland in the southwest, a mountainous region in the north, and scattered narrow coastal plains. The desert foreland is a continuation of the gently undulating shelf that extends eastward from Saudi Arabia. The mountainous region, extending from the Musandam peninsula to Sur southwest of Muscat, forms a chain distinct from the rest of the Arabian peninsula. These mountains, ranging up to 10,000 feet in elevation, contain great thicknesses of shelf carbonate rocks. The presence of extensive uplifted folds of deep sedimentary deposits and rocks formed as part of the deep oceanic crust overlying the carbonate rocks is a geologic anomaly unique to the Arabian peninsula. Late Tertiary folding and subsequent erosion have exposed these rocks to reveal the total sedimentary section as well as the metamorphic basement. The interior valleys of the mountains generally are narrow, steep-sided, and alleviated with partially cemented sand and gravel.

The coastal plains run along the Batinah coast in the north and the Salalah coast in the south. The Batinah plain is a series of coalescing alluvial fans emanating from the wadis

(stream channels) along the mountain front. These fans are composed of materials ranging from silt to boulders, becoming finer graded with increasing distance from the mountain front. The alluvial materials, ranging up to 100 m or more in depth, are commonly cemented into a conglomerate.

2.3 Climate and Rainfall

Oman's climate and rainfall vary greatly. There are two seasons: winter, generally from November to April; and summer, from May to October. April and October are considered transitional months. Winter is the rainy season in the north but little rainfall occurs along the south coast during this period. The average annual rainfall at Seeb is 100 mm, but actual rainfall varies widely from year to year. In the years 1976-81, it varied from 3.7 mm to 182.6 mm. Rain can occur in the summer as a result of unsettled weather from a southwesterly airflow. Most of this rain falls on the inner side of the northern mountains. In the south, rainfall coincides with this southwesterly wind of the *kharif* monsoon. Rainfall on the southern coast averages about 100 mm, increasing to some 300 mm in the mountains. On the leeward side of the mountains rainfall drops to only 50 mm per year.

2.4 National Water Policy

In November 1988, His Majesty Sultan Qaboos bin Said issued Royal Decree Number 82/88 as the basis for conserving the nation's water resources. The decree stated that "the Sultanate's water reservoir is considered as [a) public national wealth to be exploited according to the Government's instruction," thus establishing that all groundwater and its extraction for any purpose could be regulated by the government.

In October 1989, His Majesty issued Royal Decree Number 100/89 creating the Ministry of Water Resources and appointing H.E. Khalfan bin Nasser Al Wahaibi as its Minister with authority to perform the tasks listed below:

- Formulate policies and regulations regarding water resources
- Monitor hydrologic systems
- Conduct surveys and perform water resources research
- Conduct hydrologic assessments
- Collect and analyze water samples

- Evaluate the potential for long-term, sustainable water resources supplies
- Establish and maintain a water resources database
- Manage and preserve the nation's water resources through long-term planning and administration

Before Royal Decree Number 100/89, water resources had been administered by various agencies and ministries—the Public Authority for Water Resources, the Ministry of Environment and Water Resources, the Ministry of Electricity and Water—none of which was dedicated to water resources assessment and management. The creation of MWR established an entity dedicated solely to water resources, and since its inception, the Ministry has moved rapidly to fulfill its mission.