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Final Report

EVALUATION OF REMOTE SENSING APPLICATIONS FOR THE PUBLIC AUTHORITY FOR WATER RESOURCES AND GOVERNMENT OF OMAN ORGANIZATIONS

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EXECUTIVE SUMMARY

The present contract between the Public Authority for Water Resources (PAWR) and the Omani-American Joint Commission through the Environmental Research Institute of Michigan (ERIM) was established to provide expert advice in the area of remote sensing and its applications to water resources in Oman. Both meteorological and earth resources remote sensor systems are considered. This advice was provided to the Public Authority for Water Resources, the Directorate General of Meteorology and other Sultanate of Oman government agencies by holding a number of meetings with government officials and by conducting a series of five seminars and workshops.

The first seminar was devoted to the basics of remote sensing systems. Secondly, a seminar and workshop was presented on the applications of remote sensing to meteorology, followed by a seminar and workshop on the applications of remote sensing to flood forecasting. The fourth and fifth seminars and workshops were directed toward water resources inventory and/or monitoring and land use classification and landscape analysis with remote sensing techniques. A final workshop involved the definition and location of linear features in large scale imagery from earth resources satellites.

Remote sensing capabilities and their present use in the Sultanate of Oman were reviewed with several government agencies. Recommendations are made for the upgrading of capabilities in the detection of meteorological events, in the procurement of multispectral scanner and thematic mapper imagery, and in the establishment of in-country facilities for receiving and processing future remote sensing data. Further recommendations are made for the training programs and personnel requirements that will be necessary to develop fully the potential applications of currently available remote sensing data and technology.

In summary, this report presents the observations and conclusions made by the two consultants regarding the present status of remote sensing in Oman. The short term needs and the long term requirements for procurement and optimal use of this technology are reviewed.

PRESENT AND PAST USES OF REMOTE SENSING IN OMAN

Interviews were conducted with a number of government personnel at Ministries and Directorates who were potential users of remote sensing data. These discussions provided a representative sampling of the possible applications of remote sensing to practical, water resources related problems in Oman, but they were not comprehensive enough to reach all government agencies. It should be pointed out that our reception by the Omani personnel was always cordial, and the discussions were frank. The desire to improve the training and capabilities of the government personnel was obvious.

Extensive interest was found in remote sensing techniques and data, and most agencies indicated a desire to further explore the possible use of such information. Evidence of previous use of remote sensing was limited to the Public Authority for Water Resources (PAWR), the Ministry of Defense (MOD), Petroleum Development of Oman (PDO) and the Directorate General of Meteorology. The most active use of near real-time remotely sensed data was found in the area of meteorological forecasting. All other user agencies require the less frequent aerial photography, Landsat Multispectral Scanner (MSS), and Thematic Mapper (TM) images. The most active use of Landsat MSS and TM hard copy images was found in geological investigations conducted by the PAWR and PDO. In both agencies there is little demand for repeat coverage since one-time, cloud-free coverage is adequate in arid areas. Use of imagery, both aerial photography and satellite, within the MOD has been limited to the mapping and cartographic work of the ministry, however, this agency has some potential water resources applications. In only one instance has a time series of satellite data been used to define changes over time in water consumption.

The present Omani staff doing meteorological forecasting are receiving and using imagery from the meteorological satellites on a regular basis and appear to have the best knowledge of remote sensing in general. They recognize the need for more extensive and more timely data, as well as for further training in the applications and data processing areas. Since their work generally requires interpretation of black and white imagery from a minimum of frequencies, further training and/or added personnel will be needed if their agency becomes involved in receiving and/or processing earth resources data such as provided by the TM.

The PAWR and PDO groups, while being the most extensive users of aerial photography, Landsat MSS and TM images, are dominantly operated by expatriates. Well trained Omani personnel in the geologic exploration for both water and oil are limited in numbers thus indicating a need for recruiting and personnel training in these agencies. It appears that the exposure to remote sensing data during the seminars

held in conjunction with this investigation is the first opportunity for the Omani civil servants in these agencies to become involved with the potential applications.

The use of data in both PAWR and PDO has been confined to selected scenes whereas the entire country had Landsat MSS coverage in 1972 and TM coverage in 1985. On the few images received there has been limited use of varied band combinations and no use of linear combinations of bands to enhance the images. Such limitations are to be expected when the processing techniques are dictated by a specific need and supplied by a distant contractor, but the images may not serve these and other applications very effectively. This situation indicates that future use of these data may require optional processing to produce acceptable images for applications in agriculture, mineralogy, planning, etc. In order to ensure the most appropriate remote sensing data for a specific task there should be provision for interactive systems and close communications between the user and the processor. Under the present conditions this interaction has been difficult to obtain.

Some contacts were made with personnel of the new Sultan Qaboos University where an active interest in remote sensing was expressed. The computer centre of the university will be equipped with a large capacity computer, and there is a desire to use the facilities for processing the digital tapes from Landsat MSS and TM systems. An expressed desire to create a multi-disciplinary remote sensing center at the university was made. First classes will be held at the universitiy during 1986, thus the first bachelors degrees will be granted in 1990. Staff selection is in progress and there was, therefore, no identification of departments or staff that would be involved with remote sensing training. Comprehensive training in remote sensing can be offered with or without current data; however, some temporal data at relatively close intervals would be required for applications in any dynamic fields such as agriculture. These data are not available over Oman at the present.

The MOD has immediate needs for high resolution large area imagery for updating the nation's maps. With consideration of the rapid changes occurring in Oman, it is reasonable to conclude that repetition of data collection over future years will be required to satisfy the need for map revisions. The enhancement of TM data that is required for mapping in desert areas is quite different from enhancements for other users. This use of the data is another example of applications that would be enhanced if a "hands on" or interactive processing system was available. Although this ministry has graduate engineers among its civil service employees who work on ground water development, there was no evidence that remote sensing products were being used. No plans to send any water related personnel to the seminars provided with this project existed. The water supply people in MOD engineering division rely on

PAWR to locate well drilling sites thus eliminating duplication of interpretation work.

In the Ministry of Agriculture and Fisheries (MAF), the Ministry of Environment (ME) and the various planning organizations, there are applications of remote sensing where existing data has not as yet been used. There is, however, a desire to learn the techniques and use these types of data. Both the MAF and ME will need frequent data for maximum benefit from remote sensing. The development of agriculture and fisheries to a point of self sufficiency is a major goal of the Sultanate of Oman. To most rapidly approach this goal without endangering the water resources and environment will require a constant and continuing monitoring program that can be made more effective and efficient by use of remote sensing data. The MAF is staffed with enough personnel to begin immediate use of the data. They appear to have enough Omani personnel with adequate background for more intense training in the use of the data.

The ME on the other hand is a new and developing ministry undergoing the development of a staff at present. Their needs for remote sensing systems will develop after the organization is more complete and the initial efforts to establish ground level monitoring and inspection systems are more fully developed. It appears that this agency will require a considerable amount of local remote sensing information as opposed to the large area coverage provided by satellite systems.

Planning agencies have an immediate need for the TM data. Personnel, mostly expatriates, from these groups are eager to acquire the TM images in order to interpret them prior to submission of reports. Additional copies of the Muscat and Salalah scenes already in the possession of PAWR would be of value to these agencies.

These series of interviews revealed that about nineteen agencies in Oman conduct at least some water resources work. Approximately ten of these agencies would gain significant benefits from applications of remote sensing data and techniques in one form or another. No potential user seemed to be aware that time series data would be useful for some applications. These discussions revealed that more use of existing data by Omani personnel would occur if increased exposure of the data could be accomplished and if more intensive training could be offered. The local security practices appear to have hampered the circulation of remote sensing data thus restricting the opportunities for Omani personnel to learn more about the data and techniques provided by remote sensing products.

RECOMMENDED REMOTE SENSING PROGRAM FOR PAWR AND OTHER GOVERNMENT AGENCIES

The PAWR and other government organizations concerned with mapping or determining location in some sense are using existing aerial photographic products effectively at the present time. Some improvement in the existing practice may be possible with use of color infra-red film; however, testing of this possibility should be limited to small areas for geologic mapping and other small areas for agricultural, environmental, planning, and mineralogical applications. It may prove to be more cost effective to use the color infra-red aerial photographs in situations where small area events such as flooding, changes in municipal development, pollution of fish habitat, and changes in crop conditions are the subjects of interest. Costs of such products will be minimized if high altitude photography can be acquired. For example, a single pass along the coastal plain at high altitude would provide coverage of the major portion of the agricultural areas.

Some improvement in geologic mapping for both water and mineral exploration may also be possible in the mountain areas of Oman through the use of night and day thermal mapping using thermal scanners in aircraft. The thermal inertia differences between various formations have been used in other parts of the world as an added tool for geologic mapping. The mapping of thermal inertia, like the color infra-red photography, should first be tested in limited areas. In addition thermal mapping may in some instances be used to detect pollution effects. The use of existing satellite digital scanner data, both the MSS and the TM, has been essentially limited to use of hard copy, false-color images within the PAWR while some more sophisticated manipulation of the digital data has been done for PDO. In both instances the objective has been to prepare maps of geologic structure to aid in site selection for drilling. This program can and should be expanded to each district office. The participation of expatriate and Omani personnel should be encouraged and can readily be accomplished by purchase of additional images and by an in-house training program.

It has become obvious through the seminars, workshops and interviews that outside of PAWR, PDO and the National Survey Authority of MOD, little use is being made of existing data. In each of these agencies the use is essentially limited to expatriates and the transfer of knowledge concerning its availability and use is further restricted by security precautions. These problems can be overcome to some extent by establishment of interagency agreements and an extensive training program for selected Omani personnel from all agencies where there are potential applications. Recognizing the current shortage of native personnel, one must conclude that efforts should be made to recruit new people with some background in mathematics and physics in order to have a source of trainable personnel for remote sensing development.

Application of remote sensing data and techniques to soils mapping, crop identification, crop monitoring, coastal waters monitoring, water supply and consumption can aid various departments in the Ministry of Agriculture and Fisheries (MAF). The various planning agencies in both the northern and southern regions would benefit from up-to-date maps, land capability mapping, current land use, water supply and current water consumption estimates that can be derived from or improved by use of remotely sensed data. The Ministry of Petroleum and Minerals (MPM) has potential for applications in exploration for minerals. All these applications need to be encouraged.

Future needs for exploration of remote sensing data, as well as the current needs of some agencies, such as MPM, will require more sophisticated computer facilities. It is recommended that these needs be met by the establishment of a central data procurement, archiving and processing facility. Furthermore, it is recommended that the facility should be established in the Directorate General of Meteorology. This agency is staffed with Omani personnel with experience and training on collecting, processing and using remote sensing data pertaining to meteorology and could readily expand to encompass earth resources data. The agency will initially require some participation of consultants or expatriates; however, the center would primarily be staffed with Omani personnel from the beginning.

Caution should be exercised to ensure that such a center maintains a good rapport with other user agencies and provides the user with the opportunity to interface with the computer operation of the centre. The users should make the final decision as to whether or not the final product is acceptable for the required task. With the number of small computers in the capital area increasing rapidly, it should be feasible to allow many user agency personnel to examine small portions of the image. The decision of adequacy could then be made without the user going to the main processing center.

RECOMMENDED PROGRAM FOR PROCUREMENT AND ENHANCEMENT OF IMAGERY

The needs for aerial photographs and imagery will most likely remain site and application specific, but some effort should be made to consolidate the collection of aerial photographs by the various governmental agencies in order to reduce duplication of area coverage. Aerial photographs and scanner imagery could conceivably be requested at a common scale suitable for several users. In addition, the specification of color infra-red film collected simultaneously would reduce the overall costs and provide suitable images for several user agencies.

Anticipated expansion of the use of aerial photographs and imagery in some agencies, such as the Ministry of Agriculture and the Sultan Qaboos University, will require the purchase of such items as light tables, stereoscopes, zoom transfer scopes and low cost elevation mapping devices. Within the PAWR the primary equipment required for effective use of aerial photographs is available. The organization should acquire one Zoom Transfer Scope with a Vertical Measurement Module for use at a central location.

The collection of some satellite imagery from meteorological systems is presently on-going within the Directorate General of Meteorology, and it is recommended that expansion of this program should proceed as Mr. Smigielski, consultant in meteorological remote sensing, recommended. Direct collection of data from earth resources satellites is not feasible from a cost standpoint. These data (at present MSS and TM data) should be purchased as they become available.

The current procedure has been to purchase satellite imagery as hard copy photographs from one private source for use in PAWR. For geologic interpretation, several different combinations of bands and color assignments will enhance the representation of geologic materials. The field geologist should have single band images from the MSS and TM systems available in order to determine first hand which bands may be valuable in a false color image. Negatives for single band data can be purchased directly from the EROS Data Center at a reasonable cost (U.S. $80). If these data are purchased as images from EROS, they may be supplied as black and white positives, negatives or print at the present time. Availability and price are dependent on whether or not someone has previously requested the scene, as only a portion of the more recent data has been processed. Color composites from EROS, if processed after June 1, 1985, will consist of bands 2, 3, and 4 using the improved density look-up tables. When the color composite was made prior to that date, it may have poor contrast characteristics. In Oman, for the very near future, only those scenes over mountains and coastal areas would be required. After selection of the individual bands showing the best

separation of known geologic formations, color composites made from the most appropriate three bands can be ordered.

False color images can be made in two ways. Color composites may be made by combining the single band images photographically, or one may return to the original computer compatible tape of digital data to produce the composite. For PAWR uses in geologic mapping, it is recommended that scenes in the Muscat, Sohar and Salalah regions should first be investigated band by band. False color combinations (several) should then be made using the photographic combination of the data. The false color composite derived in this manner will serve to separate geologic material. If fine definition and good resolution are needed by the geologist for any specific scene, for instance for mapping linear features or roads, the required false color image should then be regenerated from digital data.

If additional enhancement is desired (for the location of minerals in particular) use should be made of the ratioing of bands and principal components techniques. When using these techniques, false color images can only be accomplished by using the computer generation of the image. Thus the purchase of the digital tape is required. Regardless of the product desired or the level of interpretation of the imagery, it is imperative that the field geologist, or user in any discipline, make the final decision as to suitability of the color combination or enhanced product.

The preceding recommendations for satellite data use and enhancement apply to the near future. The procurement and enhancement of data for the long term can best be accomplished by establishment of a central data processing system in the Directorate General of Meteorology. This government agency has demonstrated that they not only have the desire to establish a processing center for earth resources satellite data, but they are also the only agency with adequately trained and experienced Omani personnel to handle the tasks. A request for funding and establishment of a procurement and processing facility has been made by this Directorate, and it is recommended that support of the proposal be given by PAWR and other government agencies in order to facilitate future data requirements.

Such a center should provide facilities for digital processing and hands-on interfacing with the user, as well as production of hard copy images for those users who require them. There are moderately priced interactive systems for color enhancement of digital data that attach to small computers such as the IBM PC systems already available in PAWR and some other user agencies. It would be wise to structure the main processing center in such a way that individual user agencies could have at least one interactive system in it where personnel could determine the product that would best serve their needs.

Additional data processing should be developed at the university in order that students and faculty may in the future be trained in applications of remote sensing data. The facilities need not be extensive but must be adequate to teach the fundamentals of remote sensing and should involve or be accessible to a wide range of departments or disciplines.

RECOMMENDATIONS FOR EQUIPMENT

The PAWR should acquire at least one Zoom Transfer Scope with a Vertical Measurement Module for use at one or more central locations such that when needed it would be available to all PAWR personnel.

For future needs in the application of remote sensing data, it may be advisable to purchase one or more Video Image Processors that can readily be attached to the IBM PC systems currently in use by PAWR and some of the other agencies. Portions of the digital data from the Landsat systems are available on floppy disks from EROS Data Center. This array of accessories for the PC allows hands-on manipulation of the data to determine the enhancement required for the task at hand.

The future development of a Central Data Processing Center will require a moderate size computer such as a VAX 780 or equivalent. A film recorder converts digital output from the computer to film, and a complete photo laboratory capable of producing hard copy products up to 125 cm x 125 cm, will also be required. The main frame computer must have interfacing and display capabilities and should be accessible from terminals from outside user stations either located in a user room or at the user's facility. Security can be controlled on such systems as long as the user terminal is not equipped with hard copy output devices. Similar user terminals will be required at the university for teaching and research purposes.

In addition to the ordinary film processing equipment, developers, enlarger, printers, etc., a color compositor should be available in the central photo laboratory. This piece of equipment is required to combine and expose color film when the single band images are used to make false color imagery.

Prices on these recommended items of equipment may vary considerably outside the country of manufacture, thus no prices are quoted in this report.

RECOMMENDED TRAINING PROGRAM

Some seminar/workshop training similar to, but more intensive than those presented in this contract should be arranged over the next two to three years. Future seminars should be more specific and oriented to single disciplines, i.e., agriculture, mineralogy, environment, planning, etc. In each discipline an intensive workshop on fundamentals should be provided for two separate groups of Omani personnel, those having little background in science and groups of personnel having more extensive science backgrounds. The latter group should include Omanis and expatriates who will be working with and instructing the first group in daily field work.

In some instances, for example analysis of linears, expatriate personnel are available within PAWR who are fully capable of conducting training programs of this nature. In general, the expatriate personnel should be kept up-to-date on new techniques in order that the technology may be transferred to new Omani employees on a daily hands-on training basis. Applications of remote sensing technology can best be accomplished by persons who have had hands-on experience, so some follow-on practice must be provided after seminars and workshops.

Advanced training for professionals and technicians associated with the proposed central data processing operations should be provided. These training programs can be accomplished best by sending selected personnel to the USGS-EROS Data Center and/or to such applications facilities as ERIM or one of the university centers in the United States. Some of these training programs may be readily combined with the present Omani-American Joint Commission training programs that are already underway.

SOURCES OF REMOTE SENSING DATA, PRODUCTS AND TECHNOLOGY

A relatively complete listing of sources for remote sensing data, processing, products and technical services can be found in the listing of Sustaining Memberships of the American Society for Photogrammetry and Remote Sensing. The latest listing is found in "Photogrammetric Engineering and Remote Sensing" Volume LI No. 7, pp. 783-1046 published July 1985. A few selected sources are listed here for some suggested products, equipment and technology that have been recommended.

Bausch & Lomb Incorporated, Optical Systems Division
Photogrammetric Products
P.O. Box 450, Rochester, NY 14692, USA
(Source of Zoom Transfer Scope & Vertical Measurement Module.)

Daedalus Enterprises Incorporated
P.O. Box 1869, Ann Arbor, MI 48106, USA
(Source of aircraft scanners - visible, near infra-red and thermal.)

Earth Satellite Corporation
7222 47th Street, Chevy Chase, MD 20815, USA
(Source of digitally processed imagery.)

Eastman Kodak Company
343 State Street, Rochester, NY 14650, USA
(Source of infra-red, color and color infra-red film.)

Environmental Research Institute of Michigan (ERIM)
P.O. Box 8618, Ann Arbor, MI 48107, USA
(Source of aircraft sensor data; enhanced satellite image processing, digital mosaicking and mapping; remote sensing training and in-country project support.)

EROS Data Center
Sioux Falls, SD 57198, USA
(Source of first generation digital and film products for worldwide satellite data.)

Finn Map Oy
P.O. Box 74, SF00510, Helsinki, Finland
(Source of mapping products - list office in Oman.)

Hope Industries, Incorporated
3701 Moreland Road, Willow Grove, PA 19090, USA
(Source of photoprocessors and enlargers.)

IBM Corporation, Scientific Centers
1530 Page Mill Road
P.O. Box 10500, Palo Alto, CA 94304, USA
(Source of image processing computers and systems.)

Spectral Data Corporation
P.O. Box 11356, Hauppauge, NY 11788, USA
(Source of Video Image Processor and accessories for use with desk top computers.)

COMPUTER SEARCHES OF RELATED PUBLISHED REFERENCES

(Excerpted references relating to remote sensing applications are listed in section beginning on p. 27.)

LIST OF PUBLICATIONS PROVIDED TO PAWR

2 copies	Manual of Remote Sensing Second Edition, Vol. 1 and Vol. 2, 2724 pages, American Society of Photogrammetry and Remote Sensing, Falls Churca, VA 22046, USA
1 copy	Remote Sensing: The Quantitative Approach by Swain
2 copies	Remote Sensing Principles and Interpretation by Floyd Sabins.

LIST OF IMAGERY PROVIDED TO PAWR

8 copies	1:250,000 scale Black & White Prints of Oman from Shuttle Imaging Radar (SIR-A)
4 copies	1:250,000 scale Color Infra-red Print of Oman from Landsat (MSS)
3 copies	Landsat False Color TM Images made from digital data, bands 2, 3, 4 from Muscat scene
6 images	False Color Images made from standard negatives; in pairs, Muscat and south of Muscat
	2 images using bands 7, 5, and 4 as blue, green, and red
	2 images using bands 3, 4, and 5 as blue, green, and red
	2 images using bands 2, 3, and 4 as blue, green, and red

REFERENCES ADDED TO PAWR LIBRARY

Manual of Remote Sensing Second Edition
Colwell, Robert N.
American Society of Photogrammetry
210 Little Falls Street
Falls Church, VA 22046
Printed by Sheridan Press

Satellite Hydrology
Deutsch, Morris; Wiesnet, Donald R., and Rango, Albert
American Water Resources Association
Proceedings of the Fifth Annual William T. Pecora Memorial Symposium on Remote Sensing, 1979
5410 Grosvenor Lane, Suite 220
Bethesda, MD 20814
[Phone (301) 493-8600]

Remote Sensing Principles and Interpretation
Sabins, Floyd F. Jr., 1978
Copyright 1978 W. H. Freeman and Company

Remote Sensing - The Quantitative Approach
Edited by Swain, Philip H. and Davis, Shirley N. (1978)
McGraw Hill International Book Company

SEMINARS AND WORKSHOPS

REMOTE SENSING

Seminar 1: Dr. Bruce Blanchard and Mr. Frank Smigielski
General Introduction to Remote Sensing, October 5

Seminar and Workshop 2: Mr. Frank Smigielski
Applications to Meteorology, October 6

Seminar and Workshop 3: Mr. Frank Smigielski
Applications to Flood Forecasting, October 7

Seminar and Workshop 4: Dr. Bruce Blanchard
Applications to Problems in Hydrology: Water Resources Inventory and Monitoring, October 8

Seminar and Workshop 5: Dr. Bruce Blanchard
Applications to Land Use and Water Resources Planning: Landscape Analysis and Land Use Planning, October 9

Seminar and Workshop 6: Dr. Bruce Blanchard
Lineation Analysis, October 10

SEMINAR 1 - REMOTE SENSING

This first seminar on remote sensing is a general introduction to the subject - history, techniques, etc., plus some details of the applications of remote sensing to meteorology.

Topics to be covered include:

- Developments in Remote Sensing Technology
  - History of Remote Sensing
    - photography - color, color IR, aerial photography, scanners, radar
  - Fundamentals of Remote Sensing
    - optical or visible, near infrared, far infrared, microwave
  - Platforms
    - handheld, truck mounted, aircraft, spacecraft
  - Orbits
    - geostationary, polar orbiting, shuttle orbiting
  - Progression of Spacecraft Sensors 1972
    - Landsat, AVHRR Meteorologic Satellites, Thematic Mapper, SPOT, Seasat, SIR-A

SEMINAR 4 - APPLICATIONS OF REMOTE SENSING FOR WATER RESOURCES INVENTORY & MONITORING

1. Remote sensing data as a supplement to conventional data.

2. Advantages of remote sensing data: synoptic views, timeliness, cost reduction, spatial integration, spectral separation and combinations, archival value and compression of information for storage.

3. Some limitations of remote sensing data: cost of manipulation, some forms integrate too much information, interpretation of images can be erroneous, various levels of training are required for different sensor products.

4. Two major approaches are used in water resources applications of remote sensing digital data, i.e., classification and averaging of digital values or ratios of digital values.

5. Selection of proper remote sensing and data type: data use, costs availability of systems, ground support required, competence of user.

6. Examples of applications: location of borehole sites, dam site selection, land use assessment, soil classification, water quality impoundments, water depth in coastal areas, water consumption and change in consumption.

SEMINAR 5 - THE USE OF REMOTE SENSING FOR LAND USE, LANDSCAPE ANALYSIS AND WATER RESOURCES PLANNING

1. Air photo products and interpretation: film types, cost considerations, equipment required, stereo requirements, desired product and limitations of air photos.

2. Spacecraft sensor data available: Landsat, Thematic Mapper, Seasat, SIR-A, shuttle camera, future sensors.

3. Use of Landsat and Thematic Mapper film products for soil mapping, land use mapping, drainage pattern analysis.

4. Verification of mapping (for geometric accuracy, for interpretive accuracy). Training and experience requirements.

5. Use of digital classification techniques
   - (a) Filtering and color enhancement.
   - (b) Training techniques
   - (c) Statistical approaches.
     - (i) Clustering
     - (ii) Principal components

6. Evaluation of accuracy acceptability.

PERSONS CONTACTED

Omani- American Joint Commission

David Mandel	Acting AID Representative
Edvard Markeset	Chief Engineer
Ivan Johnson	Water Resources Training Consultant

Public Authority for Water Resources

William Doyel	Technical Secretary
Robert Dingman	Head, District Offices Department
Rodney Lynn	Training Officer
Melving Thompson	Head, Surface Water Unit
Wayne C. Curry	Engineer, Surface Water Unit
George Piperingos	Chief Geologist
George Courtney	Geologist
Dominique Dodge	Micropaleontologist
Pamela Stellar	Geologist

Public Authority for Water Resources, Interior District

G. Chase Tibbetts	District Chief, Interior District
Gordon Stanger	Consulting Geologist, W.S. Atkins
Kent Kane	Assistant to District Chief
John Mahalich	Contract Geologist
Jose Bustamante	Contract Geologist

Public Authority for Water Resources, Southern District

Alvin Pendleton	District Chief
Roger Callen	Senior Field Hydrologist
Peter Rippon	Geologist
Solomid N. Limos	Hydrogeologist
Anastacia B. Santarin	Hydrologist
Richard Flint	Geologist
A. Mahendran	Hydrogeologist

Public Authority for Water Resources, Sharqiyah District

R. Mitchel	Acting District Chief
Horst Weier	Hydrologist
Pat Considine	Geologist
Yasser Bin Salim Al Harthy	Hydrology Technician
Abdulla Bin Said Al Shukery	Assistant Field Technician
Hilal bin Shamis Al Harthy	Trainee Hydrology Technician
Saud Bin Said Al Esry	Assistant Field Technician

Public Authority for Water Resources, Capital District

Don Davison	District Chief
Saleh Bin Issa Al Mazroi	Hydrogeologist
Gyanesh Chandra Bhatnagar	Hydrogeologist
Suleiman Bin Nasser Al Riyami	Hydrologist
Ahmed Bin Said Al Barwany	Hydrology Technician
Ahmed Bin Said Al Mawaly	Assistant Hydrology Technician

Ministry of Communications, Directorate General of Meteorology

Mohammed Bin Salem Al Bussaidi	Deputy Director General
Ahmed Al Harthy	Acting Director of Climatology and Meteorology
Subhi Hassan Abdul Ali	Acting Director, Forecasting and Observing Practices
Ahmed Ba-Omar	Director Regional and International Affairs Division
B.P. Singh	Meteorological Forecaster, Salalah

Ministry of Defence, Engineering Division

Robert Wheatley	Chief Engineer
Abdulla Ali Al Harthy	Manager, Water and Public Health Services
Hamed M.L. Mahruky	Training Director
N.T. Whitworth	Senior Public Health Engineer

Ministry of Electricity and Water

Ralph Leidholdt	Director Public Utilities, Capital Area Municipalities

Ministry of Petroleum and Minerals, Salalah Office

Hayat A. Qidwai	Geologist
Mohammed Ishaq Khalifa	Geologist

Planning Committee for Development and Environment in the Southern Region

Robert Peter Whitcombe	Ecologist
Mohamed Awad	Economist
Rowan MacTaggart	Regional Planner

Minister of State, Wali Dhofar

Ahzon Ahmad Shanfari	Director General, Land Planning
R. Weymann	Town Planning Advisor

Pan American, Salalah Airport

Ted Pankiw	Supervisor, Meteorology

Ministry of Agriculture and Fisheries

Majid Al Khanjari	Director of Administration Directorate General of Water Resources and Irrigation
Zakaria Yahya Al Riyami	Head Water Resources Department
Ali Nassar Al Harthy	Chief, Administration and Financial, Water Resources Department
R.A. Abou Saia	Civil and Water Resources Engineer, Water Resources and Irrigation
Hamdi Abu Zayd	Administration Expert
Salim Alwi Babood	Director, Water and Irrigation Department
Salim Saeed Al Rajb	Deputy Director, Water and Irrigation Department
Mustafa Ahmed Medani	Hydrologist, Water and Irrigation Department

Sultan Qaboos University

Abdul Majed Osman	Acting Vice Chancellor

Ministry of Defence, National Survey Authority

Colonel J.F. Codd	Technical Director
T.V. Zed Zorichak	Head of Surveys and Control Branch

Ministry of Defence, Engineering Division

Robert Wheatley	Chief Engineer
Abdulla Ali Al Harthy	Manager, Water and Public Health Services
Hamed M.l. Mahruky	Training Director
N.T. Whitworth	Senior Public Health Engineer

Ministry of Environment

N.T. Kapadia	Advisor

PERSONS ATTENDING REMOTE SENSING SEMINARS
OCTOBER 5-10, 1985

Name and Title	Organization	Seminar/Workshop Attended					
		#1	#2	#3	#4	#5	#6
Salim Ali Issa Al Mandhry Snr Hydrology Technician	PAWR (Seeb)	x	x	x	x	x	x
Ahmed Bin Said Hilal Al Barwany Hydrology Technician	PAWR (Seeb)	x	x	x	x	x	x
Hamad Bin Salim Hamed Al Mahrooqy Snr Hydrology Technician	PAWR (Sohar)	x	x	x	x	x	x
Said Bin Ahmed Bin Suleiman Al Hattaly Snr Hydrology Technician	PAWR	x	x	x	x	x	x
J.A. DeReus Seismic Interpreter	Petroleum Development of Oman (PDO)	x	x	x	x	x	x
C.H. Mercanton Review Geologist	PDO	x			x	x	
Majjid Bilarab Sultan El Batashi Chief of Technical Section WRD	Ministry of Agriculture & Fisheries (MAF)	x	x	x	x	x	x
Mohamed Atef Surveying Engineer	MAF	x			x	x	x
Bernard Blasco Hydrogeologist WRD	MAF	x			x	x	x
Robert Dingman Acting Technical Secretary	PAWR	x					
Colonel J.F. Codd Technical Director National Survey Authority	Ministry of Defence (MOD)	x					
Zakaria Yahya Al Riyami Director WRD	MAF	x					
Edvard Markeset Chief Engineer	Omani-American Joint Commission (OAJC)	x					

Anjab Sajwani Project Officer	OAJC	x					
Ron Catterall Director, Computing Center	Sultan Qaboos University	x			x	x	x
Afifa Said Al Falahy Geologist	Ministry of Petroleum & Minerals (MPM)	x	x	x	x	x	x
Asadullah Ahmed Taki Soil Scientist	MAF Agricultural Research Station (ARS)	x			x	x	x
Emad Abdul Majid Water Scientist	MAF (ARS)	x	x	x	x	x	x
Ahmed Said Salim Al Mauly Hydrology Technician	PAWR	x	x	x	x	x	x
Yussuf A. Bahri Assistant Controller	Ministry of Environment (ME)	x	x	x	x	x	x
Suleiman Abdulla Al Jahdhamy Meteorological Forecaster	Directorate General of Meteorology(DGM)	x	x	x	x	x	x
Anwar Iqbal Sheikh Hydrogeologist	PAWR	x	x	x	x	x	x
G.C. Bhatnagar Hydrogeologist	PAWR	x	x	x	x	x	x
John Kent Kane III Hydrogeologist	PAWR	x	x	x	x	x	x
Hamid Juma Hamid Al Sabany Field Technician	PAWR	x	x	x	x	x	x
Dr. Robert P. Whitcombe Ecologist	Planning Committee for Development & Environment in the Southern Region (PCDESR)	x	x	x			
Abdullah Said Al Shukry Hydrology Technician	PAWR	x	x	x	x	x	x

Yaser Salim Rashid Al Harthy Hydrology Technician	PAWR	x	x	x	x	x	x
Saleh Khalaf Nasser Al Mawaly Snr Hydrology Technician	PAWR	x	x	x	x	x	x
Murad Ali Karam Al Balushi Trainee Technician	PAWR	x	x	x	x	x	x
Hamed Salim Hamed Al Muqbali Trainee Technician	PAWR	x	x	x	x	x	x
Ahmed Ba-Omar Chief of International & Regional Affairs Division	DGM	x	x	x			
Ahmed Hamood Mohamed Al Harthy Acting Director Climatology & Meteorological Applications	DGM	x	x	x	x	x	x
Mohamed Salim Al Busaidi Deputy Director General	DGM	x	x	x	x	x	x
Subhi H. Abdul Alli Acting Director Forecasting & Observing Practices	DGM	x	x	x			
Said Mohammed Al Nebhani Hydrologist	Ministry of Electricity & Water (MEW)	x			x	x	x
Hilal Mohammed Al Mukhani Hydrologist WRD	MAF	x			x	x	x
Yahya Ramadan Al Balushi Head Water Pollution Affairs	Council for Conservation of Environment & Prevention of Pollution	x	x	x	x	x	x
Dr. Hans Haussler Senior Field Geologist	PAWR				x	x	x
A. Ivan Johnson Training Consultant	OAJC		x	x	x	x	x

Rodney Lynn Training Officer	PAWR	x			x	x	x
Gordon Stanger Consultant Hydrologist	W.S. Atkins (for PAWR Interior District)		x	x			
Yahya Al Kindy	DGM		x	x			
Ishtiad Ahmed Khan	DGM		x	x			
Suleiman Nasser Al Riyami Hydrogeologist	PAWR	x	x	x	x	x	x
K. Rajagopalan	DGM		x	x			
Dhudi P.M.	DGM		x	x			
Saeed Parwiz Iftikhar	DGM		x	x			
Sajjad Hasanian Jawad	DGM		x	x			
Said Mubarak Al Zehibi	DGM		x	x			

BIOGRAPHICAL SKETCH

Dr. Bruce J. Blanchard is a consultant on remote sensing applications in water resources and environmental problems. He holds a BS in Agriculture from Oklahoma State University, an MS in Civil Engineering - Water Resources and a Doctor of Engineering in Civil and Environmental Engineering from the University of Oklahoma. His training in remote sensing dates from 1942 when early airborne magnetometers and radar were used to locate submarines and ships. He has authored more than 45 research reports primarily in the remote sensing applications field.

Dr. Blanchard's work experience includes fifteen years as a hydraulic engineer with the Agricultural Research Service of the U.S. Department of Agriculture where he initiated studies on estimation of watershed runoff coefficients by use of remote sensing techniques, studies on ground water supplies and studies of seepage and water loss from earth dams. The initial study of application of remote sensing to characterize watershed parameters with Landsat data was done during this period of employment. Moving to Texas A&M University, he taught in the Agricultural Engineering Department and served as Director of the TAMU Remote Sensing Center while continuing research on applications of remote sensing. In 1980, he returned to government research at the NASA Goddard Space Flight Center as a hydrologist developing microwave techniques for classification of soils, hydraulic conductivity of soils and estimation of soil moisture.

Retiring from government service in September 1984, he has since worked as a consultant on applications of remote sensing data and techniques to water resource problems. He is affiliated with Satellite Hydrology Associates and on this project is under contract with the Environmental Research Institute of Michigan (ERIM) to perform studies funded by the Omani-American Joint Commission.

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اخرى تتعلق ببرامج التدريب واحتياجات التوظيف الهام لتطوير كل الطلبات المتوقعة للبيانات المتوفره حاليا والخاصه بالاستشعار من على البعد وتكنولوجيتها .

وبصفه عامه فان التقرير يوجز الملاحظات والخلاصات والتى قام باعدادها اثنين من الاستشاريين وذلك فيما يختص بالوضع الحالى للاستشعار من على البعد فى سلطنة عمان بالاضافة الى احتياجات المدى القريب ومتطلبات المدى البعيد للحصول على،واختيارات الاستخدام لهذه التكنلوجيا .

موجز تنفيذى

تم انشاء العقد الحالى بين الهيئة العامة لموارد المياه وبين اللجنة العمانية الامريكية المشتركة عبر معهد الابحاث البيئية فى متشجان وذلك لتوفير الخبره الاستشاريه فى مجال الاستشعار من على البعد وامكانية تطبيقها على موارد المياه بالسلطنة . وقد أُخذ فى الاعتبار الاستشعار من على البعد فى كل من انظمة الارصاد الجويه والموارد الارضيه . تم توفير هذه الاستشارة الى الهيئة العامة لموارد المياه ، المديرية العامة للارصاد الجويه والدوائر الحكومية الاخرى فى سلطنة عمان وذلك عن طريق عدة اجتماعات مع المختصين فى الوزارات والدوائر الحكومية ذات العلاقه بالاضافة الى عقد خمس ندوات وورش عمل .

تم تخصيص الندوة الاولى حول اسس انظمة الاستشعار من على البعد . ثانيا تم عقد ندوة وورشه عمل حول تطبيقات الاستشعار من على البعد على الارصاد الجوية وتبع ذلك انعقاد ندوة وورشه عمل حول تطبيقات الاستشعار من على البعد على تنبوء الفيضانات . كما كانت الندوة وورشه العمل الرابعة والخامسه حول جرد مصادر المياه بالاضافة الى الرقابة و ترتيب استخدام الاراضى وتحليل سطح الارض وذلك عن طريق استخدام اساليب الاستشعار من على البعد . وشملت ورشة العمل الاخيرة معرفة وتحديد المعالم الخطيه فى صور جويه على نطاق واسع من اقمار صناعية للمصادر الارضيه .

تم مراجعة الامكانيات المتاحه والاستخدامات حاليه للاستشعار من على البعد فى سلطنة عمان بواسطة عدة دوائر حكومية . وجاءت التوصيات لترفيع الامكانيات فيما يختص بكشف حوادث الارصاد الجويه للحصول على مسوحات نبطيه طيفيه متعدده ومبحث خرائط جويه ، وانشاء أجهزة داخل القطر وذلك لاستلام ومعالجة بيانات الاستشعار من على البعد فى المستقبل . كما جاءت توصيات

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