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LITERATURE RELEVANT TO REMOTE SENSING OF WATER QUALITY

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JULY 1983

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LITERATURE RELEVANT TO
REMOTE SENSING OF WATER QUALITY

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PREFACE

This bibliography was prepared in response to a need for a comprehensive literature source to support research pertaining to remote sensing of water quality. This need was identified in 1980 as a priority by the working group on Remote Sensing of Water Quality associated with the American Society of Photogrammetry's Hydrospheric Sciences Committee (the Remote Sensing Applications Division). An attempt was made to compile as complete a listing as possible from domestic and foreign literature available in English as of March 1983.

We would like to thank the following people whose contributions were invaluable: Thomas Alfoldi, Ottawa, Canada; John C. Munday, Gloucester Point, Virginia; Charles Trees, College Station, Texas; Siamak Khorram, Durham, North Carolina; Robert Ragan, College Park, Maryland and all our other friends and colleagues who made reference materials available to us. Technical assistance by Joseph Langdon and Babu Banerjee is also gratefully acknowledged.

We are confident that this document will be valuable to researchers interested in issues relevant to remote sensing of water quality.

Elizabeth Middleton
Richard Marcell
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Merry, C. Airborne Spectroradiometer Data Compared with Ground Water Turbidity Measurements at Lake Powell, Utah. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. National Aeronautics and Space Administration. CH-155290 1977. 44pp.


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Barker, J. Monitoring Water Quality from Landsat Satellite Observation of Virginia. National Aeronautics and Space


Khorram, S. Water Quality Mapping from Landsat Digital Data. School of Geoscience, Louisiana State University, Baton Rouge, Louisiana. 18pp.


Philpot, W. and V. Klemas. The Use of Satellites in Environmental Monitoring of Coastal Waters. College of Marine Studies, University of Delaware, Newark, Delaware. 1979. 79pp.


B. MONITORING FOR DETERMINATION OF EUTRIFICATION AND LAKE CLASSIFICATION


Boland, U. and K. Blackwell. "The Landsat-1 Multispectral


“An Empirical Study of Factors Affecting Blue-Green Versus Non Blue-Green Algal Dominance in Lakes.” Institute for Water
Researc
Michigan State University, East Lansing, Michigan.


C. MONITORING FOR LAND USE/WATER QUALITY EFFECTS


Barker, J. Landsat-1 Data as it has been Applied for Land Use and Water Quality Data by the Virginia State Water Control Board; II, Monitoring Water Quality from Landsat. National Aeronautics and Space Administration. NASA Th X-58166 1975. pp.383-481.


Oman, G. and H. Sydor. "Use of Remote Sensing in Determination of Chemical Loading of Lake Superior Due to Spring Runoff."


IV APPLICATION OF REMOTE SENSING ACCORDING TO WATER BODY TYPE A. OCEANS


Ocean Water and Remote Sensing. Limnology and Oceanography. Also University of California, San Diego, Scripps Institute of Oceanography, Visibility Laboratory. SLU Ref. 77-2.


b. COASTAL WATERS


American Society of Civil Engineers. "Coastal Sediments '77." Proceedings of the Fifth Symposium of the American Society of Civil Engineers Waterway, Port, Coastal and Ocean Division.


Johnson, R. "Quantitative Mapping of Chlorophyll a
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Barker, J. "Landsat-1 Data as it has been Applied for Land Use and Water Quality Data by the Virginia State Water Control Board, II, Monitoring Water Quality from Landsat." National Aeronautics and Space Administration. NASA TM X-58168 1975 pp.383-481.


"Water Mapping from Satellite Data: an Automated Procedure."
National Aeronautics and Space Administration. Johnson

Welby, C. W. and K. Holman. Application of Satellite Remote
Sensing to North Carolina Development of a Monitoring
Methodology for Trophic States of Lakes in North Carolina.
National Aeronautics and Space Administration. NASA

Welby, C., A. Witherspoon and K. Holman III. "Trophic State
Determination for Shallow Coastal Lakes from Landsat
Imagery." World Health Organization. Water Quality

Wezernek, C., F. Tanis and C. Bajza. Trophic Analysis of
Inland Lakes. Environmental Research Institute of Michigan.
November 1975.

Wezernek, C., F. Tanis and C. Bajza. "Trophic State Analysis of
pp.147-164.

Yarger, H., J. Coiner, G. Janes, et. al. "ERTS-1 Study of
Reservoirs in Kansas." Proceedings of the 8th International
1477pp.

Yasuoka, Y. and T. Miyazaki. A Study on the Use of Remote
Sensing to Assess Water Quality of Lake Kasumigaura.
27pp.

Zwick, H., et. al. "Airborne Estimation of Water Quality
Parameters in Lake Ontario." Proceedings of the 6th Canadian
Symposium on Remote Sensing. 21-23 May 1980, Halifax, N.S.,

Zwick, H., S. Jain and R. Bukata. A Satellite/Airborne and
In-Situ Water Quality Experiment in Lake Ontario. Canadian
Center for Remote Sensing. CCIRS Number 1024285 Category
1-02-02/2-03-60 1979. 18pp.
V MANIPULATION, PROCESSING AND INTERPRETATION OF REMOTELY SENSED DIGITAL WATER DATA

A. PREPROCESSING/PROCESSING, CALIBRATIONS AND CORRECTIONS (NON ATMOSPHERIC)

Alfoldi, T. "Reference Notes to the Landsat MSS High Gain Data." In preparation, Canada Center for Remote Sensing, Ottawa, Canada.


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