definition of the

**TOTAL EARTH RESOURCES SYSTEM**

FOR THE

**SHUTTLE ERA**

**VOLUME 7**

**USER MODELS: A SYSTEM ASSESSMENT**
TERSSE

DEFINITION OF THE
TOTAL EARTH RESOURCES SYSTEM
FOR THE
SHUTTLE ERA

VOLUME 7

USER MODELS: A SYSTEM ASSESSMENT

PREPARED FOR

EARTH RESOURCES PROGRAM OFFICE
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PREFACE

The pressing need to survey and manage the earth's resources and environment, to better understand remotely sensible phenomena, to continue technological development, and to improve management systems are all elements of a future Earth Resources System. The Space Shuttle brings a new capability to Earth Resources Survey including direct observation by experienced earth scientists, quick reaction capability, spaceborne facilities for experimentation and sensor evaluation, and more effective means for launching and servicing long mission life space systems.

The Space Shuttle is, however, only one element in a complex system of data gathering, translation, distribution and utilization functions. While the Shuttle most decidedly has a role in the total Earth Resources Program, the central question is the form of the future Earth Resources system itself. It is only by analyzing this form and accounting for all elements of the system that the proper role of the Shuttle in it can be made visible.

This study, entitled TERSSE, Total Earth Resources System for the Shuttle Era, was established to investigate the form of this future Earth Resources System. Most of the constituent system elements of the future ER system and the key issues which concern the future ER program are both complex and interrelated in nature. The purpose of this study has been to investigate these items in the context of the total system utilizing a rigorous, comprehensive, systems oriented methodology.

The results of this study are reported in eight separate volumes plus an Executive Summary; their titles are:

Volume 1 Earth Resources Program Scope and Information Needs
Volume 2 An Assessment of the Current State-of-the-Art
Volume 3 Mission and System Requirements for the Total Earth Resources System
Volume 4 The Role of the Shuttle in the Earth Resources Program
Volume 5 Detailed System Requirements: Two Case Studies
Volume 6 An Early Shuttle Pallet Concept for the Earth Resources Program
Volume 7 User Models: A System Assessment
Volume 8 User's Mission and System Requirement Data
Executive Summary.
BACKGROUND

User models were identified early in the TERSSE study as a system element; the development of which was critical to system progress. The treatment of user models in the state-of-the-art assessment (reported in Volume 2) was necessarily brief and contextual. At the completion of that effort, several members of the study team refocused on the user model question for four weeks in order to develop a greater understanding of the nature of this system element and the role that it plays in total system operation. A briefing on the results of this work was made to JSC personnel on 28 September 1973. The charts used in the briefing are reproduced in this volume as a stand-alone discussion of user models.
USER MODELS: A SYSTEM ASSESSMENT

We have chosen to include in the definition of user models any explicit process or procedure used to transform information extracted from remotely-sensed data into a form directly useful as a resource management information input. Merely reformatting or plotting information does not constitute user modelling, nor do all applications of remotely-sensed data require user models. But a significant fraction of applications do not permit the direct use of extracted information (such as acreage) but require the additional transformation of it, in conjunction with ancillary data to produce the final TERSSE output (such as a forecasted production level).

As such, user models form the interface between the TERSSE and the resource managers whom it serves. Models are not only the information interface but are also technological and operations interfaces. Technological because they are the "translator" between the system designer (who is accustomed to talking in terms of multispectral signatures or satellite characteristics) and the resource manager (who is accustomed to talking in terms of economics or his particular earth science). Models are the operations "translator" because they are the final functional step in the process of operating satellites and ground systems in synchronization with the resource manager's information needs schedule.

The current situation in user models is that, with a few exceptions, the remote-sensing community occasionally discusses the need for a model but it is so far downstream from his favorite or immediate problem that only the vaguest of definitions is provided. The resource management specialists, on the other hand, are conducting a truly amazing amount of research into mathematical models of a wide variety of resource management processes. Alas, this research for the most part does not acknowledge the existence much less exploit the technology of remote sensing.

The study team has recommended that the development of appropriate user models be given the same type (not to say level) of attention now afforded to sensors or any other system element. User model development requires focus and attention if applications systems are to become a mature reality.

The foregoing recommendation constitutes a management challenge. We know relatively well how to bring a new sensor into the inventory, but methodologies for developing user models are nonexistent. Questions arise such as "does the forcing function lie with the resource manager or NASA?" or "how should the steps of model development be synchronized with sensor or preprocessing system development?" We feel that the first steps to answer the challenge should be a joint NASA/user study of the problem with the specific objective of developing guidelines and management strategies for a systems approach to user model development.
USER MODELS

- WHAT ARE THEY?
- HOW DO THEY RELATE TO THE TOTAL PROGRAM?
- WHY ARE THEY IMPORTANT?
- OBSERVATIONS ON THE CURRENT SITUATION
- AN ANALYSIS OF SOME CURRENT EXAMPLES
- PRELIMINARY RECOMMENDATIONS

AN UNDERSTANDING OF USER MODEL DEVELOPMENT IS KEY TO DEVELOPING THE TOTAL SYSTEM
A set of land use planning models in their user context of producing a 10-year regional plan.
USER MODELS - WHAT ARE THEY?

- A TOOL FOR TRANSLATING A SET OF PARAMETERS INTO USEFUL INFORMATION
  - REMOTELY-SENSED INPUTS
  - ANCILLARY INPUTS

- A METHOD FOR DESCRIBING A DYNAMIC RESOURCE PROCESS OR CYCLE
  - PHYSICAL PROCESSES
  - BIOLOGICAL PROCESSES

- A STRUCTURED PROCEDURE FOR SOLVING A RESOURCE PROBLEM
**USER MODELS: RANGE OF CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Tailored to Specific System/Area</th>
<th>OR</th>
<th>Useful for Many Systems/Areas</th>
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<tbody>
<tr>
<td>Rigorous, Explicit</td>
<td>OR</td>
<td>Intuitive, Abstract</td>
</tr>
<tr>
<td>Input/Output Oriented</td>
<td>OR</td>
<td>Process Oriented</td>
</tr>
<tr>
<td>Machine Programmable or Graphically Solved</td>
<td>OR</td>
<td>Operated &quot;By Inspection&quot;</td>
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</table>

*Graphically* Solved

Operated "By Inspection"
THE INFORMATION CASCADE

CORRECTED IMAGES

EXTRACTING PROCESSING

PARAMETERS

ANCILLARY DATA

MODELLING

TOTAL EARTH RESOURCES SYSTEM BOUNDARY

RESOURCE INFORMATION

FULL-SCALE RESOURCE MANAGEMENT
USER MODELS ARE THE "TRANSLATOR" BETWEEN THE SYSTEM WHICH ACQUIRES INFORMATION AND THE RESOURCE MANAGERS WHO USE IT
USER MODELS ARE THE INTERFACE BETWEEN ERS AND ITS CUSTOMERS.
USER MODELS - WHY ARE THEY OF INTEREST?

DATA COLLECTION → TRANSLATION → DATA USE

- SIGNATURES
- SENSORS
- DATA SYSTEMS
- PLATFORMS
- CONTROL / SCHEDULING
- MANAGEMENT

TECHNOLOGICAL INTERFACE

INFORMATIONAL INTERFACE

OPERATIONS INTERFACE

- RESOURCE SCIENCES, ENGINEERING
- ECONOMICS, MARKET FACTORS
- DATA BASIS
- PLANNING, MONITORING, CONTROL ACTIVITIES
- RESOURCES MANAGEMENT
USER MODELS: WHY ARE THEY OF INTEREST?

IN TOTAL SYSTEM DEVELOPMENT:

• TO VERIFY UTILITY OF REMOTE SENSING FOR SPECIFIC RESOURCE MANAGEMENT PROBLEMS

• TO DETERMINE OPERATIONAL ERS SYSTEM REQUIREMENTS

• TO ENCOURAGE USERS TO INTERFACE WITH R&D SYSTEM
  - REMOVES TECHNOLOGICAL MYSTIQUE
  - KEEPS USERS AWAY FROM UPSTREAM ENGINEERING

DEVELOPMENT OF USER MODELS IS A SEGMENT OF SYSTEM DEVELOPMENT
USER MODELS: A SUMMARY OF THE CURRENT SITUATION

MODELING WORK SORTS INTO TWO PILES:

THE AEROSPACE PILE
- BROAD, GENERAL, NON-QUANTITATIVE
- ALWAYS INCLUDES REMOTE SENSING
- USUALLY BENEFITS - ORIENTED
- RESOURCE MANAGEMENT NOT UNDERSTOOD
- NOT GENERALLY USEFUL TO RESOURCE MANAGER

THE RESOURCE SPECIALIST PILE
- DETAILED, RIGOROUS, EXPLICIT, NARROW
- ALMOST NEVER INCLUDES REMOTE SENSING
- SOMETIMES BENEFIT - ORIENTED
- REMOTE SENSING NOT UNDERSTOOD
- NOT GENERALLY USEFUL TO ERS DESIGNER

THERE ARE EXCEPTIONS - SOME BRIDGES ARE BEING BUILT!
### ERTS-1 Investigator Modelling

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<th>Activities</th>
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<td>Ag/Forestry/Range</td>
<td>Langley refining forestry yield model; Dethier using phenology model</td>
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<tr>
<td>Minerals/Geology</td>
<td>Morrison/Woley looking at erosion modelling; many references to inexplicit, unprogrammable &quot;models&quot;</td>
</tr>
<tr>
<td>Water Resources</td>
<td>Hollyday, Schumann working on DCP measurements, basin areas as inputs to stream flow models; Coker working on Tampa Bay circulation model for dredging</td>
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<tr>
<td>Marine Resources</td>
<td>Kemmerer modelling menhaden location correlations with image and sea truth data</td>
</tr>
<tr>
<td>Land Resources</td>
<td>Raj and others providing inputs for existing regional planning models</td>
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</table>

ERTS-1 investigations are in the "what can we see and map" phase - a small minority are thinking models.
### Analysis of ERTS-1 Investigations*

<table>
<thead>
<tr>
<th>Subject Areas with Potential for User Models</th>
<th>No. Investigations Reported</th>
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<th>New</th>
<th>Investigation in Extractive Processing Stage or Using Data Directly</th>
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*As reported in proceedings of NASA symposium on significant results obtained from the Earth Resources Technology Satellite-1 NASA SP-327
SCIENTIFIC USER MODELS EXISTING OR IN DEVELOPMENT

- GRASSLAND BIOME
- DECIDUOUS FOREST BIOME
- CONIFEROUS FOREST BIOME
- DESERT ECOLOGY
- TROPICAL FOREST BIOME
- TUNDRA BIOME

STATUS: LARGE SCALE DIGITAL SIMULATION SPONSORED BY NATIONAL SCIENCE FOUNDATION (PART OF "ANALYSIS OF ECOSYSTEMS RESEARCH PROGRAM OF INTERNATIONAL BIOLOGICAL PROGRAM"

IBP IS THE GARP OF ECOLOGY
OPERATIONAL MODELS ARE USED IN MANY RESOURCE MANAGEMENT AREAS - THE NECESSITIES OF THE REAL WORLD HAVE FOSTERED APPROPRIATE RESPONSES

OPERATIONALLY, REMOTE SENSING PEOPLE ARE PRIMARILY ON THE OUTSIDE, LOOKING IN
- REMOTE SENSING SYSTEMS NOT OPERATIONAL
- MODELLING INTERFACES NOT DEVELOPED

NOT ONLY MUST DATA ACQUISITION BECOME OPERATIONAL - WE NEED PROVEN, INTERFACEABLE MODELS TOO
MODELS ARE INDEED THE POTENTIAL TRANSLATOR BETWEEN THE SYSTEM AND MANY OF ITS USERS.

THE FIELD OF MODELLING IS RICH WITH EFFORT BUT MOST MODEL DEVELOPMENT CURRENTLY INVOLVES RESOURCE SPECIALISTS WITH NO REMOTE SENSING SYSTEMS ORIENTATION.

NASA IS INVOLVED IN MODEL DEVELOPMENT, BUT THE EFFORT APPEARS TO BE CONCENTRATED IN DISCIPLINE AND CENTER NUCLEI.

A SYSTEMS APPROACH TO REMOTE SENSING MODEL DEVELOPMENT IS NEEDED.
WHAT NEXT?

POSTULATED NASA OBJECTIVE

- TO UNDERSTAND, THEN LEAD, WHERE APPROPRIATE THE USER MODEL DEVELOPMENT PROCESS AS A PORTION OF NASA'S TOTAL SYSTEM DEVELOPMENT RESPONSIBILITIES

PROPOSED ACTIVITY

- DEVELOP CASE STUDIES FOR EXAMINING SUCCESS FACTORS IN MODEL DEVELOPMENT
  - FORCING FUNCTION
  - TEAM SKILLS
  - ORGANIZATION/MANAGEMENT
  - FUNDING
  - DEVELOPMENT STAGING
  - RELATIONSHIP TO TOTAL R&D PICTURE

- USER MODEL WORKSHOP
  - TOTAL SYSTEM FOCUS
  - REPORTS FROM MODELERS

- DEFINE DEVELOPMENT GUIDELINES, MANAGEMENT STRATEGIES FOR TOTAL SYSTEM APPROACH TO MODEL DEVELOPMENT
USER MODELS:

ILLUSTRATIVE EXAMPLES
ARID LAND EROSION

OUTPUT: PREDICTION OF EROSION DUE TO ALTERNATIVE GRAZING, FLOOD CONTROL AND LAND DEVELOPMENT POLICIES

SOURCE: USGS/ERTS INVESTIGATION (NO MODELING UNDERWAY)

REMOTE SENSING: MEASUREMENT OF TOPOGRAPHY, EROSION, METEOROLOGY, LAND DEVELOPMENT
ARID LAND EROSION

- Combination of climatic changes, grazing practices is causing loss of vegetation cover in arid regions (S. Arizona) which leads to major erosional changes of regional topography, land suitability.

- Model needed for translating measureable conditions of region into predictions to assess alternative regulation strategies for grazing, flood control facility construction, land development.

- Morrison/Cooley (USGS) in the investigative mode, under ERTS sponsorship. Currently mapping, developing understanding of contribution of remote sensing. Quantitative understanding stated as good, but no modelling effort under way.

- Remote sensing potential exists for measuring topology erosion, meteorology and land development.
ARID LAND EROSION

ERODIBLE SOIL TYPES, TOPOGRAPHY, PRECIPITATION, RUNOFF, DRAINAGE CHARACTERISTICS

OVER GRAZING PRACTICE

CLIMATIC CHANGES

AMELIORATIVE MEASURES

PROPOSED HIGHWAY, URBAN DEVELOPMENT CHANGES

EROSION DYNAMICS MODEL

VEGETATIVE STRESS PHASE

SHEET EROSION PHASE

GULLYING PHASE

VEGETATION CONDITION

PREDICTION OF RATE OF HEADWARD GROWTH, WIDENING, DEEPENING
OPTIMUM SHIP ROUTING

OUTPUT: BEST ROUTE TO MINIMIZE TRANSIT TIME, FUEL CONSUMPTION AND MAXIMIZE SAFETY FOR SEA CONDITIONS AND SHIP PERFORMANCE

SOURCE: U.S. NAVY (et al.)

REMOTE SENSING: HEIGHT AND DIRECTION OF WAVES, METEOROLOGY
OPTIMUM SHIP TRACK ROUTING

• The problem is to determine the optimum route for a ship between two ports. The optimum route is the one that minimizes transit time while maximizing the safety of the passengers and cargo.

• The Model is needed for derivation of necessary corrections to great circle (or minimum distance) route to account for projected sea surface roughness, direction of waves, and sailing characteristics of ship in question.

• Navy has implemented early model in the late 1950's. Many mathematical refinements for calculation of minimum transit route and for calculation of projected sea surface conditions have been and are still being introduced by several research groups.

• Remote Sensing has potential for:

  (1) Direct measurement of wave heights and direction. This potentially could obviate necessity for a large uncertain calculation of these parameters from surface wind data which suffer from many data sparse areas over the oceans.

  (2) Direct measurement of surface winds over ocean areas - particularly important in tropics.
FIGURE 1

DURATION GRAPH
CUMULATIVE SPECTRA FOR WIND SPEEDS FROM 10 TO 20 KNOTS AS A FUNCTION OF DURATION

<table>
<thead>
<tr>
<th>TO FIND</th>
<th>MULTIPLY BY</th>
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<tbody>
<tr>
<td>Significant Wave Height</td>
<td>2.83</td>
</tr>
<tr>
<td>Average Wave Height</td>
<td>177</td>
</tr>
<tr>
<td>9th Highest Wave Height</td>
<td>560</td>
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</table>

10 Knots

12 Knots

14 Knots

16 Knots

6 Hours

5 Hours

4 Hours

2 Hours

1 Hour

0 Hours

Duration Graphs for Wind Speeds from 10 to 20 Knots as a Function of Duration.
FIGURE 3

DISPERSION DIAGRAM
FREQUENCY 0-0.11
R 0-3000 NM
T 0-5 DAYS
f = 0.66/R

5 days
40 28 24 20 18 16 14 12 10 T
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h
0h

1 day
40 28 24 20 18 16 14 12 10 T
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h
0h

3 days
40 28 24 20 18 16 14 12 10 T
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h
0h

4 days
40 28 24 20 18 16 14 12 10 T
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h
0h

5 days
40 28 24 20 18 16 14 12 10 T
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h
0h
**FIGURE 5**

**RANGE OF E FOR TYPICAL HEIGHT VALUES**

<table>
<thead>
<tr>
<th>Range of E</th>
<th>√E</th>
<th>E</th>
<th>Av. Ht.</th>
<th>Sig. Ht.</th>
<th>Av. 1/10 Ht.</th>
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<td>.18</td>
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<td>100</td>
<td>127</td>
</tr>
</tbody>
</table>
FIGURE 6

SHIP SPEED (KNOTS)

WAVE HEIGHT (FEET)

ASTERN
ABEAM
AHEAD
AIR POLLUTION MODEL

OUTPUT:
FORECAST OF AIR POLLUTION DISTRIBUTION

SOURCE:
MODELS UNDER DEVELOPMENT CONSIDER MANY SOURCES AND WIND TRANSPORT

REMOTE SENSING:
MEASUREMENT OF DISTRIBUTION OF POLLUTION (RELIETING REQUIREMENTS FOR DYNAMIC MODELING)
• The purpose is to forecast the concentration distribution of atmospheric pollution within an urban and/or industrial region.

• The Model is needed to account for the multitude of sources, source types, pollutant types, meso and micro-meteorological conditions that influence the future concentration of air pollution coinciding with population centers, impacting industrial facilities and activities, and affecting surrounding agricultural areas.

• Models are being developed to simulate observed pollutant dispersions giving some array of sources and source types. To simulate meso-meteorological processes in urban areas and pollutant transport; also air pollution control strategy modeling is under way.

• Potential exists for direct measurement by remote sensing of detailed 3-dimensional pollutant distributions, thus eliminating complicated atmospheric diffusion calculations.
MAJOR ELEMENTS OF AN AIR-POLLUTION CONTROL DECISION MODEL SYSTEM

REGIONAL SCENARIO
- DEMOGRAPHIC
- SOURCE/RECEPTOR INVENTORY
- LAND USE
- REGIONAL BOUNDARIES

POLLUTANT TRANSPORT MODEL
- REGIONAL METEOROLOGICAL DATA
- TERRAIN FEATURES
- INPUT FROM OTHER REGIONS

PREDICTED SUB-REGION POLLUTANT GROUND LEVEL CONCENTRATIONS
- SOURCE EMISSION TRANSFORMATIONS
- DESIRED CONTROL MEASURES

CONTROL STRATEGY/TACTICS DECISION MODELS
- CONTROL DEVICE COST/EFFECTIVENESS
- DECISION BASIS
- AVAILABLE CONTROL OPTIONS
- ABATEMENT OBJECTIVES

OBTAINABLE GROUND LEVEL CONCENTRATION DISTRIBUTION
- OPTIMAL STRATEGIES AND TACTICS
- TOTAL ABATEMENT COSTS

POSSIBLE TYPES
- MULTIPLE SOURCE DISPERSION MODELS
- NUMERICAL ADVECTION - DIFFUSION SIMULATION MODELS
GREAT LAKES ICE FORECASTS

OUTPUT: DETERMINATION OF ACCESSIBILITY OF SHIPPING CHANNELS AND PORTS

SOURCE: IFYGL STUDY

REMOTE SENSING: ICE COVER AND THICKNESS, WATER AND GROUND TEMPERATURES, WATER CURRENTS AND ROUGHNESS
GREAT LAKES ICE FORECASTS

• The problem is to forecast the status of the ice cover on the Great Lakes in order to advise shipping interests as to the accessibility of a specified port or the navigability of the channels.

• The model provides a practical means to empirically integrate routine ice observations with meteorological measurements and measurements of the physical characteristics of the lakes and the near-lake shore to produce a forecast of the navigability of the shipping channels.

• The problem is being studied as part of IFYGL (International Field Year on The Great Lakes). Mechanical systems for prevention of ice formation are being developed.

• The Winter Navigation Board has been established (River - Harbor Act of 1970) to conduct a Winter Navigation Program to study and test the feasibility of extending the navigation season for the Great Lakes and the St. Lawrence Seaway.

Program Features

- Ship voyages beyond normal season
- Observation and surveillance of ice conditions and ice forces.
- Environmental and ecological investigations
- Technical data on vessel design
- Ice control facilities
- Aids to navigation
- Physical model studies
- Coordinated collection and dissemination of key weather info to shippers.

• Measurement of ice cover thickness, water surface temperature, ground surface temperature, water surface roughness, currents can potentially be made by remote sensing.
OUTPUT: STATISTICAL ESTIMATE OF HARVESTABLE TIMBER VOLUME IN LARGE SCALE STANDS

USERS: USFS TIMBER COMPANIES (e.g., Weyerhauser)

TYPICAL MODEL: P.G. LANGLEY'S MULTISTAGE MODEL (DEPENDS ON REMOTE SENSING INPUTS TO PROPORTIONAL PROBABILITY SAMPLING PROCESSES)
FOREST YIELD MODELS

- The problem is to predict or estimate the volume of merchantable timber in stands in forest areas. Both estimates of current timber volume and predictions of future volume are required. Both the U.S. Forest Service and lumber companies are interested in these yield estimates—the Forest Service because stand yield is a factor in U.S. forest management which the U.S. Forest Service is charged with and the lumber companies because of the impact of stand yield on harvesting plans and thus profits.

- A number of forest yield models, all designed for ground data input have been devised and are currently in use by both USFS and private companies. Langley's multistage forest yield model is unique in that it was designed specifically for remote sensing input and large area survey—it is currently being tested.

- Remote sensing plays a crucial role in providing inputs to Langley's multistage forest yield model. Acreages of species of trees and tree stands are used. Estimates of tree height and/or basal area may be obtained from remote sensing—research is currently underway to understand how to obtain these parameters.
LANGLEY'S MULTISTAGE SAMPLING
FOREST YIELD MODEL

- Forest/Non-Forest
- Forest Species
- Broad Forest Species Classes
- Ground Sampled Tree Volume
- Calculate Yield
- Subset of Each Area
- Stratify Area
- Statistical Expansion
- Yield Estimate
MIGRATORY FISH LOCATION

OUTPUT: LOCATIONS OF FISHING AREAS WITH HIGH PROBABILITY OF FISH CONCENTRATIONS

USERS: NMFS/NOAA (DEVELOPING CONCEPTUAL MODELS) COMMERCIAL FLEETS (USING EMPIRICAL MODELS)

REMOTE SENSING: POTENTIAL SOURCE FOR TEMPERATURE, WEATHER, SALINITY, WATER COLOR, SEA STATE, TURBIDITY, CURRENT, CHLOROPHYLL INPUTS
MIGRATORY FISH LOCATION

- Problem is to predict or delineate likely areas for fish in oceanic and coastal waters. Both NOAA and commercial fishing companies are interested in delineating likely areas so that the fishing fleet can be directed to areas where probability of success is maximized.

- Conceptual models were being developed under NOAA sponsorship. No operational use of models now except empirically by fishing fleet operators.

- Remote sensing ideally suited to delineation of temperatures and temperature fronts and of fronts in clear weather.
MIGRATORY FISH LOCATION

CHLOROPHYLL CONCENTRATION

TEMPERATURE OF OCEAN

TEMPERATURE FRONTS

CORRELATION OF HIGH CHLOROPHYLL, SUITABLE TEMPERATURE, FISH MIGRATION PATTERN

AREAS OF HIGH PROBABILITY OF FISH

SEASON
TIME IN LIFE CYCLE

FISH MIGRATION PATTERN

TEMPERATURE PREFERENCE OF FISH SPECIES

OCEAN CURRENTS
CROP YIELD MODELS

OUTPUT: STATISTICAL ESTIMATE OF HARVEST VOLUME BY CROP SPECIES

USERS: AGRIBUSINESS - HARVEST STRATEGY
        PROCESSORS - BUYING STRATEGY
        USDA - POLICY AND STATUTORY

REMOTE SENSING: TO ESTIMATE ACREAGES, BIOMASS, CATASTROPHIC FACTORS

TYPICAL MODEL WITH RS: CALIFORNIA RAISIN MODEL
CROP YIELD MODELS

- Problem is to estimate the yield of important agricultural crops on a periodic basis or to obtain quick estimates of pre-harvest yield to plan harvesting strategy. Both USDA, agribusiness, and food processors are interested in the former, USDA for statutory reasons and agribusiness and food processor for determining marketing and buying strategy. Agribusiness interested in the latter.

- Operational models based on stratified sampling and periodic introduction of more ground collected information are now in use at USDA-SRS for estimating monthly forecast crop yield. Some operational sampling models (e.g., California Raisin Survey) are currently conducted using remote sensing data and paid for by agribusiness. Research on new models being funded by USDA-SRS, and being studied by NASA-JSC (wheat).

- Remote sensing can impact yield models, especially to provide estimates of productive acreage of crops and catastrophic factor assessment (e.g., lodging, drought, hail damage).
CROP YIELD ESTIMATION

HISTORICAL EXPERIENCE

PLANTING INTENTIONS

FIRST ADJUSTMENT

SECOND ADJUSTMENT

THIRD ADJUSTMENT INCLUDING PROBABILITY OF SURVIVAL

FOURTH ADJUSTMENT INCLUDING PROBABILITY OF SURVIVAL

FIFTH ADJUSTMENT

GROUND SAMPLED YIELD

ACTUAL PLANTED ACRES

METEOROLOGICAL DATA (e.g., SOIL MOISTURE)

CROP PHENOLOGY

CATASTROPHIC FACTORS AND DISEASES

FINAL ESTIMATE
## CROP STRESS

**OUTPUT:** QUANTITATIVE PREDICTIONS OF PEST/DISEASE STRESS INFLUENCES ON YIELD

**USERS:**
- USDA, STATE AGRICULTURAL DEPARTMENTS
- AGRIBUSINESS

**TYPICAL APPLICATIONS:**
- CORN - SOUTHERN LEAF CORN BLIGHT
- BRAZILIAN COFFEE

**REMOTE SENSING:** TO MEASURE STRESS, ASSESS EFFECT OF REMEDIES
CROP STRESS (BRAZILIAN COFFEE)

- The problems are: 1) to predict the spread of pests, disease, or other stress factors so that remedial action can be instituted, or 2) to estimate the impact of stresses on yield in cases where no remedial action is possible or feasible. Both USDA and agribusiness interests are concerned with this -- USDA because of the impact of stresses on yield predictions and the need to notify farmers of impending stresses (e.g., corn blight) and agribusiness because of the potential loss of profits.

- A number of empirical models exist for predicting stress (e.g., drought, where irrigation is a feasible remedy). USDA has sponsored work in house on the effects of stress on yield. Some work on this topic has also been done at Agriculture Experiment Stations. The Brazilians have constructed a model for the impact of frost on coffee production. The effects of corn blight on corn yield were being empirically studied at LARS.

- Remote sensing could have an impact on the assessment of degree of stress and on the previsual detection of stress. Also remote sensing could be used to assess the effects of remedial treatment.
ACRES OF COFFEE PLANTED

STANDING BIOMASS

AGRONOMIC CORRELATION OF STANDING BIOMASS AND CROP DAMAGE

YIELD IMPACT OF CROP DAMAGE

CORRELATION WITH TOTAL ACREAGE

COFFEE PRODUCTION AS A FUNCTION OF TIME
OUTPUT: ESTIMATES OF FLOCK SIZES TO ESTABLISH HUNTING CONTROLS, LIMITS

TYPICAL MODELS: BSFW MODEL PREDICT MALLARD POPULATIONS

REMOTE SENSING: CAN DETERMINE HABITAT INFLUENCE OF FLOCK SIZE
WATERFOWL PRODUCTIVITY MODELS

• Problem is to estimate the production of new migratory waterfowl, by species, for the U.S., Canada, and Alaska. An estimate of the ratio of new production to total population is desired. Both U.S. and Canadian Wildlife Services need this information to help set hunting limits each fall and to insure that enough birds survive to breed the next year.

• At present, some empirical models exist relating habitat quality to production of some species of ducks (e.g., Mallards). Current estimates of new production and total population are computed from stratified samples taken by serial observers. The current program and modeling research are funded by the Bureau of Sports Fisheries and Wildlife and the Canadian Wildlife Service.

• Remote sensing can impact the habitat assessment required as part of estimating new production.
A CONCEPTUAL WILD FOWL PRODUCTIVITY MODEL

NUMBER OF PONDS AND LOCATION

SURROUNDING LAND USE

DISEASE AND PREDATION

POND TYPE (e.g., PERMANENT, EPHEMERAL)

EARLY SUMMER ESTIMATE OF NUMBER OF OLD BIRDS

PRODUCTIVITY ESTIMATE BY SPECIES FOR EACH STRATUM

STATISTICAL EXPANSION

NEW PRODUCTION BY SPECIES

PRODUCTION RATIO (NEW / OLD) FOR EACH STRATUM

STATISTICAL EXPANSION

PRODUCTION RATIO BY SPECIES

*INDICATES EVENTUAL REMOTE SENSING IMPACT
PHYSICAL/BIOLOGICAL MODEL OF WATER BODY

OUTPUT: DUE TO BIOLOGICAL/MECHANICAL INTERACTIONS WITH IMPACT ON FISHING, NAVIGATION, RECREATION

SOURCE: INSTITUTE FOR ENVIRONMENTAL STUDIES (UNIVERSITY OF WISCONSIN)

REMOTE SENSING: CAN PROVIDE INPUTS ON ENERGY, NUTRIENTS, WATER INFLOW
A PHYSICAL/BIOLOGICAL MODEL OF A WATER BODY

- The purpose of the model is to describe the transformations of a water body subject to complex mechanical and biological interactions.
- A typical source of a model is the Institute for Environmental Studies - University of Wisconsin - (Watt, K)
- This type of model has been used to explain transformations of water bodies.
- Potential contributions of remote sensing are inputs of various types of energy, inputs of nutrients and water inputs some of which can be obtained by remote sensing.
- Model inputs are Radiation, Thermal and Mechanical Energy, organic material and nutrient inflow and water inflow.
- Model outputs are energy outflow of water body (thermal, chemical, latent heat); change in nutrient and sediment levels in water body. These have potential impact on fish productivity, recreational and economic value of water body and surrounding land.
A COMPARTMENT MODEL SHOWING (1) THE MAJOR INPUTS
(2) THE POOLS OF PLANTS, ANIMALS, DISSOLVED
NUTRIENTS AND DETRITUS, AND (3) THE MAJOR
OUTPUTS OF AN AQUATIC ECOSYSTEM. AFTER
WATTS AND LOUCKS (1969)

LAKE WINGRA AQUATIC ECOSYSTEM

INPUTS
- ENERGY
  - RADIATION (LIGHT)
  - THERMAL
  - MECHANICAL (WIND)
  - FIXED ORG. MATTER
- NUTRIENTS
  - NITROGEN
  - PHOSPHORUS
  - CO₂
- WATER
  - PRECIP.
  - STREAMS
  - SEDIMENT

PRIMARY PRODUCERS
- 1. ALGAE
- 2. AQUATIC MACROPHYTES

GRAZERS
- ZOOPLANKTON
- FISH
- BENTHOS
- MUSKRAT
- DUCK
- MAN?

CARNIVORES
- ZOOPLANKTON
- FISH
- MAN
- BENTHOS

DECOMPOSERS
- DETRITUS

OUTPUTS
- ENERGY
  - THERMAL
  - CHEMICAL (FIXED ORG. MATTER)
  - LATENT HEAT (EVAPOR.)
- DISSOLVED NUTRIENTS
- SEDIMENTS
TYPICAL OUTPUT: PREDICTION OF EFFECT OF STEAM PLANT ON MARINE LIFE

TYPICAL MODEL: PHYSICAL/DIGITAL MODEL OF GALVESTON/ TRINITY BAY

REMOTE SENSING: TIDAL PHASES, RIVER INFLOW, TEMPERATURE, SALINITIES, METEOROLOGY
ESTUARINE FLOW DYNAMICS

• Man-introduced substances and activities are threatening natural utility and productivity of coastlines. Better knowledge of near-shore circulation patterns are needed to better manage the sea/land resources for the long term benefit of man.

• Typical models used are the physical and digital hydrodynamic and thermal models of the Galveston-Trinity Bay System.

• Specific objectives are to determine heating effect of steam plant on small marine life and to correlate spatial and temporal characteristics of estuarine effluents with other environment parameters.

• Model sensed inputs required are tidal phases in bays, meteorological parameters, river in-flow rates and temperatures, subsurface temperatures and salinities.

• Typical outputs are prediction of effects of man-induced activity such as thermo-electric plants on marine plant and animal life.
TYPICAL ESTUARINE USER MODEL

MAN-CAUSED INPUTS

TIDAL INPUTS
RIVER FLOW INPUTS
METEOROLOGICAL INPUTS

THREE DIMENSIONAL HYDROLOGICAL MODEL

SEDIMENTATION CONDITIONS

THERMAL MODEL

SEA LIFE CONDITIONS

SEA LIFE MODEL

THERMAL INPUT FROM POWER STATION
COMPUTED ASTRonomical Tide for two locations in Galveston Bay for three different friction factors: observed value also shown. After Reid and Bodine (1968).
COMPARISON OF OBSERVED AND COMPUTER ASTRONOMICAL TIDE FOR THREE LOCATIONS IN GALVESTON BAY USING FINAL FRICTION FACTOR. AFTER REID AND BODINE (1968).
COMPARISON OF MEASURED AND COMPUTED TIDAL ELEVATIONS IN GALVESTON BAY (STOVER et al. 1971).

```
\[ HSL \]

-0.5
-1.0
-1.5

1.0
0.5
HSL
0.0
-0.5
-1.0
-1.5

MORGAN POINT
--- OBSERVED
--- MODEL

SOUTH TEXAS CITY DIKE
--- OBSERVED
--- MODEL

RAILROAD CAUSEWAY
--- OBSERVED
--- MODEL

TIME IN HOURS
```

```
\[ MSL \]

1.0
0.5
HSL
0.0
-0.5
-1.0
-1.5

KEMAH DOCKS
--- OBSERVED
--- MODEL

TIME IN HOURS
```
CALCULATED VELOCITIES FOR CONDITIONS OF
PREVIOUS FIGURE WITH ADDED DIVERSION ACROSS
UMBRELLA POINT (TOP RIGHT)
CALCULATED TIDAL-AVERAGE VELOCITIES FOR TEN-YEAR-MEAN INFLOW
COMPARISON OF VELOCITIES FROM PHYSICAL MODEL AND MATHEMATICAL MODEL. RANGE 1, ATKINSON ISLAND TO MESQUITE KNOLL

PHYSICAL MODEL: STATION 2
MATHEMATICAL MODEL

VELOCITY (FT/SEC)

TIME (HOURS)
COMPARISON OF VELOCITIES FROM PHYSICAL MODEL AND MATHEMATICAL MODEL. RANGE 6, RED FISH ISLAND TO EAGLE POINT

![Graph showing comparison of velocities]

**Physical Model:**
- Station 4
- Station 5

**Mathematical Model**

**Time (Hours):** 5, 10, 15, 20, 25
COMPARISON OF VELOCITIES FROM PHYSICAL MODEL AND MATHEMATICAL MODEL. RANGE 6, RED FISH ISLAND TO SMITH POINT

![Graph showing comparison of velocities from physical and mathematical models.](image-url)
SALINITY CONTOURS FROM MEASUREMENTS OF
17 SEPTEMBER 1968 IN GALVESTON BAY
INFLOWS IN TRINITY RIVER AND HOUSTON SHIP CHANNEL (AT MORGAN POINT) FOR 1968 WATER YEAR
LOCATION MAP AND COMPUTATIONAL GRID
FOR THERMAL DISCHARGE MODEL
ENVIROMENTAL CONDITIONS AT P. H. ROBINSON PLANT ON 2 - 3 OCTOBER

- **Air Temperature**
- **Relative Humidity**
- **Outfall Temperature**
- **Shortwave Radiation**
- **Tidal Record**
- **Wind Speed and Direction**

**Data Run**

**Time - Hours**

**OCT 2** | **OCT 3**
--- | ---
0 | 0
3 | 3
6 | 6
9 | 9
12 | 12
15 | 15
18 | 18
21 | 21
24 | 24

**Time - Hours**

**OCT 2** | **OCT 3**
--- | ---
0 | 0
3 | 3
6 | 6
9 | 9
12 | 12
15 | 15
18 | 18
21 | 21
24 | 24

**Time - Hours**

**OCT 2** | **OCT 3**
--- | ---
11 | 11
14 | 14
17 | 17
20 | 20
23 | 23

**Direction of Time Axis Is Parallel To Shoreline**
CALCULATED TEMPERATURE (°F) CONTOURS WITH MEASUREMENTS FROM BOAT TRAVERSE.
P. H. ROBINSON DISCHARGE IN GALVESTON BAY.
FROM STOVER et al. (1970).

(a) 2 October, 2:00 P.M.

(b) 2 October, 5:00 P.M.
COLUMBIA RIVER BASIN

OUTPUTS: EFFECTS OF ALTERNATE WATER STORAGE/RELEASE STRATEGIES TO IMPROVE OVERALL RIVER MANAGEMENT (HYDRO-POWER, IRRIGATION, FLOOD REDUCTION, NAVIGATION, RECREATION)

SOURCE: PLANNING RESEARCH CORP/NASA (CONCEPTUAL MODEL KNOWN TO EXIST)

REMOTE SENSING: DEPENDS ON MULTISPECTRAL SENSING AND SAR
A USER MODEL FOR WATER MANAGEMENT IN THE COLUMBIA RIVER BASIN

- The purpose of the Model is to specify sensing and system requirements needed to maximize benefits of hydropower output, recreational utilization and irrigation capability without incurring excessive flood risks.

- The source of the Model is Planning Research Corporation, under NASA Contract (NAS w-1816). Analysis of User Model has been made as part of Total River Basin Management Model. Model has not yet been used with remotely sensed data.

- The Model potentially can make use of satellite-mounted multi-spectral sensors and synthetic aperture radar.

- The Application of Model and to total management system projected to provide cost benefits to Pacific Northwest and the nation.
RIVER BASIN MODEL

SATELLITE BASED SENSORS

PRECIPITATION INVENTORY / SNOWMELT AND RAIN MODEL

SURFACE / SUBSURFACE / BASE WATER FLOW MODEL

METEOROLOGY

POWER, IRRIGATION, FLOOD-CONTROL, NAVIGATION, RECREATION

RIVER FLOW MODEL

RESERVOIR MODEL

MANAGEMENT OPTIONS
### MAJOR DIFFERENCES BETWEEN DOSAG-1 AND QUAL-1 MODELS

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### PROJECTED BENEFITS - IMPROVED WATER MANAGEMENT IN MILLIONS OF DOLLARS

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<td>Better utilization of hydro-power</td>
<td>100</td>
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</tr>
<tr>
<td>Better utilization of water for irrigation</td>
<td>60</td>
<td>80</td>
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<td>Reduced losses from floods</td>
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<tr>
<td>Increased utilization for recreation and navigation</td>
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<td><strong>Total benefits projected</strong></td>
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<td>203</td>
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*Columbia River Basin only*
OUTPUTS: LAND USE/ TRANSPORTATION PLAN

SOURCE: SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

REMOTE SENSING: DATA ON PRESENT LAND USE, INVENTORY, DEVELOPMENT PATTERNS, TRANSPORTATION
A DESIGN MODEL FOR PLANNING LAND USE

- The purpose of model is to design a systematic plan for land use and transportation system for an urban area.

- Source of model is the Southeastern Wisconsin Regional Planning Commission. Plan has been designed but has not yet made use of remote sensing.

- Model depends on information on present land use and transportation facilities. These potentially can be obtained by remote sensing.

- The model inputs are land use and survey data, transportation data, land development costs and planning policies.

- The model outputs are a designed plan for use of urban areas and a transportation plan and evaluation of transportation plans by simulation.
A "WEIGHTED VALUE" MODEL

OUTPUT: A MAP SHOWING PREFERRED LAND USE

TYPICAL SOURCE: NEW YORK DEPARTMENT OF PARKS / STATEN ISLAND

APPROACH: "PARALLEL PROCESSING" WEIGHTING MATRIX (OVERLAYS)

REMOTE SENSING: CAN PROVIDE DATA ON GEOLOGY, PHYSIOGRAPHY, HYDROLOGY, ETC.
A "WEIGHTED VALUE" USER MODEL FOR LAND USE PLANNING

- The problem is to determine how land can be allocated to best meet complex requirements of an urban area. The model is needed to provide a rational approach for applying weighted values in planning land use.

- The area is gridded and values assigned to each grid element for land suitability parameters such as drainage, scenic value, proximity to transportation. Overlays are made to provide a weighting matrix depicting overall land suitability for a specific set of functions.

- The model requires data on land characteristics (e.g., geology, physiography, hydrology, etc.) which potentially can be obtained by remote sensing.

- The model has been used by the New York Park Commission on Staten Island.

- Required inputs are distributed data on geology, land forms, vegetation, present land use, etc.

- Outputs are composite region maps of recommended land use.
A "WEIGHTED VALUE" MODEL FOR LAND USE PLANNING
A "WEIGHTED VALUE" MODEL FOR
LAND USE PLANNING

BEACH QUALITY

INTERTIDAL HABITAT VALUE

SCENIC VALUE (LAND)

STREAM QUALITY

GEOLeOGIC FEATURES VALUE

SCENIC VALUE (WATER)

WATER WILDLIFE VALUE

PHYSIOGRAPHIC FEATURES VALUE

ECOLOGICAL ASSOCIATIONS VALUE