A Workshop on Challenges in Ecosystem Modeling and Decision-Making: USAE District and Division Needs Workshop Summary

Introduction

The nation's water resources are affected by human activities at multiple scales from urban communities to major river basins. Because of the impacts of these activities, the Corps of Engineers has ecosystem management and restoration projects that also span multiple scales, from urban streams to the Upper Mississippi River. However, technologies for system-wide assessments for sustainable and adaptive management at these multiple scales are not readily available.

The System-Wide Water Resources Program (SWWRP) is developing decision support systems to assist U.S. Army Engineer Districts and Divisions in management and ecosystem restoration decisions that need to be made at multiple scales. A listening workshop was held at the Engineering Research and Development Center, Vicksburg, MS on 22 June to solicit input from selected Districts on their needs, approaches, and desired attributes of a decision support system to assist in managing and restoring aquatic ecosystems. The agenda for the workshop is shown in Attachment 1 and the workshop participants are listed in Attachment 2.

SWWRP

The SWWRP goal is to provide the Corps and its partners with the capabilities to: 1) balance resource development with ecosystem requirements; 2) restore and manage water resources over multiple spatial and temporal scales; and 3) achieve environmental sustainability. To achieve this goal, SWWRP will focus on developing decision support systems that assemble and integrate the essential components of water resources management to: 1) transition from site-specific to holistic, integrated assessment and management; 2) apply current and improved approaches for forecasting system-wide outcomes of management; and 3) expedite alternative evaluation, trade-off analysis, and decision support across watersheds and basins.

SWWRP will build from District and Division input, experience, and approaches being used to address water resources and ecosystem restoration issues, including urban stream restoration in Philadelphia and Atlanta, redesigning reservoir withdrawal structures in F.W. Walter Reservoir to achieve downstream improvements, coastal restoration along the Gulf and Northwest Coasts, and restoration of the Upper Mississippi River basin. Workshop participants presented their on-going efforts, some of the issues they have encountered, and the scales at which projects are being conducted.

This white paper documents some of these projects, approaches, scales, and needs. It also provides a tentative approach for integrating this information within a decision-making context.

Spatial and Temporal Scales

On-going and proposed projects span the full range of spatial scales, from restoration of individual urban stream reaches in Philadelphia and Atlanta to restoration of the Upper Mississippi River basin in St. Paul and Rock Island Districts. Watershed projects are being conducted by nearly every District, and are a major focus for Albuquerque District. Both freshwater and coastal projects are being conducted, with Galveston, Fort Worth, and Seattle Districts involved with coastal restoration projects. Some of the ecosystem management and restoration projects include:

- Upper Mississippi River
- Navigation pool enhancement
- Backwater area restoration
- Wing dam/dike improvement
- Wetland enhancement
- Riparian habitat
- Seagrass restoration
- Shoreline protection
- Minnesota River
- Side channel improvement
- Island creation
- Wetland creation
- Wetland restoration
- Wet prairie creation
- Beach nourishment
- Forest enhancement

Time scales of concern in these projects range from episodic storm events on the order of hours and days to geomorphic time frames of decades and centuries (e.g., 100 year storm, stream channel formation). Seasonal and annual time scales also were pertinent for nearly every project discussed at the workshop. Time frames of interest include both historical periods of record, and future forecasts of land use/land cover and associated changes.

Management Endpoints and Objectives

Management endpoints ranged from endangered species to reduced phraeophyte stands and from “natural” downstream flow regime to sustainable upper Mississippi River islands and landscapes. Management objectives and management practices to achieve these endpoints include:

- Hydrologic modifications
- Water quality improvement
- Reduced soil erosion
- Restore native prairie
- Structural BMP implementation
- Mine land restoration
- Floodplain restoration
- Beach nourishment
- Sea grass replenishment
- Habitat alteration
- Revegetation
- Stream bank stabilization
- Reduced nutrient loading
- Non-structural BMP implementation
- Stormwater management
- Fish passage construction
- Wet prairie restoration
- Habitat protection/conservation

Tools and Tool Boxes

While there are clearly needs for additional models, there are also a number of tools that are already populating an ecosystem management and restoration tool box. Some of the existing tools that currently are being used by various District offices for ecosystem management and restoration include:

- HEC-RAS hydrologic model
- HEC 6 sediment transport
- FLO2D
- Regional Hydrologic Model
- CE-QUAL-W2
- ICM
- IBI
- HIS
- HGM
- HEAT
- GSSA hydrologic model
- HSPF watershed model
- RMA2
- Selected biotic species models
- CE-QUAL-RIV
- SIAM
- HEP/mHEP
- SAM
- URGWOM

Several of the presentations included not only tools that are currently being used, but also attributes that the Districts would like for both tools and a tool box. For example, Galveston District included a tool (modeling) “wish list” as part of their presentation:

- User friendly desktop interface
- Scalable ecological models (river reach to basin)
- Realistic field data requirements
- Interactive benefit/impact display
- Linkable/interactive models
- Auto-tracking changes and updates
- Nationwide standardization
- GIS Interactive models
- Quantitative/qualitative habitat valuation
- On-the-fly capabilities for design alternatives

In addition to these desired attributes, Jacksonville District indicated that the following models are needed to contribute to managing the South Florida Everglades ecosystem:

- Enhanced hydrologic models
- Vegetation succession models
- Biotic species/community model
- Restoration optimization model
- Landscape water quality models
- Soil/sediment transport/process models
- Landscape evolution models
- ET Tool

For the South Florida Everglades presentation, needs were expressed as a function of questions that are being asked and questions being asked are a function of restoration effort goals and objectives. The "needs" summarized here are very generic and not related to specific needs.

Decision Support System (DSS)

Decision Support Systems are being developed for use in management and policy decisions. St. Paul and Rock Island Districts discussed a DSS framework for the Upper Mississippi River while Seattle District discussed a PSNER NST framework for nearshore projects in Puget Sound.

The purpose of most DSSs is to assist managers and other decision-makers in making comparative analyses and assessments of various alternatives in both their near field, near-term, and in far-field, long-term effects. In addition, most Districts also want to use the DSS to assist with project design, prioritization, implementation, tracking, and management.

The general framework for the Minnesota River and Upper Mississippi River DSS is shown in Figure 1. The DSS would consist not only of a family of models, but also data and information needed to evaluate management decisions, including socioeconomic information. The DSS would permit evaluations and inventories of existing conditions, forecasting future conditions, and evaluation and assessment of management alternatives considering socioeconomic and ecological benefits and costs (impacts). The DSS would integrate watershed and both freshwater and estuarine aquatic models.

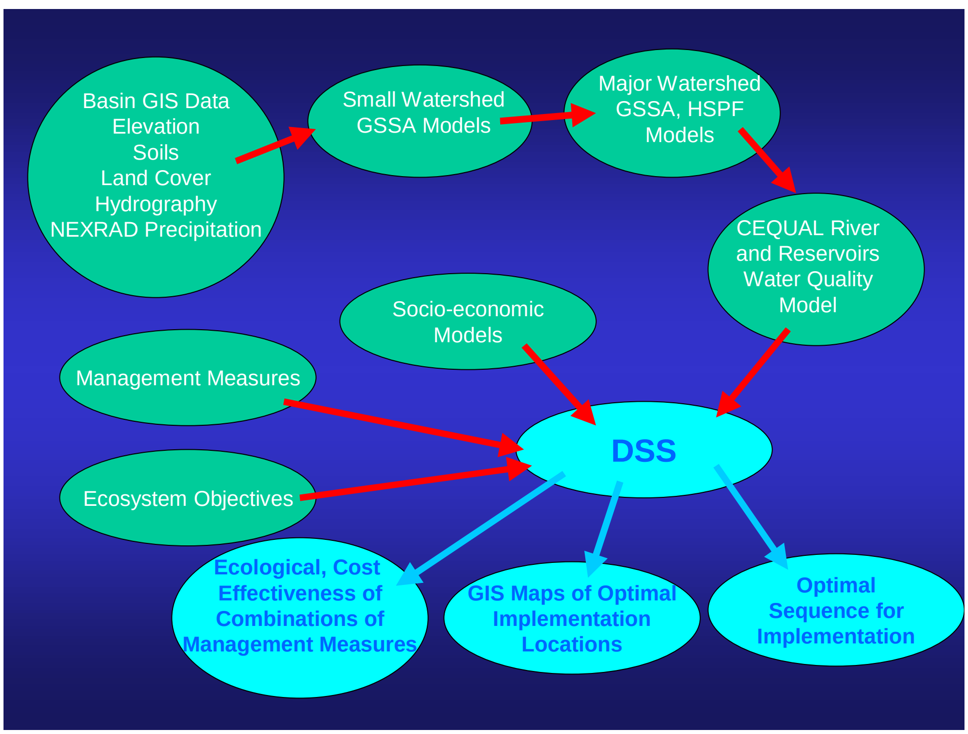

Figure 1. Upper Mississippi River DSS framework.

Seattle District is developing tools within a DSS framework that will contribute to analysis of spatial change over time, nearshore typology, valuing ecosystem components, tracking and managing multiple restoration actions over time, managing monitoring information, and seamlessly integrating project results both for reporting, and for strategic needs assessments.

Multi-Criteria Decision Analysis (MCDA)

ERDC scientists have been refining a process for using multiple criteria to assist in the decision-making process. Multi-criteria decision analyses have been used for over 30 years in making decisions within the electric power industry (Keeney and Raiffa 1976). MCDA provides a structured process for making decisions, integrates decision inputs, and permits trade-off analyses among objectives and alternative. Regardless of the decision, there will be some risk associated with each given alternative. MCDA permits these risks to be evaluated and compared among alternatives as well as the benefits. It is a robust method for predicting benefits, risks, and uncertainties associated with each alternative. In addition, it is fully compatible and complementary with DSSs.

Synthesis and Tentative Integrative Approach

The District presentations highlighted a number of ecosystems, objectives, issues, elements, approaches, and desired outcomes that must be considered in reaching decisions on which alternative management and ecosystem restoration practices to implement for projects at multiple scales. These presentations clearly showed Districts have projects with multiple time and space scales (e.g., specific backwater improvements in Navigation Pool 18 within the Upper Mississippi River restoration project; seasonal water quality changes within a reach and associated vegetation successional patterns over a decade). These presentations also indicated the depth of thought and effort that has already gone into addressing multiple-scale issues associated with projects. The challenge for SWWRP is to build on this knowledge base, complement these efforts, and inject additional science and engineering into the decision-making process. A tentative approach is shown in Figure 2 and discussed below.

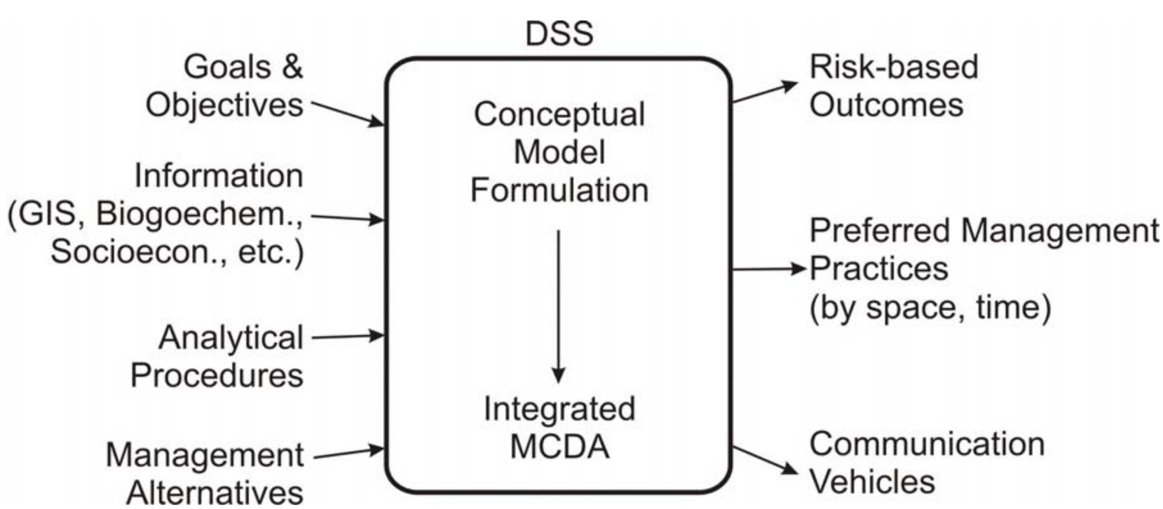

Figure 2. Possible DSS framework for SWWRP.

Risk-based approaches for decision-making have been used for over 30 years in assessing potential effects of policy and management actions on human health. Over the past 15 years, ecological risk assessment procedures and protocols have been developed, albeit, not to the extent of human health risk assessment, but there is a framework and protocols. In general, decision-makers have greater intuition and comfort with risk than with uncertainty.

Risk-based approaches for decision-making offer several advantages: 1) they indicate to everyone – managers, decision-makers, and the public – that there is risk (uncertainty) associated with the decision; 2) they provide a contextual basis for individuals to make their own assessment and evaluation of options, regardless of whether they are risk-takers or risk-averse; and 3) they permit relative comparisons among the costs and benefits associated with different options. Building a decision support framework on the foundation of risk analysis or assessment has appeal. In addition, this is both an active area of research, and an area where additional research at larger scales would significantly benefit Corps of Engineer projects.

Conceptual models should be considered an integral part of any ecosystem management or restoration project, for several reasons. First, conceptual models illustrate the linkages among not only ecological, but also socioeconomic endpoints, indicators, stressors, and sources. Conceptual models are formulated around the desired socioeconomic, ecological, and management outcomes. In some cases, these desired outcomes might not be quantitative (e.g., aesthetic appeal). In such cases, conceptual models can be used to link quantitative indicators to the desired qualitative outcome so the measurement endpoint is clear. Second, the linkages in conceptual models represent the risk hypotheses related to the ecosystem of interest, and, therefore, are part of the risk-based foundation for decision-making. Third, Aristotle stated the mind thinks in pictures. Conceptual models are representative pictures that are useful for conveying information to decision-makers and the public. Even if quantitative linkages cannot be made among some of the endpoints and indicators, the picture shows the linkages. Finally, conceptual models can identify which indicators and processes are important in influencing system response, which models might be needed to evaluate project alternatives, how these models should be linked or coupled, and how the results from model simulations relate back to the desired endpoints.

Conceptual models can also help decision-makers and the public understand hierarchical relationships of scale, and the interrelationships among social, economic, and ecological factors and indicators. Each of the Districts mentioned the multiple scales that are associated with many of their projects and the desire to be able to evaluate results from a river reach scale to the watershed and basin scale. Conceptual models have been used to describe some of these hierarchical linkages (See Gunderson and Holling 2002). Not only does ERDC have a template for conceptual model construction, conceptual models were included in some of the DSSs proposed by the Districts, so their use is already incorporated in some projects.

A tool box with suites of tools, rather than just a few tools, was desired by the Districts. While dynamic models were the primary tools discussed at the workshop, several districts did indicate that empirical models were not only useful, but being used as part of several projects. Attention will be needed to ensure that consideration is given to the compatibility of model time and length scales when linking models to address environmental problems, not only hierarchically, but also within ecosystems. The example previously given of water chemistry model predictions at daily time steps coupled with vegetation succession models using seasonal or annual time steps, highlights one potential incompatibility among time and spatial scales in tools used in District projects.

In addition to dynamic and empirical models, it is suggested that order of magnitude estimates (OME) or back of the envelope procedures be included in the tool box and used in virtually every project. These OME procedures produce results that are usually within 2-5 times of the actual measured value, and help bound both procedures and results for managers and the public (Fischer et al. 1979). Weight of evidence approaches, if not explicit, are implicit in any decision framework. Using OME and empirical models to complement dynamic models is not only cost-effective, but provides collaborative and corroborative insight into dynamic model output. If there is divergence among estimations from OME, empirical, and dynamic models, greater attention needs to be paid, not only to the estimation approaches, but also the risk hypotheses and conceptual understanding of how the system functions.

The use of physical-based models in engineering studies is well founded. However, the “soft sciences” econometric, psychometric, and sociometric models, such as structured equation models (path analysis), logistic regression, and changepoint analyses, have been used to directly test physical, chemical, and biological data relationships. Greater use of these analytical procedures should be considered, particularly for larger scale systems. In addition, these analytical procedures were developed to incorporate economic and social indicators relevant for decision-making. Every DSS framework presented at the workshop included socioeconomic indicators. Incorporating these analytical models in project analyses might enhance the capability of integrating socioeconomic indicators with biogeophysical indicators from the “hard” sciences.

The general architecture, and elements, of a DSS has been developed for the Upper Mississippi River. In addition, DSS frameworks have also been considered by other Districts. Building on this architecture should streamline the process of SWWRP moving toward a DSS that can be applied to multiple projects at multiple scales. In general, the tendency is to populate these frameworks with desired tools and spatial analysis capabilities as the next step. As illustrated by the DSS structures already formulated by the Districts, the first step in decision support is to ensure the goals and objectives are clearly articulated; that performance or success criteria have been developed; that conceptual models have been formulated that identify the relevant processes and indicators; and that these conceptual models are clearly linked to the goals and objectives of the projects, as well as the stressors/sources that need to be ameliorated or managed to achieve the desired outcomes; and that a preliminary set of alternative structural and non-structural management practices have been identified. Without this context, determining which analytical tools are needed to evaluate alternatives is a shot in the dark.

Embedding multi-criteria decision analyses within these DSSs would help provide both structure and approaches for incorporating risk, uncertainty, and trade-off analyses in the system. While DSSs are clearly the desired approach for decision-making for Districts because of the range of project scales (e.g., from individual sites and river reaches to entire watersheds and basins), DSS development is a long-term process and will require a long-term commitment if these systems are to reach fruition. Simply having the DSS and MCDA framework will contribute to improved decision-making as these DSSs are developed and implemented. The key will be to avoid "magic-bullet" thinking that one DSS or one modeling platform will provide the Corps with *the* approach for managing and restoring ecosystems.

Finally, these projects need to be implemented through active adaptive management. Unfortunately, adaptive management has become a phrase that can mean anything to anyone. Interestingly, it is really nothing more than good engineering practice – know what you are trying to accomplish, establish your design and performance (success) criteria, build it, and monitor its performance to see where engineering modifications might be required.

In active adaptive management, management actions are conducted considering explicit hypotheses and associated monitoring protocols. As noted above, the hypotheses are incorporated into the conceptual model as risk hypotheses. In addition, these hypotheses can be related directly to the project goals and objectives, and desired outcomes. Post-implementation monitoring is critical! This is the Achilles heel for many Corps projects. In many cases, there are no funds allocated for post-implementation monitoring, or these funds are diverted after a year or two of monitoring. We know of no other way of assessing the effectiveness of management practices than monitoring. The conceptual model identifies the information and indicators needed to evaluate and assess project performance, and time and length scale considerations help define appropriate frequencies and locations for monitoring specific indicators, so the monitoring program design and implementation should be relatively straight-forward.

Time and length scale analyses will be conducted based on the ecosystems, objectives, issues, elements, approaches, and desired outcomes discussed by the various Districts at this listening workshop. These analyses will help guide model integration, not only across project scales (e.g, river reach to river basin), but also within ecosystems (e.g., chemical processes with biological processes). In addition, several other elements identified at the workshop will be considered, including: conceptual model formulation based on risk hypotheses, with examples; multi-criteria decision approaches; and large scale adaptive management examples, such as the Glen Canyon Dam Adaptive Management Program.

Citations

Fischer, H.B., C.J. List, R.C.Y. Koh, J. Imberger, and N.H. Brooks. 1979. Mixing in Inland and Coastal Waters. New York. Academic Press.

Gunderson, L.H. and C.S. Holing, eds. 2002. Panarchy: Understanding Transformations in Human and Natural Systems. Washington, DC. Island Press.

Keeney, R.L. and H. Raiffa. 1976. Decisions with multiple objectives. New York. Wiley Publishers.

Attachment 1 Workshop Agenda

Challenges in Ecosystem Modeling and Decision Making
June 22, 2006

0830 Introductions
0845 Workshop Overview - Ashby
0850 Overview of SWWRP - Ashby
0900 Field input and discussion – presentations by Dan Wilcox (MVP) and Hank DeHann(MVR)

1000 Break

1015 Field input and discussion – presentations by Shawn Komlos (SAJ), Seth Jones (SWG), Brian Zettle (SAM), and Becky Griffith (SWF)

1200 Lunch

1315 Field input and discussion – presentations by Heather Jensen (NAP), Jeff Dillion (NWS), and Ondrea Hummel (SPA)

1445 Break

1500 MCDA Overview – Todd Bridges (ERDC-EL)
1530 Discussion (needs identified, next steps, opportunities for collaboration

1700 Adjourn

Attachment 2 Workshop Attendees

Name	Organization
Steve Ashby	ERDC-EL
Brian Zettle	SAM
Hank DeHaan	MVR
Drew Miller	ERDC-EL
Elly Best	ERDC-EL
Todd Bridges	ERDC-EL
Barry Bunch	ERDC-EL
Ken Pathak	ERDC-ITL
Kent Thornton	FTN Associates
Christina Laurin	FTN Associates
Jeff Dillion	NWD
Ondrea Hummel	SPA
Antisa Webb	ERDC-EL
Becky Griffith	SWF
Alison Sleath	ERDC-CHL
Jane Smith	ERDC-CHL
Dave Soballe	ERDC-EL
Morris Mauney	ERDC-EL
Heather Jensen	NAP
Earl Edris	ERDC-EL
Barry Payne	ERDC-EL
Andrea Catanzaro	SWG
Jan Stokes	SWG
Seth Jones	SWG
Shawn Komlos	SAJ
Dan Wilcox	MVP
Mark Dortch	ERDC-EL
Scott Jackson	ERDC-EL