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Plans for the Land Management System (LMS) Initiative

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The Land Management System (LMS) is an initiative of the U.S. Army Engineer Research and Development Center (ERDC) to address technology requirements related to land and water resource management in both military and Civil Works mission areas. The purpose of LMS is to provide relevant tools and information to land and water resource managers and decisionmakers to enhance their ability to understand and communicate past, current, and potential impacts of management decisions.

This report provides details of plans to design, develop, and transition LMS as an integrated computer-based capability, and to test and evaluate this capability for solving specific land and water resource management problems at field sites.

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Foreword

This study is being conducted for the U.S. Army Corps of Engineers Research and Development Directorate (which established the Land Management System [LMS] Special Project Office in March 1997) under Congressional Project Number 212040622720A917, "Computer-based Land Management System," Work Unit BJ9, "LMS Management." The proponents are Dr. Lewis E. Link, Director of Research and Development for the U.S. Army Corps of Engineers (CERD-Z) and Dr. Donald Levernz, Deputy Director of CERD.

The work is being performed by the LMS Special Project Office, which is a virtual organization established within the U.S. Army Engineer Research and Development Center (ERDC) to plan and direct the development of LMS. Mr. William D. Goran, located at the Construction Engineering Research Laboratory (CERL) in Champaign, IL, is the LMS Director; Dr. Jeffery Holland of the Coastal and Hydraulics Laboratory (CHL) and Dr. John Barko of the Environmental Laboratory (EL), both located at the Waterways Experiment Station in Vicksburg, MS, are the Associate LMS Directors. All members of the LMS Development Team helped draft and/or review the plans in this document. This team includes Dr. Tom Hart and Mr. David Mathis of CERD, Mr. Andrew J. Bruzewicz of the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Mr. Joseph Swistak of the U.S. Army Topographic Engineering Center (TEC), Dr. Windell Ingram of the Information Technology Laboratory (ITL), and Mr. Arlen Feldman of the Hydrologic Engineering Center (HEC) and Mr. Darrell Nolton of the Institute for Water Resources (IWR), both elements of the Water Resources Support Center (WRSC). The ERDC technical editor was Gloria J. Wienke, Information Technology Laboratory.

The Director of CERL is Dr. Michael J. O'Connor.

Executive Summary

The Problem

Managing land and water resources has become an increasingly difficult and challenging task. Federal land and water resource managers face many new legislative requirements; inputs from increasingly sophisticated and often conflicting interest groups; and demands to accurately predict and evaluate the costs, benefits, options, and potential short term, long term, and cumulative consequences of any proposed management action. In particular, the Department of Defense's (DOD's) Civil Works and military land management challenges encourage the development of integrated modeling/decision support technologies capable of predicting the environmental quality impacts of anthropogenic activities, including evaluation of alternative management decisions, on the landscape/ecosystem. DOD's land management challenges include the need to:

- Integrate multiple uses of land and water resources
- Sustain mission use of training and testing ranges
- Clean and rehabilitate contaminated sites
- Restore aquatic and upland ecosystems
- Manage noise propagation
- Partner with stakeholders in ecosystem and watershed planning and management
- Evaluate proposed activities on wetlands (permitting)
- Manage coastal zone, watershed, and riverine resources
- Conduct dredging operations
- Assess chemical and biological threats and risk pathways
- Manage the nation's waterway in response to water supply, flood control, and navigation
- Respond to floods, hurricanes, tornadoes, and other emergencies.

These challenges are multi-disciplinary in nature and, in many cases, represent concerns applicable to the Departments of Interior, Energy, and Agriculture, the Environmental Protection Agency, and other agencies.

Current and emerging technologies offer many capabilities to help managers address these difficult demands. These technologies include geographic information systems (GIS), remote sensing, landscape process modeling and simulation, group collaborative forums and conferencing, expert systems, multi-dimensional visualization tools, decision support systems, and web-based data mining tools. Yet, these systems have only limited linkage with ecological modeling and decision support tools, and they lack the full interoperability needed to support the DOD land management decisionmakers. Thus, while there is great potential for these technologies to help land and water resource managers, they currently are disconnected pieces that need to be blended together into an integrated framework to achieve their highest productivity.

The Solution

The Land Management System (LMS) is an evolving development of the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) to design, develop, support, and apply an integrated capability for modeling and decision support technologies relevant to DOD (and other agency) management of lands, seas, and airspace. The concept for LMS is derived from extensive experience of the USACE laboratories in providing numerical models and computational systems to land and water resource managers at military (Tri-Service) installations, and Army Corps of Engineers Civil Works, Districts, and Divisions.

The first objective of LMS is to provide an integrated computational framework that brings together relevant science and technology to DOD land managers in a more complete and responsive manner. The framework involves focusing, shaping, and integrating existing science and technology (S&T) investments towards common approaches and objectives, and designing an evolutionary and scalable computational environment that accommodates computer-based technologies emerging from these S&T investments.

LMS is not a new funding line or program. Rather, it is a strategy to extend the value of existing diverse investments in S&T across the DOD by identifying clear paths for product development, avoiding duplicate investments in delivery systems, and strengthening the teaming between scientists and managers. LMS development represents a process for accomplishing these objectives, and a product that delivers iterations of the results of this process to users ranging from managers to range specialists to researchers.

The second objective of the LMS development is to maximize synergism between military and Army Civil Works technology initiatives. The USACE research laboratories serve decisionmakers at military Tri-Service installation facilities and Army Civil Works land and water resources projects. These different user communities operate from different appropriations, report through different chains, and serve different national needs. Although specific mission uses differ widely between these projects/installations, their specific resource management concerns are remarkably similar.

The third objective of the LMS development is to improve the timeliness and effectiveness of technology delivery into land management business processes. Investments in technology have traditionally experienced a long time lag between problem identification in the user communities and the infusion of new solutions that effectively address the problem in the user's business environment. There are many reasons for these time delays, and there is much variability in the timeframe between problem identification and delivery of the solution. Creating a common computational framework for land management decisionmaking that is applicable across differing (but related) user communities within DOD, will streamline and focus technology delivery by:

- Creating a common, single point-of-entry from which DOD resource managers can access the key technologies needed for land management and decision support;
- Developing a set of protocols for model-to-model linkage, and model-to-data connectivity, so that new technology investments in modeling and simulation, basic science, and information technology will seamlessly mesh with new data collection, assimilation, and management activities at the installation level; and,
- Establishing a technology base that, by design, will grow naturally as marketplace technology advancements (such as in GIS, networking, computing, and new basic science) occur. This, in turn, provides DOD with high-leveraged improvements at minimal cost to the warfighter.

The Approach

Development of the LMS involves four main components: (1) establishing the LMS Protocols, (2) developing a catalog/advisor for computer-based tools, (3) developing iterative versions of the LMS, and (4) conducting the LMS Field Applications Program. The LMS Protocols provide common procedures for linking existing computer-based tools and for developing new tools. The catalog provides a reference for tool seekers, advice on tool usage, advice on data suitability and tool combinations, and an interface to tool seekers and builders in other organizations. The LMS versions refers to a series of evolving software releases (starting with LMS 2000 in FY00) that provide an initial level of land management modeling and decision support capabilities to users.

The Applications Program relates to site-specific field-testing, validation, and implementations of LMS. Primary application sites are Fort Hood, TX, three Civil Works sites (Pool 8, Redwood Basin on the Minnesota River, and Peoria Lake) on the Upper Mississippi River System, and Marine Corps Air Ground Combat Center at Twentynine Palms, CA. The leaders of the application site teams serve as members of the integration team. The requirements for the application sites provide inputs to help frame LMS development priorities and as an immediate context to test and evaluate LMS capabilities.

A final key to the overall LMS development strategy is the focused, purposeful, technical partnering with other research organizations. This focused partnering provides for leveraging and acceleration of the best of external research and development while maintaining the requisite level of critical in-house mass to ensure that DOD is a “smart” technology investor.

The Benefits

LMS is designed to improve the capabilities and effectiveness of the DOD in both land and water resource management. The Corps of Engineers technology programs annually design and develop dozens of new tools and databases for land and water resource management. Traditionally these capabilities have been implemented in support of separate mission areas and designed as “stand alone.” By bringing all of these tools and databases together in a linked and interactive framework, LMS developers are providing the ingredients necessary for improved understanding and management of human activities on the landscape.

Within the framework provided by LMS, duplicate development of land management tools will be reduced. A development environment providing access to and information about all relevant tools and models for land management will be provided. This will combine the very best available both within the Corps and from users deciding to take advantage of the LMS approach. User access to and information about the tools and models will be facilitated by the catalog and model advisor. Finally, software development and maintenance costs will be reduced due to a common software framework using a single interface and providing linkages to relevant data and models.

This on-line version contains minor corrections to the printed version.

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1 Introduction

Background

The Land Management System (LMS) is an initiative of the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) focused on improving analysis and management capabilities in several of the USACE major mission areas. These mission areas include the U.S. Army Civil Works programs (navigation, flood control, water supply and quality, recreation, environmental restoration, etc.), military installations operations and management (specifically military land management), and military engineering and terrain-related operations (trafficability analysis, military hydrology, littoral operations, line-of-site analysis, etc.).

LMS is a consistent delivery framework for computer-based land and water resource management and analysis tools. It was established to provide delivery of the right information to the right place at the right time using an integrated approach to models, modeling systems, and decision support systems. Traditionally, development of individual models, linked models solving a set of related problems, and decision support systems has occurred in a piecemeal way, focusing on narrowly defined problems and problem sets. This piecemeal approach was necessitated by a range of constraints including limited computing power, insufficient understanding of physical processes and related biological responses, and the stovepiping of technology programs to address single problem issues.

LMS provides a cost-effective alternative to the traditional approach through development of a common, integrated framework providing solutions to land and water management problems. The LMS includes information about and access to all LMS environmental models and their data, assistance in selecting the most appropriate models to deal with a single problem or a suite of land management problems, the transparent movement of data between LMS models, and output supporting land management decisions through the evaluation of management alternatives. Access will be provided using commercial and government-developed software tools.

Initially, LMS will evaluate existing models, systems of models, and decision support systems. The first LMS built from these “legacy” (pre-existing) components will be expanded to include a growing collection of models developed both inside and outside the Corps through the adoption of protocols enabling their integration into a linked operating environment. In a parallel effort following ongoing industry-driven developments, new (and next versions of existing) models will be developed with links to evolving standards for data exchange.

Savings in cost and time will be realized through two major pathways: unique bridging software will no longer have to be written to enable the exchange of data between models incorporated into the LMS; and a common interface and display environment will eliminate the need to develop this portion of any new software. Programming efforts will be exclusively directed toward the computational portions of the new models and modeling systems.

LMS has its roots in a study initiated by the Director of Research and Development in the summer of 1995. This study evaluated current modeling and simulation research and developed a plan for land management modeling Research and Development (R&D). The study was, in part, a response to a report released in the summer of 1995 by the Defense Science Board on the Department of Defense's (DOD's) Environmental Security Program. The Board recommended expanding the use of modeling and simulation tools and techniques to evaluate DOD environmental problems. It further recommended DOD take a proactive approach to future conservation issues. The study was also responding to the desire of the Director of Research and Development to better integrate the Military R&D and Civil Works research on computer-based land and water resource management tools. An inter-laboratory team, led by Dr. Richard Price (Environmental Laboratory [EL]) and Dr. David Tazik (Construction Engineering Research Laboratory [CERL]), completed their study in the fall of 1995 and recommended the establishment of a land management modeling and simulation research program. Based on the recommendations of that study, the Director of Research and Development, in consultation with laboratory directors and others, established the LMS initiative.

A Special Projects Office for LMS was established in 1997 under the Director of CERL. A Director of Special Projects and two Assistant Directors, one for Systems Development and Integration and the other for Process Related Research directed toward land management, were designated. The Director, Assistant Directors, and the various representatives from most of the ERDC Laboratories, the Hydrologic Engineering Center, and the Institute for Water Resources, both elements of the Water Resources Support Center, and several Corps of Engineer Districts comprise the LMS Development Team. Researchers throughout the ERDC laboratories (and their partners) form project teams to perform specific tasks associated with LMS.

Objective

The objective of this report is to provide information on plans for the design, development, testing, evaluation, and sustaining support for LMS. These plans are to be used as a roadmap for the various teams and organizations working on LMS, and to help proponents, partners, and end users better understand LMS plans and processes. The design and development of LMS involves coordination of numerous efforts across many different programs and organizations. The plan describes how this coordination will be accomplished and what purposes will be served.

Approach

The Corps of Engineers Research and Development Directorate (CERD) established the LMS Special Project Office in March 1997, as a virtual team. The three individuals assigned to this office (Mr. William Goran, CERL; Dr. Jeffery Holland, Coastal and Hydraulics Laboratory [CHL]; and Dr. John Barko, EL) are from different laboratories, have historically worked in different program areas, and continue to report through different supervisory chains. Most of the specific tasks being performed under the LMS "framework" reflect this same virtual teaming structure. Since LMS relationships are matrixed into line management organizations, communication is essential across the virtual organization and up and down the line management structures of all the participants.

LMS touches program planning and execution processes across the Corps laboratory organization (and beyond) with the goal of bringing diverse efforts and participants into a coordinated framework. To accomplish this coordination, the LMS Special Projects Office has developed coordination processes and teams that address components of LMS. Figure 1 illustrates the relationships and members of different teams and tasks associated with LMS.

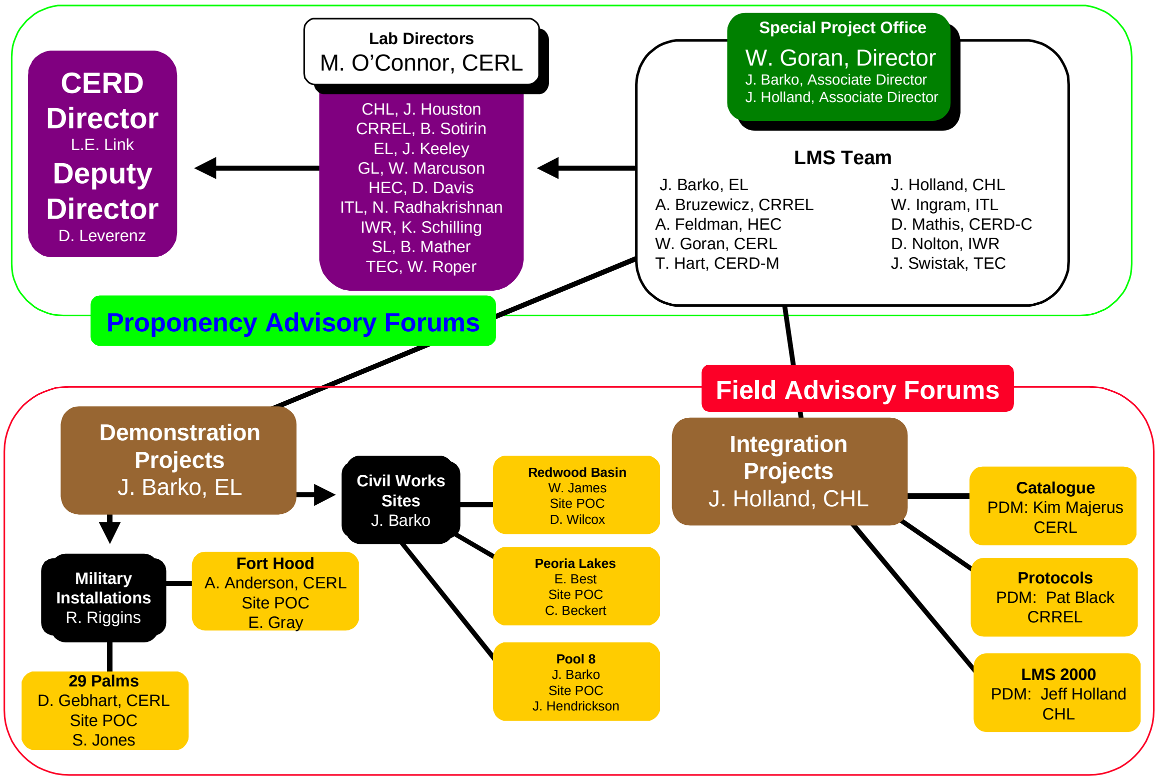


Figure 1. LMS organization approach.

Scope

The scope of this planning document is for the planning period of LMS, which extends over 6 years, to Fiscal Year 2004 (FY04). Information on LMS 2000+* (see Chapter 5) is focused primarily on near-term (FY99 and FY00) work efforts.

Information Access

LMS information is being provided through several different mechanisms. First, a series of videoconferences and workshops is being held to provide planning information and seek reviews and inputs to these plans from members of the ERDC workforce. Second, these plans are all being posted (and updated) on the LMS website listed on the following page. Third, there are in-progress reviews

* LMS 2000+ refers to the first version of LMS (to be released early in calendar year 2000) and the subsequent versions that will be released in later years.

conducted at the LMS field sites, and at many workshops held by ERDC staff with partnering organizations and agencies.

Frequent updates and revisions to this plan will be provided through the LMS public web listing (http://www.denix.osd.mil/LMS) under the Defense Environmental Network Information eXchange (DENIX). There is also a password-protected DOD site (http://www.denix.osd.mil/DOD/Working/LMS/lms.html) that can be accessed, under DENIX, by selecting the DOD menu, under the main menu, then selecting Working Groups. The title of the website is "LMS Working Group." You may obtain a password for DENIX through on-line registration, by selecting "registration" on the DENIX main menu (http://www.denix.osd.mil). You may also contact Kim Grein, commercial 217-373-6790, FAX 217-373-7270 to obtain a login for DENIX. Figure 2 shows the LMS Work Group web listing. Special features include the events calendar and the discussion forum. Technology transition is discussed in more detail in Chapter 8.

Figure 2. LMS Public web listing.

2 LMS Objectives

Managing land and water resources has become an increasingly difficult and challenging task. Over the past few decades, Federal land and water resource managers have faced many new legislative requirements; inputs from increasingly sophisticated and often conflicting interest groups; and demands to accurately project and evaluate the costs, benefits, options, and potential short term, long term, and cumulative consequences of any proposed management actions. Current and emerging technologies that offer many capabilities to assist managers in addressing these difficult demands include: geographic information systems (GIS), remote sensing, landscape process modeling and simulation, group collaborative forums and conferencing, knowledge-based systems, multi-dimensional visualization tools, decision support systems, and web-based data mining tools. While there is great potential for these technologies, through applied science, to help land and water resource managers, they currently are disconnected pieces and parts that need to be blended together into an integrated framework in order to be most effectively used by resource managers and decisionmakers.

Across the DOD, millions of dollars are being invested annually, from both R&D and operational accounts, on improved landscape process understanding; on the design, development, enhancement, testing, or application of numerical models that represent specific landscape processes; and on the development of systems that facilitate decision support relating to military installation or Army Civil Works resource management. But these investments are widely scattered and the results frequently are used by only a few land and water resource managers, which greatly decreases the overall benefits from the investments. By providing a clearly identified development framework that meets a wide variety of DOD needs, and by coordinating implementation across DOD, LMS will help shape and focus these investments, and ensure that they work as part of a common system.

DOD's land management challenges include the need to:

- Integrate multiple uses of land and water resources
- Sustain mission use of training and testing ranges
- Clean and rehabilitate contaminated sites
- Restore aquatic and upland ecosystems
- Manage noise propagation

- Partner with stakeholders in ecosystem and watershed planning and management
- Evaluate proposed activities on wetlands (permitting)
- Manage coastal zone, watershed, and riverine resources
- Conduct dredging operations
- Assess chemical and biological threats and risk pathways
- Manage the nation's waterways in response to water supply, flood control and navigation
- Respond to floods, hurricanes, tornadoes, and other emergencies.

LMS objectives to assist with these challenges are listed in the following paragraphs.

Objective 1. Design, develop, and demonstrate a comprehensive system/framework for more adaptive and effective land management decisionmaking.

The goals of Objective 1 are:

- To continually enhance the capabilities of the Corps of Engineers and DOD land and water resource managers/analysts with a comprehensive set of models, data, and analysis tools that are evolving as the underlying information technologies and landscape process sciences evolve.
- To provide a consistent context for customers to receive products from their technology investments.
- To decrease the time and costs required to bring new technologies to customers (by eliminating the need for customized delivery mechanisms and supporting tools for each new technology).
- To facilitate effective leveraging of technology investments and the applications of technology assets and investments to all potentially relevant issues.

Objective 2. Maximize the synergism and extend the value of R&D programs and expertise to Civil Works and military land management.

The USACE research laboratories serve military installation facilities and land use managers and Army Civil Works land and water resource managers. These different user communities operate using different appropriations, report through different chains, and serve different national needs. While mission use of resources differs widely, resource management concerns are similar between installation and Civil Works land and water resource managers, as illustrated in Figure 3.

While the USACE laboratories extend technical expertise and capabilities across both these domains, LMS is an explicit effort to maximize synergism between technical investments supporting installation land managers and Army Civil Works land and water resource managers. While programmed funding streams still are separate, LMS planning straddles these domains, and LMS products and expertise will serve both military and Civil Works user communities.

Objective 3. Improve the timeliness and effectiveness of delivery of technology into the land management business processes, both Civil Works and military.

Investments in technology often have a long time lag between problem identification by user communities and the infusion of new solutions that effectively address the problem in the user's business environment. There are many reasons for these delays, and much variability in the time between identifying the problem and delivering the solution. With LMS, the USACE laboratories are implementing a more integrated approach to the technology development, testing, integration, and delivery processes.

Army Civil Works 24 Million Acres	Military Installations 25 Million Acres
Managing Rivers, Reservoirs, Harbors, Coastlines, Watersheds	**Managing** Training Areas, Testing Ranges, Installations
Sustaining Mission Use Integrated Use Planning Cleanup of Contaminants Managing erosion & sedimentation processes Protecting sensitive species & sites Preserving biodiversity Involving stakeholders	Sustaining Mission Use Integrated Use Planning Cleanup of Contaminants Managing erosion & sedimentation processes Protecting sensitive species & sites Preserving biodiversity Involving stakeholders

Figure 3. Resource management concerns of installation and Civil Works land and water resource managers.

Specific Solutions with General Applicability

LMS products will first be designed for testing at selected field sites. These sites are selected because they have significant land management challenges that typify general land and water resource management challenges across DOD, and because they have resource managers with expressed interests in working with the LMS team and helping to guide the development of the LMS products. The LMS team works with these resource managers to define management objectives, required scientific knowledge, and management tools and processes needed to reach these objectives. These efforts result in a field site plan, which then influences the direction and focuses on appropriate contributing research, demonstration, and operational management activities and programs, and helps set priorities for the LMS framework. The LMS Integration Team (see Figure 1) designs this framework consistent with DOD guidelines and policy — but assures the value, applicability, and utility of the products within this framework by testing, modifying, and integrating them at the demonstration sites to meet land and water resource management needs.

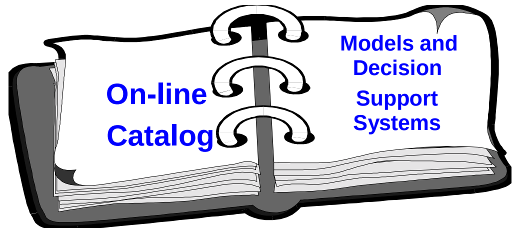
Blending Science and Management

As the challenges to land and water resource management intensify, resource managers need answers and solutions that are designed to fit directly into their business processes. To provide such solutions, technology developers and managers need to work together. The LMS field teams provide this partnering. The teams focus and shape science investments to meet needs expressed by resource managers, and then translate the results of these science technology investments into solutions and products that fit (and sometimes help shape) the managers' business process.

Industry Solutions

The LMS framework is being built with state-of-the-art foundational blocks. Whenever appropriate, these blocks are commercial off-the-shelf (COTS) software. Commercial geographic information systems (GIS), database management systems, web browsers, and collaborative tools are key components of the LMS framework. The LMS team is partnering with industry to help shape and extend commercial capabilities in areas where current commercial products require improved linkages or capabilities. Efforts are being made to work with industry consortia, and to avoid vendor-specific development approaches, although some LMS solutions may require tight coupling with specific vendor products to meet certain user requirements.

3 Catalog/Advisor



Background

Continuing rapid developments in advanced digital technologies have proven highly beneficial in supporting decisionmaking and planning for land and water management. In particular, simulation models and decision support systems have become an integral part of these activities. It is often difficult, however, for the land manager to be aware of the full gamut of available environmental simulation models that might be applied to a given situation. The LMS Catalog/Advisor provides an online catalog of available solutions fully documented with both technical and scientific details. With the catalog in place, the user will be better able to locate and assess potential models and the producers of the models will have a standard framework to follow in documenting and disseminating the models they produce.

A prototype web-based catalog has been developed that offers users dynamic, on-line access, browse, query, and output capabilities. Additionally, this tool provides a mechanism for gathering information from users across the Internet through on-line information input and data entry. In this manner, both browsing and data entry are possible from remote network locations to support population of and browsing of an on-line catalog of information. The information gathered and accessible through the existing prototype version of the catalog is listed in detail in the Appendix.

The information gathered about the models and technologies draws upon several sources including: a compilation of models and technologies prepared in the early phases of the LMS initiative, the report prepared by the U.S. Department of Agriculture (USDA) Forest Service about decision support systems for ecosystem management (U.S. Forest Service General Technical Report RM-GTR-296, 1997), standard information contained within U.S. Army Corps of Engineers Public Affairs Office “Fact Sheets,” and a workshop to refine catalog information that involved the principal investigators for this project. The catalog/advisor effort will be expanded over time in both content and functionality.

The types of computer-based technologies compiled within the prototype version of the online catalog include:

- predictive computer models
- computer simulation technologies
- applications that link technologies such as GIS, relational database management systems (RDBMS), and graphical user interfaces (GUIs)
- development environments for computer modeling and simulation
- dynamic integrated frameworks for computer interoperability
- computer applications built upon a GIS backbone
- decision support systems.

Refinements and Enhancements

The on-line catalog provides search and retrieval functions that specifically match user needs and tasks. Future efforts will enhance the functionality defined for the on-line catalog to include an “advisor” that will guide users toward information to help them both select and understand the appropriate models and databases with the best potential to satisfy their specific requirements.

The following example illustrates one potential way to use the on-line catalog and advisor. In this example, DOD personnel are responsible for an environmental impact statement (EIS) for a construction action at a DOD site. Priority environmental issues at this site include surface water movement and potential flooding, soil erosion and sedimentation, and endangered species habitat disturbance. The user browses the web-based catalog, conducts queries, and is guided by the on-line advisor to identify computer technologies that are most relevant to the environmental issues for the ecosystem(s) at the site.

The on-line catalog guides the user to a list of available computer models and simulation technologies including hydrology and hydrodynamic simulations, soil erosion prediction models linked to geographic information systems, simulations of sedimentation, and GIS-based endangered species population models. The user proceeds, guided by the on-line advisor, to further focus on the appropriate models that best match the EIS tasks. The advisor directs the user from the original list of potentially relevant models to a more concise list of models that match the EIS requirements. The on-line catalog/advisor provides the user with further details about the data needed to use the models best suited to EIS needs. Other examples of this on-line catalog/advisor technology include preparation of an integrated natural and cultural resources management plan, conducting computer-based “what if” scenarios to evaluate land management alternatives, decision support to balance multiple long-term objectives, and developing a watershed or ecosystem approach to sustaining the mission.

Further refinement and modification of the on-line catalog is underway and will continue to match the needs of a variety of DOD users and missions. Future enhancements to the functionality of the on-line catalog will provide additional browsing, searching, and reporting capabilities. As development continues, the advisor will further guide users toward the information technologies that best match their requirements and their site data sources. Figure 4 illustrates the advanced functionality for the catalog/advisor.

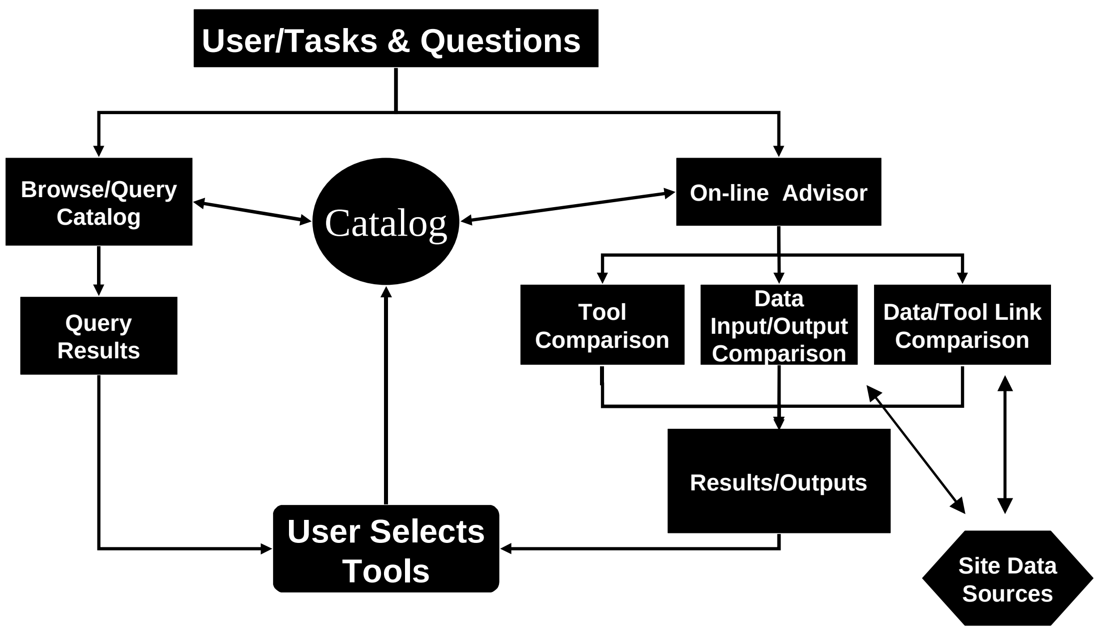


Figure 4. The on-line catalog with future functionality for the advisor.

4 Protocol Development and Implementation Process

Why LMS Protocols?

The term protocol is used in the computing community to mean a procedure for transactions or communications between two or more entities. Examples would include packets of data being exchanged between two modems or files being exchanged between two software programs. LMS protocols have two objectives: (1) interoperability between computer-based tools, models, and decision support systems, and (2) improved representations of landscape processes and dynamics, especially those involving multiple landscape analysis domains (e.g., hydrology, ecology, noise propagation, socioeconomic) that interact and experience feedback from each other over time and space. Both of these objectives can help improve the efficiency, accuracy, and value of landscape management and analysis decisions.

LMS protocols provide a basis for efficient development and application of models. They offer the model developer and user a common framework to promote reuse and interoperability of models and databases. Users and developers want landscape process models and decision support tools to fit together seamlessly without requirements for specialized code and procedures.

Users and developers also want landscape process representations to use procedures that facilitate process interactions between tools. This is a critical step in advancing our understanding of landscape phenomena. Conventional tools generally work in sequential isolation, with no opportunity for process dynamics to be altered during a process run. Data are input to a process model, the model is run, then results are exported from this model to yet another model or geospatial system. But landscape processes dynamically interact across multiple processes and domains. As an example, man-induced effects within watersheds (such as military training, forest clearing, or suburbanization) affect vegetative cover in these areas. These effects, in turn, modify both runoff patterns from storm events and the associated erosion and sedimentation on the landscape and its receiving waters. These altered hydrologic patterns, coupled with ongoing man-induced effects, provide feedback to vegetative growth and diversity, thereby again affecting hydrologic runoff and erosion/sedimentation. Protocols for these model-to-model exchanges can help achieve more accurate process representations in models and decision support environments. Ultimately, the protocols will help to evolve common elements in future visions of how to represent and analyze landscape dynamic processes, thereby driving the LMS framework for future technology investments.

What are the Components of the Protocols?

The LMS protocols must be scalable and evolutionary. That is, the protocols must operate at multiple levels and they must be designed to help shape and respond to the changes in technology (advances in COTS, hardware, networking, user interfaces, geospatial and temporal data models, and environmental quality modeling and simulation) that will affect LMS. Five levels of protocols have been established for development, with each level defined as follows:

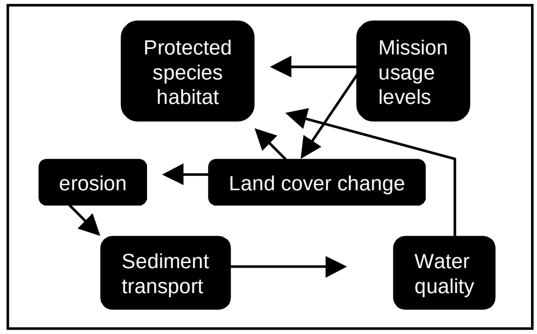
Level I -- Registration

Level I involves identification of landscape-related computer-based tools and a common set of data (metadata) about these tools. The LMS team is encapsulating this information in the catalog/advisor. A first version of this catalog has been created and populated with numerous tools. A second component of this protocol level is the model analysis, comparison, and “advisory” potentials of the catalog. These analysis functions will help inform users of more advanced levels of the LMS, and will provide direct assistance to land managers in evaluating the applicability/limitations of differing computational tools and data inputs needed for specific land management problems.

Level II -- Shared Assets and Procedures

Level II includes creating linkages for access to common or shared resources (e.g., network computing or database assets) and linkages between systems and tools (e.g., linkages with legacy systems, linkages with COTS and government off-the-shelf [GOTS]). Essentially, this protocol level relates to interoperability of systems and input/output across these systems. The level must have multiple degrees of sophistication to empower the LMS, and to evolve as interoperability options evolve. Note that developments at this protocol level will strongly engage both the COTS community and legacy system developers/maintainers.

Level III -- Linkages Between Processes



Level III relates to how data are exchanged between processes/models, and how these processes/models work together. At this level, the exchanges are still sequential, rather than synchronized and dynamic. These linkages are necessary to develop suites of tools that address specific problems, so there will be multiple suites of compatible tools that are "level III compliant"; however, because different tool suites may house different models, there may not be full compliance between suites of tools at this level. Another issue to examine at this level is interaction between tools with different data models (e.g., raster versus vector data models).

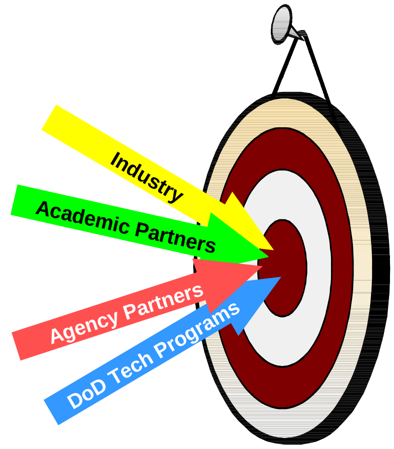
Level IV -- Dynamic Linkages Between Processes

At Level IV, data are not just serially exchanged between computer-based tools, but the tools dynamically interact with model-to-model feedback. For example, changes in a watershed (e.g., insertion of an erosion control structure or the effects of military training on vegetative cover) have a dynamic effect on sediment loading into the local receiving waters. The resulting erosion/sedimentation patterns subsequently affect vegetation, which together affect hydrologic runoff patterns in the watershed. The effect is not sequential but fully coupled, thereby requiring seamless model-to-model interactions. An important focus of this level is capturing dynamics across domains that are traditionally isolated (as a result of computational tools normally growing from specific knowledge disciplines and management stovepipes) in a cohesive, integrated framework.

Level V -- New Paradigm

Level V is an evolutionary target that will influence the future development of new technology. The primary purpose of this level is to focus future technology investments toward a fully interoperable modular land management decision support environment that grows naturally as new marketplace and scientific advances are made. This level not only supports dynamic and synchronized interactions between tools, but it is an environment where landscape features, actions, relations, and processes are available as reusable components to address specific user-defined issues.

How Will the Protocols be Developed?



The protocol levels represent a conceptual framework for the development process. The LMS development team will build on the work of many communities of experts to aid in drafting, reviewing, revising, evaluating, and testing these protocols. These communities include: (1) landscape-related computer-based tool developers, (2) legacy and new system developers, maintainers, and users, (3) commercial technology providers, such as GIS vendors (primarily through consortia such as the Open GIS Consortium), the Tri-Service CADD/GIS Technology Center, and the HQUSACE Architecture 2000+ initiative, (4) technology program managers and advisors who influence the output requirements from landscape-related technology programs, and (5) information technology and standards organizations within USACE and across the participating services and agencies that will weave these protocols into their business processes.

There will need to be a highly structured process for protocol management so that all participants in the process can easily read the current protocol and react to both the protocol and to comments about the protocol. Two primary steps will be taken to accomplish this: (1) the assignment of a protocol manager, who will keep track of versions, synthesize comments, and ensure that all voices are included in the process and (2) the protocol manager will use web-based collaborative tools to publish protocols, manage review comments, solicit interactions between commenting individuals, and keep records of the entire process.

To manage this process, the LMS development team will develop a set of draft protocols for each protocol level. These protocols will be reviewed at a series of meetings that engage the above communities in order to evaluate the protocol procedures from different perspectives.

After the initial protocol drafts and reviews, the protocols will be published in forums beyond the website that enable scientific peer review. Publication will help ensure that the protocols get wide exposure and critical review from the appropriate science and information technology communities. Presentations will also be given at multiple organizational and scientific forums to enhance wide exposure and critical review.

As the protocols are being reviewed, they will also be tested through application in the LMS 2000+ (see Chapter 5) and subsequent LMS versions. LMS versions and applications at LMS field sites will provide critical testbeds for the LMS protocols. Feedback from these testbeds (which should be mirrored by partnering organizations) will help the protocols evolve and will facilitate the credibility needed for their use and acceptance by wider user and regulatory communities.

What's the Relationship Between LMS Protocols and Architecture 2000+?

The LMS protocols should reflect the vision of the Corps of Engineers Architecture 2000+ plans. The protocols may provide an opportunity to interweave the Architecture 2000+ plans across the Corps of Engineers computer-based tool development processes. While the specific application of the protocols is related to LMS-specific domains (land and water resource management concerns), many aspects of these protocols will be much broader in potential application. Thus, the Information Management and Information Technology communities within the Corps should have a key role in the development and implementation of these protocols.

5 LMS 2000+

How Will LMS 2000+ Be Organized?

LMS 2000+ is a web-based modeling system that will make technical capabilities, expertise, and technical information readily available to the DOD user community in support of land management. The system is organized with four levels (user, modeling, data, landscape process science), each with a suite of functions, all accessible through a web-empowered user interface from the user's desktop computer. A general description of the capabilities to be delivered within each LMS level over the system's proposed 6-year development life cycle is provided in Figure 5.

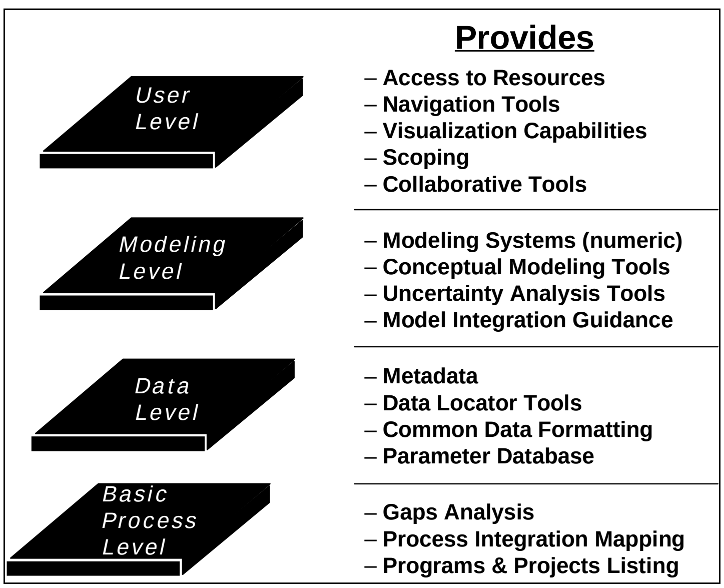


Figure 5. LMS design levels.

User Level

The User Level is the entry point for the LMS user to all LMS services, both local to the user's machine and on various other servers/computing platforms to which the user has access. The focus of this level is the web-based, network-empowered, human/computer interface to the LMS (hereafter referred to as the user environment). This environment is the one the user will conduct all LMS activities within, and from which all LMS services will be provided. The user environment will have a single, consistent look and feel on personal computers running Windows 95, 98, and NT and on UNIX workstations running X-Windows. The user environment will be developed based on a combination of marketplace standards (commercial-off-the-shelf browsers, Java, Windows, etc.) to ensure its portability and to increase its natural maturation.

Modeling and Simulation Level

The Modeling and Simulation (M&S) Level houses the suite of modeling tools, from simple screening tools to highly advanced, three-dimensional models. Standard linkages and projection methods will be developed to allow M&S results to interact seamlessly (e.g., hydrology models and sediment models). Dynamically coupled modeling technology will be used when required by the landscape processes being simulated. An ongoing evaluation of applicable technology within and external to USACE will be performed to ensure that the best of available M&S is brought into the LMS suite. New models will be developed based on requirements from users, stakeholders, and from those needs arising from the LMS field applications.

Data Level

Research and development for the Data Level will key on standardization of the gathering, harmonizing, quality control (including automated flagging of questionable values), management, and manipulation of data from multiple sources (including network servers, remotely-sensed data, and real-time data such as weather radar). Parameter databases for the M&S suite within the LMS will be developed. Standards for model metadata, data interchange between databases and GIS, and linkages to remotely sensed and real-time data will be used as available or proposed as needed. Significant partnering and leveraging, particularly through inter-agency coordination groups and with private industry, will be conducted to expand the range of investment in this level.

Basic Process Level

There are numerous processes for which significant knowledge gaps exist that are of importance in DOD land management activities. Such gaps currently include, for example, various processes important for modeling and simulating ecologically important relationships among erosion, sedimentation, resuspension, underwater light climate, vegetation, ecosystem management, genetic diversity, and persistence of biological communities. These gaps severely decrease the worth of modeling and simulation for these processes because the uncertainty associated with these predictions renders them meaningless in many cases. The Basic Process Level will be primarily conceptual — illustrating conceptual linkages between landscape processes, and identifying where known technologies provide solutions and where new technologies are needed. This level focuses on pathways for research investments.

What Specific Capabilities Are Being Created?

Table 1 lists the LMS deliverables for each projected version of the system. The table also lists the differing capabilities each LMS version will field, the projected fielding date, and the benefits of each version's capabilities to the user community. The capabilities of LMS 2000 are repeated in this table to help the reader assess the added capabilities of each subsequent LMS version. Note that differing components of the system, by design, will be used by differing user groups with highly varied levels of technical capability. This is done to provide differing users with the greatest synergism in the use of the integrated LMS across the diverse multi-disciplinary groups (e.g., range and training managers, resource managers, biologists, ecologists, engineers, nontechnical stakeholders) involved in land management decisionmaking.

Table 1. LMS deliverables.

LMS Version	Date to Field	Technical Capabilities	Benefits
2000	*20 Jan 00*	- Linked watershed-receiving water flow and sediment transport modeling (e.g., combination of WMS, SMS, HMS with RUSLE,SIMWE, SED2D) - Connectivity to NEXRAD weather radar, DTEDS - Indirect feedback to hydrologic runoff, sediment transport through initial coupling to plant model (e.g., EDYS, IDLAMS components) - Initial network-based computational framework - First generation modeling catalog and standards	- Managers (range, training area, resource) can evaluate effects of impending storms and frontal activity on training/testing and project operations, and can evaluate environmental impacts of training and project operations over short-term (days) to seasonal (months) time frames - Sets the basis for technical users to prepare for much advanced capabilities that will follow - Through partnering, sets standardized method for integrating modeling, data collection, and decisionmaking in a more holistic manner
2001	*20 Jan 01*	- Initial LMS modeling suite with screening-level tools - Standards for linking models in LMS modeling suite - Seamless connectivity to major GIS (e.g., ArcInfo, MGE, etc.) and meteorological and environmental databases in both local and network modes - Improved training footprint impact simulation - System output formatted for direct input to user decision support systems (e.g., ATTACC, ITAM, WCDS, demo site systems) - Initial metadata standards established - Metadata requirements published and implementation initiated for LMS modeling suite	- Productivity enhancement through ease of access to GIS, modeling, data - Standards for linkage of future models including user-specific models and analysis tools - Ability to use World Wide Web as an extension of local user's machine for access to remote databases, computing resources - Linkage of modeling and simulation output in formats directly importable to user decision support systems - Standardized methods for data characterization, assemblage, and archival - Descriptors for modeling and simu-

LMS Version	Date to Field	Technical Capabilities	Benefits
		- Improved model catalog with model selection criteria and guidance	lation tools themselves to empower reuse and verification - Support to users in model applicabilities, limitations, and selection
2002	*20 Jan 02*	- Connectivity of aquatic and terrestrial models in LMS suite with atmospheric transport/dispersion modeling - Links to remotely-sensed data established - Conceptualization modules added to aid user in model setup, scenario evaluation, hypothesis testing - Full-coupled physical-ecological process models incorporated Integration of environmental and human risk (as required) with modeling and simulation, initial economic modeling, and decision support - Transparent modeling and simulation to user through network services and local computing combination - Initial quantification of predictive uncertainty for LMS modeling suite	- Multi-media (air, land, water) approach to flow, transport modeling that parallels EPA risk paradigm - Seamless entry of site data into modeling frameworks - Ability for users to set up differing management scenarios for evaluation prior to implementation without the requirement for extensive computing expertise - Network-enabled connection to data sets, high performance computing resources, and other web-based technologies all from the user's desktop computer - Comprehensive system for assessing tradeoffs between management decisions, ecological (and human if needed) risk, and the cost of said decisions
2003	*20 Jan 03*	- Collaborative, web-based capabilities for multi-stakeholder involvement in decision making - Integrated economics modeling - Integration of new models and process knowledge from basic science investigations both in-house and partnered - On-line parameter database for LMS modeling suite - Initial tools to aid users in management scenario development and optimization - Full web-based connectivity for all LMS services	- Ability to collaborate with multiple stakeholders in viewing system output, assessing worth of resource decisions, and reaching consensus across the World Wide Web - Parameter databases to greatly aid users in properly setting up the LMS modeling suite - Aid to users in making optimized and adaptive land management decisions that are both technically effective and cost-effective
2004	*1 Oct 03*	- Continued improvement to LMS modeling suite, particularly in ecological modeling capabilities - Advanced multi-stakeholder decision support through network connectivity - Addition of simulatons for land restoration methods/alternatives - Near real-time feedback on management decisionmaking - Indices for measurement and translation of management decisions on ecosystem diversity - Output of all LMS results with quantified predictive uncertainty - Full economic-risk-decisionmaking connectivity over a networked environment	- Increased capability to assess management decisions on ecological endpoints as well as habitat indicators such as erosion, land cover succession, etc. - Ability to digest remotely-sensed and ground-truthed data on the fly, and synthesize them in near real-time - Development of indicators that distill multi-dimensional system output data into visually intuitive representations for multiple user groups - Ability to evaluate land restoration methods directly

Tasks Related to LMS 2000 (first version)

Develop Web-based Framework

- Develop comprehensive access to all LMS services through web-based computational environment.
- Develop a framework from combination of commercial off-the-shelf software (such as web browsers, Windows 95, 98, NT, and Java) to allow maximized flexibility and portability across computing platforms.
- Provide network access to the M&S suite, databases, and multiple computing platforms (including high-performance computing [HPC] resources within DOD).
- Integrate navigation aids to facilitate user access to LMS services.
- Provide for both network-based and localized execution of LMS.
- Provide for initial use of legacy systems by local users.

Decision Support Tools

The integration team will incorporate decision support tools within the LMS computational framework to allow managers to assess risk and worth of given management scenarios, to assist in decisionmaking, and to provide output to external management systems employed by users. Early attention to the development of these decision support systems (DSS) will provide significant support to all LMS Field Application Projects (see Chapter 6), by facilitating the integration and evaluation of new and historical data in various stages of project implementation. Regular, structured interactions among DSS developers, modelers, data collectors, researchers, and the public (e.g., through workshops), will be of great value in effectively focusing project directions. As part of the development of DSS, various models will be integrated and refined with attention to hydrodynamics, erosion, sedimentation and resuspension, water quality, and biological processes. Development of linkages to systems such as ITAM, ATTACC, IDLAMS, RFMSS, and the USACE Water Control Data System will be initiated. Report generation capabilities in formats suitable to meet National Environmental Policy Act (NEPA) requirements will be developed.

Evaluate Existing Technology

Included in evaluation will be SME,* IDLAMS, EDYS, FHASM, WMS, GMS, SMS, SIMWE, RUSLE, PRISM, modeling ongoing at ORNL under SERDP, SWARM, WCDS, HMS, RAS, Stella, training footprint models (TUDS), ecological modeling ongoing outside DOD (DOI, DOE, EPA, USDA), COTS, and appropriate risk and economic models. The best of these will be selected for use in LMS.

Model Linkage and Programming Standards

The task involves:

- Establishing inter-connectivity of legacy models, and setting standards for future model developments
- Considering the utility of DIAS, HLA, and other modeling and simulation constructs as basis for this linkage
- Empowering and standardizing future model development, allowing for leveraging of externally-developed, internally-verified models deemed appropriate for LMS inclusion
- Evaluating seamless connectivity to GIS (invoking the system from both within and external to commercial GIS environments). This task will solicit technical support from CRADA partners for this task.

LMS Model Suite

Several models are known to be viable for inclusion in the initial suite of models, directly, or after expansion of these models with subroutines needed for LMS field applications. Linkages of these models are needed to support the field applications, and for development of the first two versions of the system. LMS-compliant versions of WMS, EDYS, RUSLE, ICBM, FHASM, TUDS, SIMWE, GMS, and SMS will be developed. The need to include atmospheric transport/deposition and precipitation forecast models in this initial suite will be evaluated. Possible initial linkages include: WMS-EDYS-RUSLE; ICBM-FHASM, and TUDS with one or both of the former. This work will be conducted in tandem with the work unit listed above and with the field application projects.

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*An acronym list is provided after the Appendix.

Predictive Uncertainty for LMS Suite

In FY99 and continuing through FY01, there are two projects in the Strategic Environmental Research and Development Program (SERDP) Conservation Program related to error and uncertainty in environmental/ecological modeling. During FY99, these efforts are being "shaped" to contribute to the LMS framework, although coordination is not formally shown on LMS planning documents until FY00.

Employ/Establish Data/Metadata Standards

This task will be conducted in conjunction with multiple Federal agencies (through Federal geospatial data coordination committees), and specific DOD elements (e.g., the Tri-Service CADD/GIS Technology Center). Model-required data and parameters for models within the M&S suite will be identified. Entities, attributes, and domains for models and data will be defined. These elements will be identified in a manner that is directly compatible with Federal geospatial standards (or will become the standards). Standard links between differing data types common to land management (e.g., DTED, NATO, ESRI, MGE, etc.) will be established. Marketplace activities to ensure that standards are seamless with new GIS and database developments in industry (e.g., Open Geospatial Database Interchange [OGDI]; Open Geodata Interoperability Standards [OGIS]) will be leveraged.

Common Data Storage Formats

In concert with work previously described in this section, standards for data storage to be followed for all new or future LMS development and application activities will be established.

Connecting These Efforts

The tasks listed in the previous paragraphs will, by design, develop technological components that are the foundational pieces of all LMS versions. At the heart of LMS are the modeling and simulation tools necessary to abstract landscape level processes into a "system" and to predict potential future states of the landscape as a function of differing natural and anthropogenic influences and management scenarios.

Catalog/Advisor

As a first step toward building the LMS modeling layer capabilities, landscape process models are being described in a catalog. This catalog, which will become one of the key products of the LMS effort, has many applications. It was initiated during FY98 as a web-based tool with dozens of fields for each model and/or modeling/decision support environment. Funds for developing this catalog primarily came from the Army Civil Works Geospatial R&D Program; additional resources are programmed for FY99 improvements to this catalog and analysis of the contents. Subsequent catalog versions will provide model comparisons, and use advisory capabilities for the various models (both military and civil works-funded) described in the catalog.

Evaluation Process

From this catalog of models, a subset will be selected for the LMS evaluation process. This process will involve (1) evaluating the applicability and limitation of the models within the Model Catalog, (2) selecting a subset of these models, based on model utility, level of field verification, and potential for linkage with other LMS models for inclusion within the LMS framework, (3) directly influencing current relevant DOD development efforts that will result in modeling and simulation capabilities to meet LMS-specific needs, and (4) evaluating the issues associated with linking each of these selected models fully into LMS modeling suites. In addition, the Army Research Office and the SERDP will be sponsoring a series of workshops in selected modeling domains (e.g., hydrologic, ecologic, erosion/sediment transport) that will contribute to the catalog, help with the evaluation process, and identify process understanding gaps that will drive priorities for subsequent research initiatives.

LMS Modeling and Function Capability Suites

The initial modeling suites in LMS will be determined by the evaluation process, but will also be selected to support the requirements for specified capabilities at the LMS field application sites (see Chapter 6). These sites have been selected to typify the resource management problem issues of military installations and civil works programs. Models selected for the modeling suite will not only meet linking protocols, but will be blended into interactive sets, as necessary to meet process modeling and simulation needs from the field sites. The LMS 2000+ systems will address modeling and integration needs at the Field Application Program sites, in the following disciplines: hydrodynamics, erosion, sediment transport (resuspension, fate, and mass balance), geomorphology, biological responses (habitat, population, community, and ecosystem scales), water quality, watershed processes, air quality, military noise propagation, and socioeconomics. For models in the modeling suites, LMS functions will allow for sophisticated input/output analysis, automated data retrieval from servers, conceptual scoping for selection and design of alternatives, based upon the run requirements and available computing resources identified from the user's desktop.

The overall process of identifying computer-based tools of relevance to LMS 2000+ through evaluation to integration is shown in Figure 6.

Commercial Off-the-Shelf GIS

Essentially all DOD land and water resource managers are either direct or indirect users of GIS or GIS outputs. Generally, these are capabilities acquired from commercial providers. Pre-existing capabilities (legacy modeling and DSS) may be integrated as executable components of these COTS GIS, may have high-level linkages (through shared data model exchanges), or may simply interchange data with COTS GIS or are linked to GOTS GIS display capabilities. LMS will build upon the capabilities of commercial GIS, and, as stated above, LMS developers are partnering with commercial GIS vendors to define points of reliance and co-evolutionary development paths. There are several commercial software capabilities that LMS will rely on, including database tools, collaboration tools, and standard office suites.

Initial Versions

The initial versions of LMS draw upon elements in the catalog that may be models, modeling systems, or decision support systems (Figure 7). These will be legacy systems in the early phases of LMS development. The models and systems require data and produce output that may be displayable using COTS GIS software, GOTS software, or some combination thereof. For those models and systems selected for inclusion in LMS, protocols will be chosen or developed that enable linkage (when it is appropriate) of the components. Thus the protocols at this early stage will be translators that permit passing data between the selected models and systems.

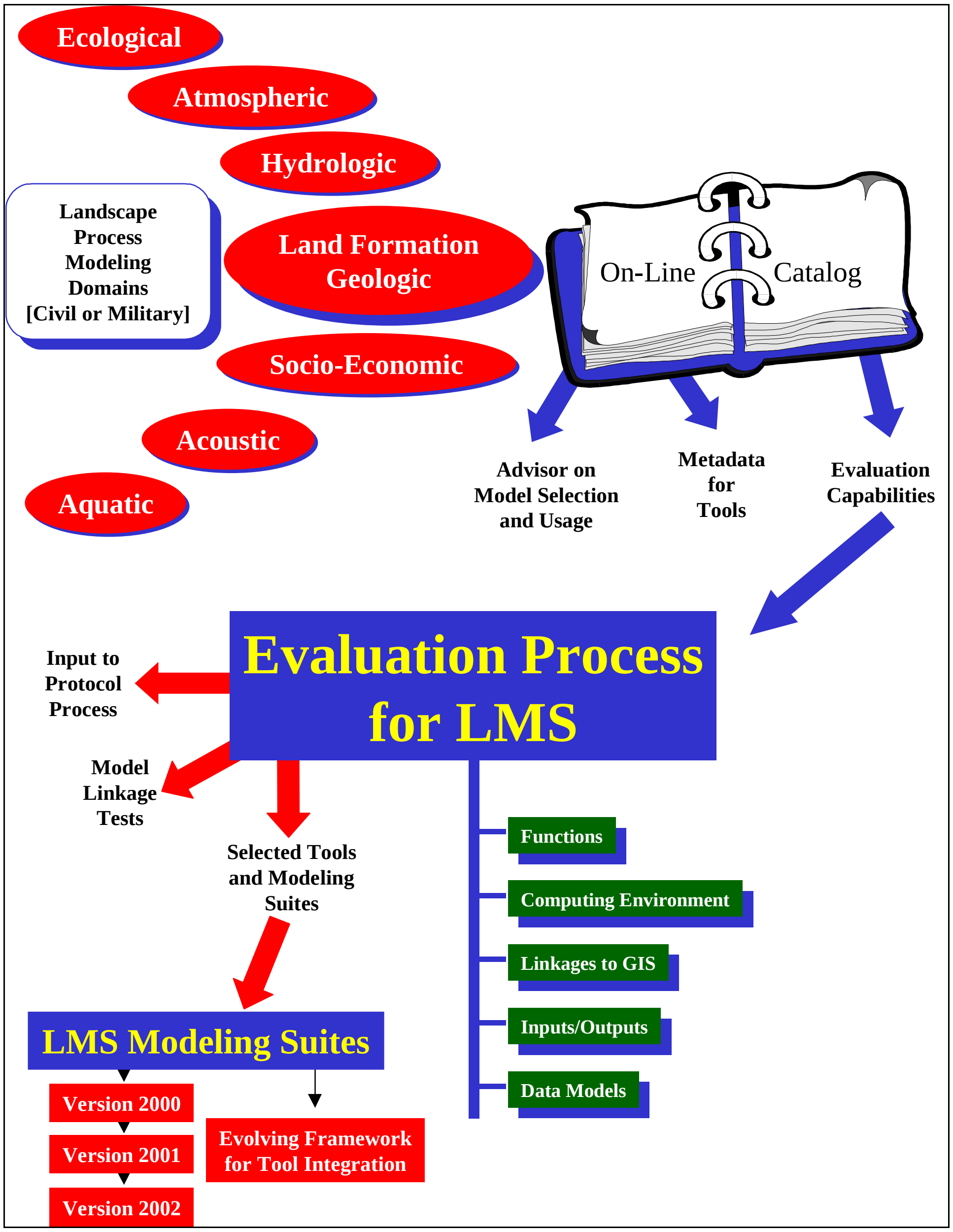


Figure 6. Process of identifying computer-based tools of relevance to LMS 2000+.

A direct consequence of this approach is that in this phase of LMS development, the protocols will potentially be pairwise translators that may apply to only two components. (For models and systems taking data in the same format, protocols will be sharable.) User access to the system will be through GUIs providing a user's view of the system. As with the protocols, GUIs will be connected to the linked models, but by design, a standardized view will be developed so that users are provided with a similar look and feel for all included models and systems.

COTS GIS also will be linkable to the LMS. This will be provided by linkage through the protocols. Figure 7 also indicates that some of the legacy systems

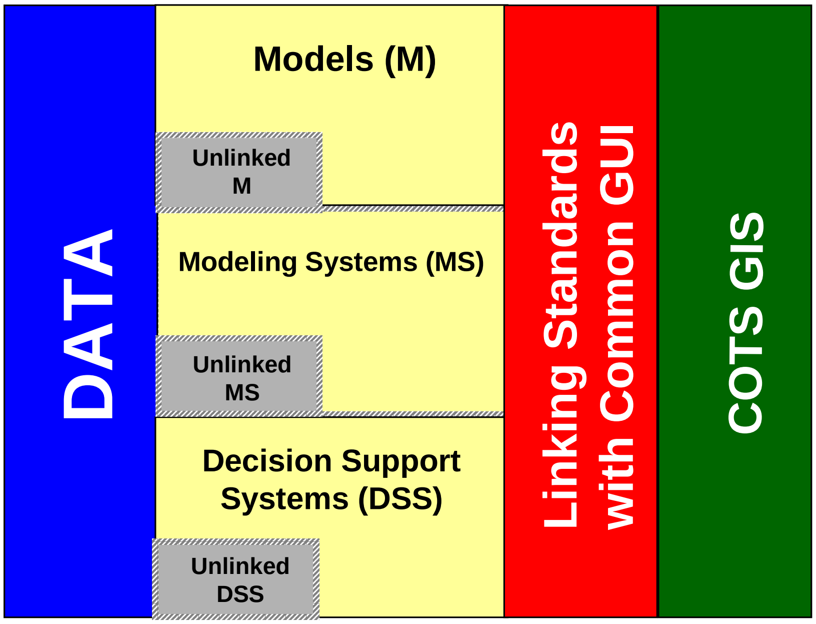


Figure 7. Initial LMS versions.

will not be included (i.e., linked to other models and systems) in the LMS. This may be due to the stand-alone nature of the model or system where linkage with other models provides no added value. Alternatively, the nature of the model and the cost of protocol development may preclude development of a translator suggesting development of a new model when funds are available. New models and systems may be joined to LMS at any time during this stage using existing, or through the development of new, protocols.

Fully Integrated Versions

In the fully integrated versions of LMS, all components will be linked through protocols that are open standards shared by industry and the government (Figure 8). New models and systems will be developed to link to these standards which will enable the movement of data between all components as necessary. Similarly, legacy systems also will have to be compatible with them. There will be a common GUI for the LMS and linkage will be provided to COTS GIS and display capabilities that are part of LMS components.

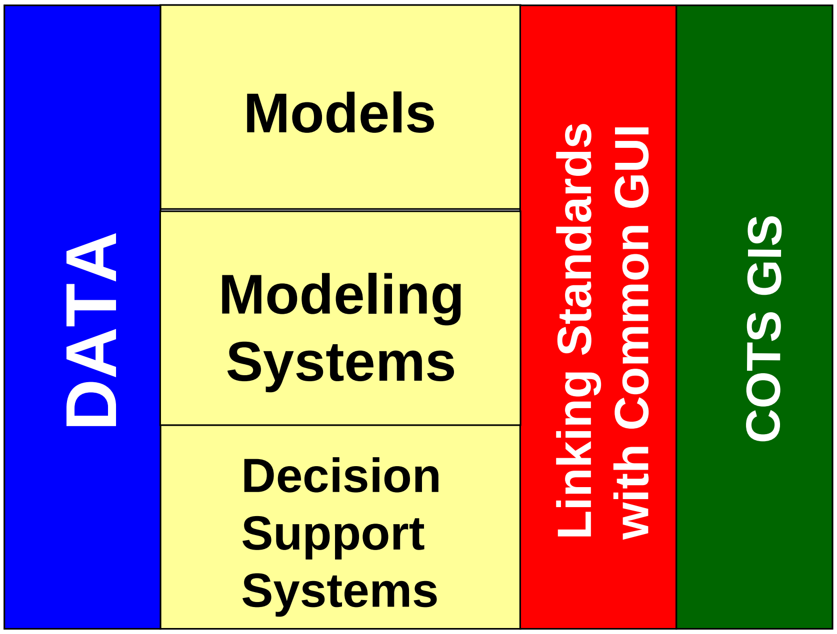


Figure 8. Fully integrated versions.

6 Field Application Activities

Goal of the LMS Field Application Program

The goal of the field application program is to improve natural resource management capabilities through the infusion of technology developed and applied in the LMS. This goal will be achieved via the series of steps and associated activities shown in Figure 9. Data will be obtained through monitoring, research, modeling, simulation, and from historical records. Data requirements, and the availability of data, vary greatly among the field application projects, so the amount of effort required to complete this step will vary greatly as well. Data interpretation will require data analysis statistically and by way of mapping in GIS environments. Modeling and assessment will constitute critical activities in the process of data interpretation. Data interpretation will provide information and knowledge to be interjected into the decisionmaking process. In support of this process, data repositories will be maintained and managed. Constituent data will be used for model calibration and verification (and parameterization) in addition to their paramount contribution to site-specific knowledge bases. The decisionmaking process will be driven substantially via the development and application of integrated modeling systems, GIS applications, and visualization, which are important components of the overall LMS plan. Decisions related to natural resource management actions will derive from careful evaluations of management alternatives using decision support tools developed in the LMS.

Objectives of the LMS Field Application Program

The LMS Field Application Program has the following major objectives:

- To provide problem solving and partnering opportunities between USACE scientists, technology developers, and interested and innovative landscape/natural resource managers in USACE's major mission areas.
- To provide site-specific and problem-specific input into the design of LMS 2000 functional capabilities.
- To provide technology test environments where scientists, technology developers, and resource managers/analysts can tackle issues, test solutions, adjust approaches, capture costs and benefits, and "demonstrate" the results to interested parties.

- To facilitate the transfer of LMS technology to land/water resource managers, both at the host sites for field application and at other similar sites.

Problem Solving

With the LMS Field Application Program, land/water resource managers at a host site initially identify and prioritize their key resource management issues. Then, scientists and technology developers work with managers to address natural resource issues by developing or adapting technologies specific to identified resource management needs. Generally a field application site will involve multiple projects over several years, with the various projects comprising an integrated program. This sustained level of interaction allows scientists, technology developers, and land/water resource managers to integrate joint solutions into business processes — with “bottom up” requirements being directly incorporated into technology program planning and resourcing, and with results of technology investments being tailored to fit resource management needs.

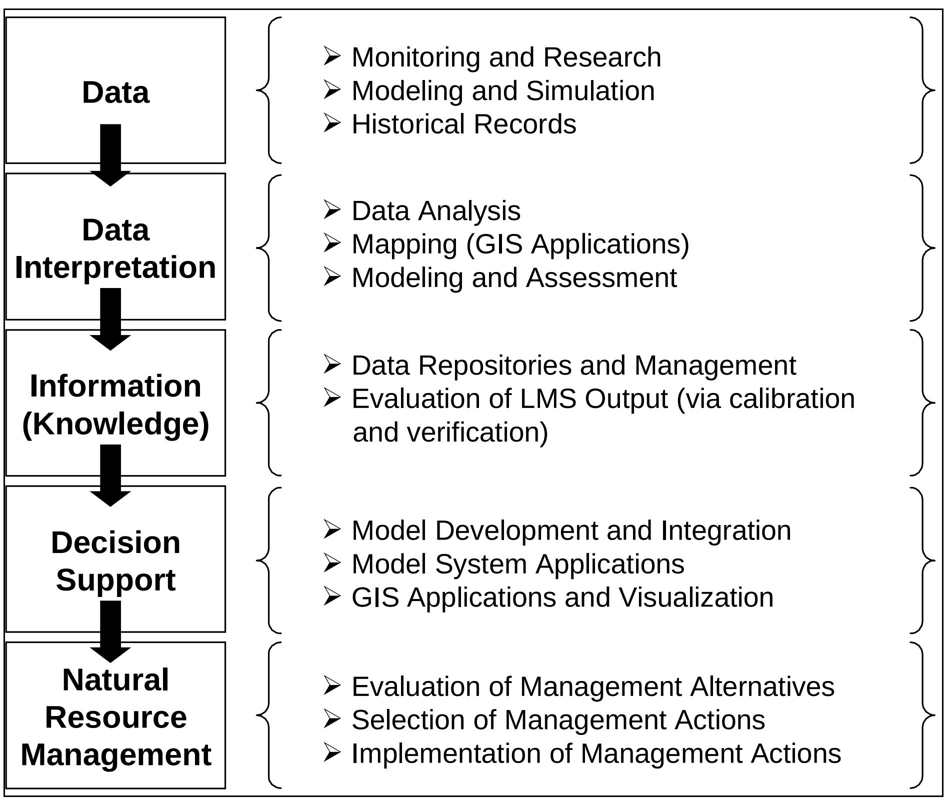


Figure 9. Integration of LMS activities within the Field Application Program.

Input to LMS 2000+

The sets of computer-based tools that comprise LMS versions are designed to be responsive to specific requirements at the field sites. However, these site-specific requirements are leveraged against more general requirements prepared by field advisory or representative user groups to ensure that technology resources are being applied to problems considered broadly important to resource managers.

Technology Test Environments

One important role of the field sites is to provide an environment for testing and validating new technologies related to the management and restoration of natural resources. To accomplish this role, extensive and well-documented digital data coverages may be required for the field sites. Across the field sites, specific procedures are used to implement testing and to validate software functions. All efforts associated with the field application program at a host site are also documented in program reviews.

Technology Transfer of Field Capabilities

The field application sites for LMS provide forums for “getting the word out” about the specific applications being developed for and tested at these field sites. Regular in-progress reviews (IPRs) at each field site provide the primary opportunity for this type of technology transfer. Many people attend these forums with the perspective of “how can this technology be applied at other sites?” One of the “closure” tasks for applications performed at LMS field sites is an analysis of costs, benefits, and issues relevant to “exporting” this same or modified application to other sites.

In addition to these IPRs, which are generally held annually at each site, all the applications at each of the field sites are described on the LMS website. Many of these specific applications are also presented at scientific and user forums.

Selection of Sites for the LMS Field Application Program

Sites are selected based upon several criteria, including:

- Interest from land/water resources managers in incorporating new capabilities into their business practices and developing collaborative partnerships with scientists and technology providers.

- Representative land/water resource management issues such as high levels of use, sensitive resources, competing multiple uses and stakeholders, and other problems and issues identified by user groups as important.
- Importance of site or problem set to the mission. Generally, sites are selected that are of high interest both locally and because they represent valuable assets in Army mission considerations.
- Support and concurrence for LMS Field Applications not only at the local level, but also from across the organizational management structure — organizational support is needed for the multi-project, multi-year partnering typical of LMS field sites.
- Synergism with existing programs/efforts. In some cases, LMS provides an added dimension to an existing initiative. For example, the Alternative Futures efforts with the Mojave Desert Ecosystem Project and Fort Huachuca/ San Pedro River areas were previously initiated efforts to which LMS was added to provide a system framework for the scenario analysis. Similarly the Upper Mississippi River System (UMRS) Field Application Project adds depth and broader dimension to the UMRS Environmental Management Program. LMS will provide a logical and cost-effective leveraging capability, added to procedures already developed and being implemented for land/water resource managers and multiple stakeholders in these areas.

LMS Field Application Program Organization

Dr. John Barko serves as the LMS Field Application Program Director. In addition, there is a Field Application Site Coordinator for each field site, and a Host Site point of contact (POC). Responsibilities for each of these positions are as follows:

LMS Field Application Program Director

The Program Director provides overall direction to LMS applications to field sites, and works closely with Site Coordinators in developing interfaces among natural resource management needs, applied research, and model development/integration activities. S/he works with others to ensure proper staffing and resources to address articulated field requirements and management needs. S/he establishes methods for validating results of modeling applications, developing decision support tools, and making management recommendations. S/he coordinates regular reviews of site activities, and works with others as necessary to update study plans. S/he is responsible for delivery of products to natural resource managers.

LMS Field Application Site Coordinator

The Site Coordinator serves as principal point of contact for technology development and coordination of Application Site activities. S/he assists the Director in conducting regular reviews, revising study plans, and working with investigators to achieve improvements as necessary in the direction of overall study activities. S/he provides the Director with regular reports on problems as well as accomplishments.

LMS Field Host Site POC

The Host Site POC serves as principal point of contact for the field site host organization. S/he provides feedback from the host organization to both the Director and Field Application Site Coordinator regarding any problems related to field site activities. S/he provides the Director with regular input to ensure effective attention to natural resource management needs in LMS applications to field sites.

Key Events Related to Project Planning and Implementation at LMS Field Sites

- Site Consideration. Site offers something new to the LMS field application program — landscape management problem sites, customer mission requirement, or other distinguishing situation
- Site Selection. Host site expresses interest in participating in field application program, staffs a letter of intent, and establishes a Point of Contact.
- Identification and Prioritization of Resource Management Issues. Working as a team, the scientists, technology providers, and host site resource managers identify key resource management issues and opportunities to help address those issues.
- Plan Formulation. Based on prioritized issues, the team develops a plan. The plan should identify specific projects, and the research, technology needs, and principal investigators for each project identified. These principals will then need to develop detailed project plans.
- Development of Project Plans. Project plans, with details concerning funding requirements, funding resources, execution timing, cross-project coordination, and critical milestones are developed. Participants' responsibilities, key milestones, and milestone completion criteria should also be identified.
- Project Execution. Projects may begin when resources and logistics allow. Projects are the responsibility of the specific Principal Investigator and (if

applicable) the host site counterpart, but the Field Application Site Coordinator and Host Site POC help facilitate and support all field site projects.

- Data Repository. All field site projects will generate data and analysis that contribute to a data repository. These repositories will follow some common guidelines (e.g., include metadata, provide accessibility to all project teams), but will also be customized to meet host site requirements and management objectives. Figure 10 provides a conceptual diagram of a host site data repository. Future catalog/advisor functions will "query" these repositories to identify data availability and status related to the usage of catalog tools.
- Field Site Reviews. There will be in-progress reviews of all projects associated with the field site. Reviews also evaluate the role the demo site is playing as one component of the overall LMS Field Application Program. Reviews are for the purpose of evaluating all the projects associated with the field site, problems to be addressed, and future plans. One of the key purposes of these reviews is to provide a forum for the Host Site POC/organization to evaluate the success of field site activities. Another purpose is to provide both a forum and documentation for technology transfer of host site activities to other locations with similar issues in land/water resource management. To help achieve both of these objectives, reviews are held on a regular basis throughout the field period.

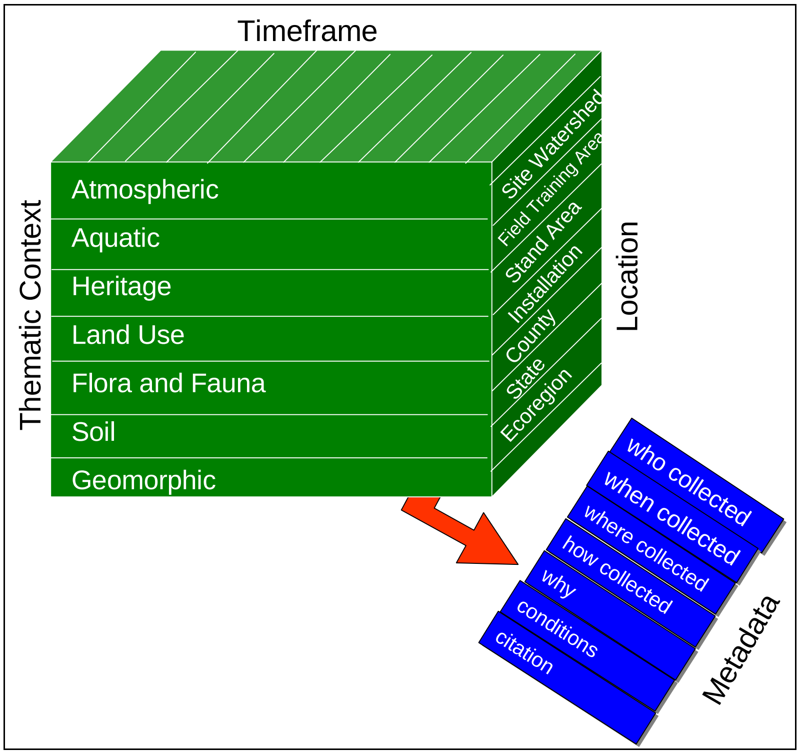


Figure 10. Conceptual diagram of host site data repository.

- Transitions and Closure. Field site activities may continue for many years, with transitions in Field Site Coordinators and Host Site POCs. Since many of the projects involve establishing monitoring facilities and extensive databases, many researchers may wish to continue work at the site, drawing upon these developed resources. As long as the host site agrees, there is no requirement to "close out" a field site as a technology test environment.
- Technology Transfer. Technology transfer occurs throughout the life of the field application program. Opportunities for technology transfer occur during the in-progress reviews, through the field websites, through articles and presentations about field site projects through technologies incorporated from field sites into LMS, and through explicit organizational plans for technology transfer. For example, the Corps of Engineers may use a field site as a test case for technologies to be fielded in other districts, once the technology is validated and documented; implementation requirements and costs are captured from the field site.

Field Application Projects

The original sites selected for field application were Fort Hood, TX, and the UMRS, with three locations in the Upper Mississippi River Basin: Redwood Basin, along the Minnesota River in southern Minnesota; Pool 8 on the Mississippi River near LaCrosse, WI; and Peoria Lakes on the Illinois River at Peoria, IL.

Workshops were held at Fort Hood, TX, and in LaCrosse, WI, during September 1997 to identify and prioritize land/water resource management issues at each of these sites. Site plans were then developed and projects initiated to address these plans. Reviews are scheduled regularly for activities at each of these sites.

In 1998, plans were developed to add the Marine Corps Air Ground Combat Center (MCAGCC) at Twentynine Palms, CA, as an additional military installation site. Figure 11 identifies demonstration locations.

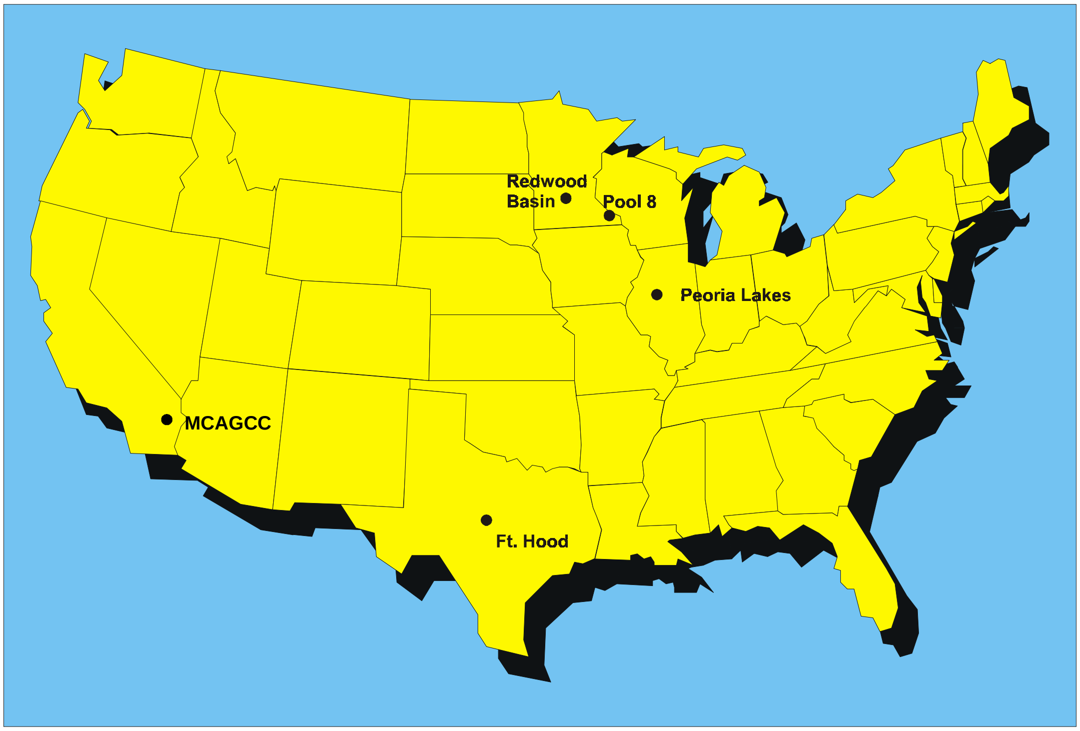


Figure 11. LMS field application locations.

Host Site Information

Fort Hood, TX

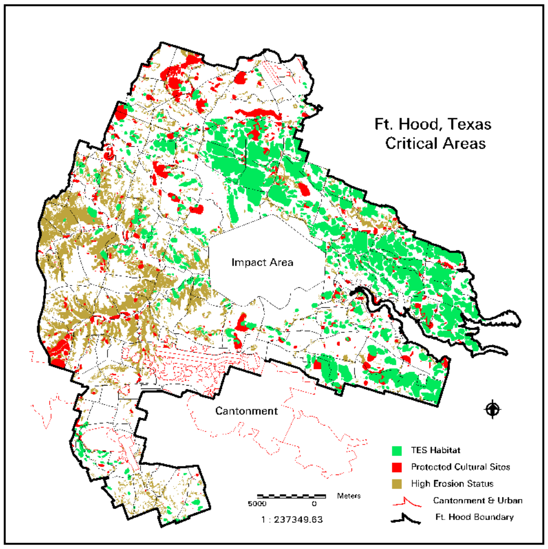
Fort Hood, a 340-square mile installation (217,337 acres), is the only post in the United States capable of stationing and training two Armored Divisions. The rolling, semi-arid terrain is ideal for multifaceted training and testing of military units and individuals. Fort Hood is *'The Army's Premier Installation to train and deploy heavy forces.'* Fort Hood is residence for the Headquarters Command III Corps.

For many years, the primary focus of III Corps was the reinforcement of NATO. As the world and the U.S. Army have changed, the Corps has also changed, and broadened its focus to be ready to deploy anywhere, anytime, and win. The mission of the III Corps is on order, to deploy to a theater of operations, conduct military operations across the spectrum of conflict, and redeploy.

In recent years, III Corps forces have fought in and supported operations worldwide, to include Grenada, Panama, Honduras, Saudi Arabia, Kuwait, and Iraq, and provided humanitarian support for Operation Restore Hope in Somalia. III Corps elements provided support for Operation Joint Endeavor in Bosnia.

III Corps major units are the 1st Cavalry Division and 4th Infantry Division; as well as the 3rd Armored Cavalry Regiment, the III Corps Artillery; and the 13th Corps Support Command.

Resource Management Challenges



Some of the enduring land and resource management issues that Fort Hood faces include: monitoring the impacts that training has on Threatened and Endangered Species (TES) populations and testing TES population viability under alternative land management strategies. Land managers are also responsible for ensuring sustained usefulness of the training areas by minimizing erosion and degradation of lands. Land managers need to have estimates of erosion potential, trafficability problems, and flooding hazards in order to ensure safe and excellent training today while making sure that future training can be accommodated on the same landscape.

Site Coordinator: Mr. Alan B. Anderson

Host Site POC: Mr. Emmet Gray

Significant areas of Fort Hood are constrained for military use because of the presence of protected species, protected cultural resources, or because of land condition problems. Minimizing the constraints to the mission while practicing good stewardship is a significant resource management challenge at Fort Hood.

Twentynine Palms

The mission of the Marine Corps Air Ground Combat Center (MCAGCC) at Twentynine Palms is to develop, administer, and evaluate the Marine Corps' Combined Arms Training Program. Along with MCAGCC's main mission, is the task of establishing and implementing the Marine Air Ground Task Force/ Expeditionary Training Center.

Combined Arms Exercise (CAX) is the primary mission of MCAGCC. The objectives of CAX are to exercise and evaluate active and reserve duty soldiers in command, control, and coordination of combined arms with a maneuver warfare live-fire environment. CAX is the most realistic live-fire training exercise in the Marine Corps. Approximately 2,500 Marines and sailors participate in each 22-day training cycle.

MCAGCC has many of the same land and water resource management issues that all installations face. Compounding the typical problems, is the location of the Center. MCAGCC is located within the Mojave Desert, which has a xeric moisture regime, low rainfall, and low humidity. Therefore, common problems like dust control and vegetation growth can be very challenging to land managers. Some of the land and water resource management issues are: water and wind erosion, dust control, vegetation establishment, threatened and endangered animal/plant species, riparian area conservation, capacity of land for mission use, noise control, tank trail maintenance, and water and air pollution.

Site Coordinator: Mr. Dick Gebhart

Host Site POC: Mr. Kip “Otis” Diehl

Civil Works Field Application Projects on the Upper Mississippi River System

The UMRS Field Application Projects incorporate a multifaceted approach and currently focus on three locations: the Minnesota River (Redwood Basin), Pool 8 on the Mississippi River, and Peoria Lakes on the Illinois River (Figure 12). These locations have somewhat different, but interrelated, suites of environmental problems with associated management and restoration needs. Natural resource issues being addressed on the Minnesota River include agriculture land use and artificial drainage, wetland losses, poor water quality, and loss of aquatic habitat. In Pool 8 of the Mississippi River, the primary issues are backwater losses due to sedimentation, island erosion, habitat deterioration, impacts of invasive nonindigenous species, and Operation and Maintenance (O&M) activities. Issues in the Peoria Lakes include sedimentation, losses of wetland and aquatic vegetation, and overall habitat deterioration. For all locations the approach involves data collection and interpretation; the application of process-oriented

R&D; mapping, monitoring, and modeling; and the development and application of numerical modeling/decision support systems to resource management needs.

Specifically, the UMRS field application effort encompasses the following activities:

1. Develop relationships between hydrodynamic conditions and substrate.
2. Create spatial data coverages for substrate and biota.
3. Link watershed-derived transport of nutrients with downstream ecological effects.
4. Conduct ecological process-oriented experimentation.
5. Develop detailed sediment and nutrient budgets.
6. Develop ecological simulations and projections.
7. Develop and apply a watershed modeling system to simulate hydrology, sediment transport, water quality, and biotic responses to changes in land use.
8. Apply conceptual and simulation models to watershed management decision-making.

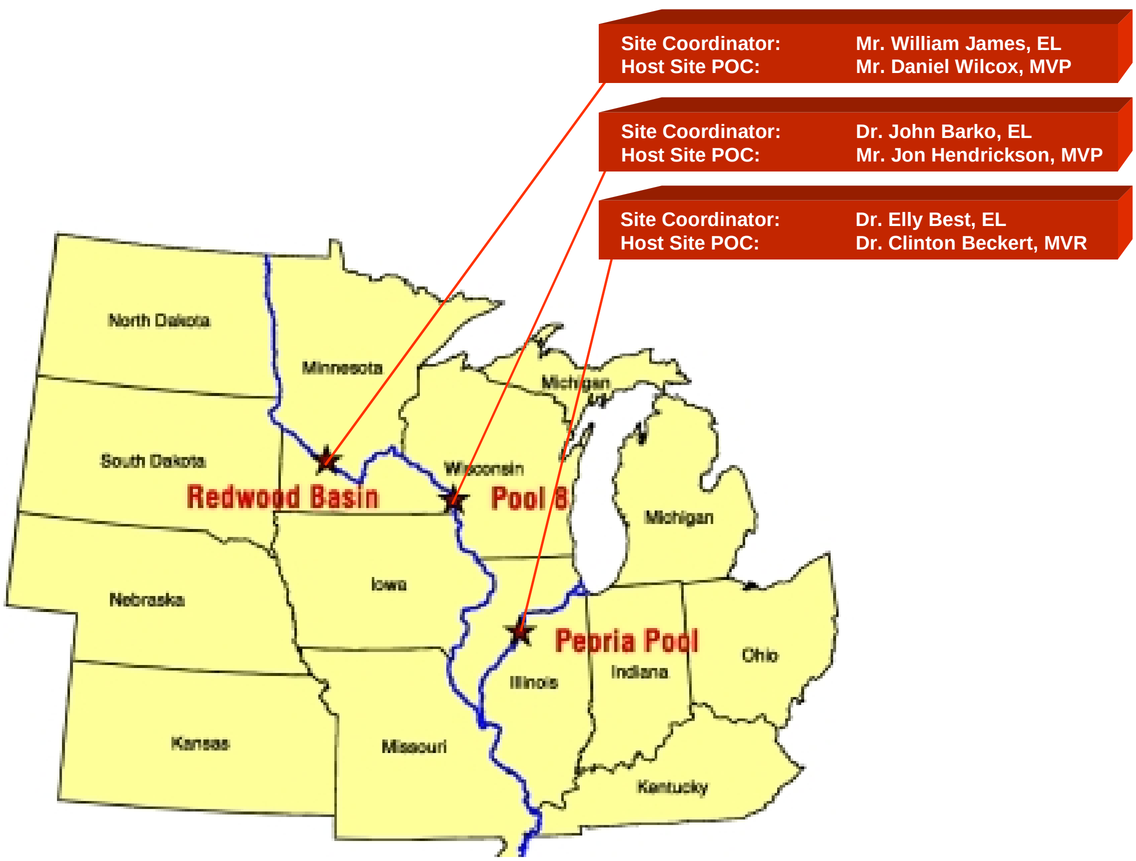


Figure 12. The Upper Mississippi River System field application projects.

Investigations are being planned and conducted to assess hydrodynamic conditions and quantify sediment transport processes, sediment deposition, and associated effects on aquatic habitat (both physical and chemical) and biotic communities, as influenced by natural events and broad river regulation activities. In the context of river regulation, attention will focus on incorporating land management and environmental quality objectives in river management. Research is being conducted on watershed influences on riverine conditions, particularly with respect to present and projected land management practices, sediment yield, and water and sediment distribution within the river floodplain.

This watershed/riverine effort is intended to result in an improved understanding of river ecology and in the development of integrated systems of geospatial and numerical models (predictive tools), driven by data and relationships derived from combinations of focused ecological investigations. Information derived from these systems will be used by river and land (watershed) managers to improve land use, water quality, and natural resources. As part of the development of these systems, numerical models will address land use issues, hydrodynamic regimes, river mechanics, sediment transport processes, and biotic responses. Techniques to characterize and forecast the geometry of channels and floodplains will be developed, based on estimates of sediment erosion, transport, and deposition. The development of methods to forecast accompanying future hydrodynamic regimes and the mosaic of riverine habitats also will be attempted. The probable biological mosaic of future riverine habitats will be assessed.

The end products of the UMRS effort will include a framework for modeling and decision support that will enable comprehensive resource management with attention to cumulative and future impacts to the UMRS. The framework will draw heavily on improved knowledge of physical and biological cause-effect relationships and integrated systems of geospatial and numerical models. Specific predictive tools will be provided in the areas of sediment transport, geomorphology, and biological response to habitat change. Fundamental information linking biotic processes in the UMRS and responses to physical conditions will be provided. Feedback mechanisms involving physical processes and conditions affected by biological components of the river will be better described. The results of this research on the UMRS are intended to help managers evaluate alternatives for watershed management, river regulation, and floodplain management in the context of improved land use and river restoration. Results will allow evaluation of implementation strategies to (1) reduce soil erosion and nutrient losses, (2) attenuate flood hydrographs, and (3) improve water quality and habitat conditions in the UMRS.

7 Technology Insertion Into LMS

LMS is a technology delivery framework. The development of this capability is, in itself, the result of a technology delivery plan. Through LMS, the Corps of Engineers research and development community and collaborators are planning, to provide computer-based technologies for land and water resource management and analysis in a common and consistent framework. Dozens of models, databases, decision support tools, data access, and visualization tools will all be delivered within this framework, and they will be available to all users of LMS.

LMS will provide an evolving suite of framework functions, such as visualization, navigation, problem scoping, linkages to commercial systems, tool and data evaluation and selection, and analysis process planning. In addition to the framework functions, products that result from dozens of technology investments supporting many different land and water resource management challenges will be delivered in this framework environment.

End users may access these products by invoking the LMS framework directly, or they may continue to work from legacy and/or a COTS system that will derive tools, new data, analysis results, or whatever is necessary from LMS to help address the specific task being undertaken by the user.

Step-by-step Transitions — Building the LMS Framework

To accomplish the technology delivery plans for LMS, several planning and coordination steps are required by the technology developers and the eventual technology users. A life-cycle plan needs to cover all phases of designing, building, sustaining, and enhancing the LMS framework capabilities. The plan includes scoping the requirements for the framework, designing and developing this framework, sustaining and enhancing the capabilities of the LMS framework to evolve as the underlying information technology base evolves, and providing and sustaining the necessary links to other technical and business systems.

This LMS framework will become a cornerstone technical system of the Corps of Engineers, and a tool to help the Corps of Engineers improve understanding and capabilities for resource management. Building and sustaining the framework requires a blending of research and operational resources (in multiple operational environments), coordination among the diverse proponents, developers, and users, and a strong program for configuration management. All of these issues need to be addressed in a life-cycle plan.

In addition to building the framework, technical programs of the Corps of Engineers and Corps of Engineers partners and collaborators will need to establish business processes that facilitate the necessary steps for their computer-based products to be integrated into and delivered through the LMS framework. The most important "new process" will be aimed at building effective teaming between technology developers and system integrators for every model, database, decision support tool, and framework capability that becomes part of LMS. To achieve this, standard steps for teaming will be needed, so that the necessary system integration steps are followed by the technology developers throughout their processes. With some variation, these steps will need to be followed for tools emerging from DOD research programs and for tools grafted into LMS from other agencies, organizations and programs.

These steps imply the creation of a "system integrator team," which is a requirement for developing and sustaining the framework. The Corps of Engineers Research and Development Directorate has created this initial team (as described in the Approach Section of Chapter 1), with a specific individual from the laboratory community in charge of overall integration activities. As LMS becomes operational, this team will need to include individuals from both research and operational elements of the Corps of Engineers, and will need to create appropriate blending mechanisms for each program area and proponent organization served by the LMS framework.

This integration team will have two primary responsibilities: (1) care and feeding of the LMS framework, and (2) integration of new capabilities into (and through) this framework. These care and feeding requirements will require frequent "new technology" infusions, some of which will evolve from industry collaborations and some of which will emerge from technology development projects. But for the most part, the LMS framework care and feeding will need operational resources, and funding will need to shift from research and development accounts to operational accounts.

The integration of new capabilities, on the other hand, is an enduring requirement related to the output of products from the research and development programs. Each new effort, proposed for delivery within the LMS framework, will need to:

- Be "scoped" regarding how the proposed new tool will interact with, complement, and supplement existing tools

- Be documented (tool metadata) in the tool catalog
- Be designed to follow LMS conventions and protocols (programming standards and techniques, languages, links, field validation when/if appropriate)
- Use data consistent with the proponent organization's common data dictionaries/standards
- Be tested, evaluated, and verified regarding performance within the LMS framework and interactions with other LMS framework tools
- Be retested and revalidated when changed, and
- Be "tagged" within a "lessons learned" usage database for comments/ experiences by users, developers, other interested parties.

The above steps will comprise the basic elements of the LMS integration approach for new tools, covering the life cycle of integration issues from conception though development and operational use.

Scoping Process

By providing an overall framework for integration of land and water resource management tools, LMS offers another advantage — a clear context into which proposed new initiatives fit. The framework allows for analysis of the proposed role and function of this new tool or framework resource, that can be based on either the framework plan, user's experiences and requirements, and/or new technology opportunities. Of course, any new proposed tool would need to be responsive to the identified requirements of the program in which the tool development/adaptation is proposed, as is currently the case for each participating program. However, the LMS framework provides a broader context for horizontal coordination across programs, and a systems perspective regarding how the proposed new tool addresses interactions between tools and enhances user's abilities to simulate or communicate geosphere/geoscience processes.

Catalog Documentation

Providing documentation of computer tools in the catalog is a step that needs to be completed before the tool development process, then revised and corrected as necessary during and after the process. Review of catalog tools is a part of the scoping process — a necessary step to obtain an understanding of how a proposed new tool complements or potentially duplicates existing tools, and to better understand and communicate why a new investment is needed.

Conventions and Protocols

The primary purpose of conventions and protocols is to define the common characteristics of capabilities provided within the LMS framework. Thus, it is critical that these common approaches be followed by each tool developer/adapter. The advantages of this are straightforward — common approaches will allow for the development of the "language of linkages" between tools, will facilitate conversions of these linkages as the language evolves, and will be necessary for the tools submitted to the LMS Integration Team to perform successfully during testing and validation.

Data Standards

LMS framework resources and tools will need to interact with data as defined by organizational common data dictionaries, such as the Tri-Service Spatial Data Standard (TSSDS) developed by the Tri-Services CADD/GIS Center. However, some elements of these standards are unique to business domains, and may vary somewhat across the domains serviced by LMS. Data input/output translators will be considered in the LMS toolbox to address these variations in corporate data dictionaries. But all LMS tools should be designed to "expect" data input and produce data outputs in compatible formats/nomenclatures.

Testing/Validation

The testing/validation effort will involve standard suites of operations that each tool will be required to perform successfully for "validation" within LMS. This validation will relate to how a tool performs within the LMS environment, separate from validating how well a model might represent measured events/processes on the landscape or in the geosphere.

These tests could be run by the tool developers/adapters, but the LMS Integration Team would need some proof or procedure for final verification. Tools within the framework would then be tagged with this verification status.

Retesting/Validation

Several circumstances will require tools to be retested. First, if a tool is upgraded, through a new technology initiative or an upgrade to the underlying COTS software, another round of testing will be necessary to confirm performance standards. Second, if framework resources are revised or upgraded, the behavior of tools may be altered, which will also require retesting. Finally, when protocol evolution advances tool interaction potential, existing tools may need re-evaluation and testing for performance related to these enhanced interactions.

Lessons Learned Database

The LMS framework will contain both a lessons learned database and a collaborative feature that will allow users to learn from and share with other users and developers. The database/collaborative tool can function as a way to capture institutional experiences about a specific tool, or that tool's interactions with other tools, or as a mechanism for facilitated communication with experts.

Resources for Technology Transition Into the LMS Framework

Completing these integration steps is an inherent part of the technology development and delivery process. As such, costs for each step along the process will need to be resourced from technology accounts, with some contribution from each participating technology program element. This is an enduring requirement — proportionate to the number and complexity of the tools that will be integrated into LMS. Thus, the "cost" will be variable, but there should be standard cost estimating procedures developed by the Integration Team to allow adequate planning within each program area (and project) to accommodate these costs.

Some of these costs will be internal to each tool development effort. When the LMS conventions and protocols and agency data standards are the way of doing business, the costs of conformance will be included in each technology development effort, rather than requiring additional costs. At that stage, the reliance on framework resources will avoid spending on duplicative framework capabilities to support stand-alone tools. Thus, over time, cost and time requirements for tool development will be reduced.

The testing and validation processes can be accomplished by the tool developer, given a suite of defined procedures that can be followed. The Integration Team will need to review and "validate" that these procedures have been followed and that the results are acceptable, and then "assign" the appropriate designation to the tool. The Integration Team will need to be funded to perform these and other functions; this will be an enduring cost, but much smaller than the current cost of each developer generating their own delivery framework for each model or decision support system.

LMS Transition Events

The current LMS planning horizon is for upgrades to the suite of LMS capabilities through Fiscal Year 2004 (October 1st, 2003 to Sept 30th, 2004). The first software release will be early in calendar year 2000 (January/February); subsequent releases will be annual. These software releases will provide the framework components for LMS (see Table 1 for version details), and will also provide suites of products nested inside this framework that have been tested to perform as planned with the appropriate linkages and exchanges with other products inside and outside the framework.

For technology developers, there will be "transition" planning for (1) technologies already developed and in use (legacy capabilities), (2) technologies under development that will need to be "reshaped" to fit within the LMS technology delivery framework, and (3) future technologies now being planned that will become component capabilities of LMS (Figure 13).

For legacy capabilities, the "path" of interactions between these legacy (and COTS) systems and LMS will be co-designed by the legacy system managers and proponents and the LMS developers. This is an important component of the technology delivery plan — to work with legacy systems and to facilitate the appropriate interactions between LMS and these legacy systems and to sequence the design of these exchanges to accommodate legacy system user needs and legacy system developers enhancement cycles. Uses of legacy systems will see additional capabilities resulting from these LMS interactions — but these additional features and options will be delivered as upgrades to the legacy system. Figure 14 illustrates how these LMS connections (tools, data, interactions) will be designed with specified legacy systems.

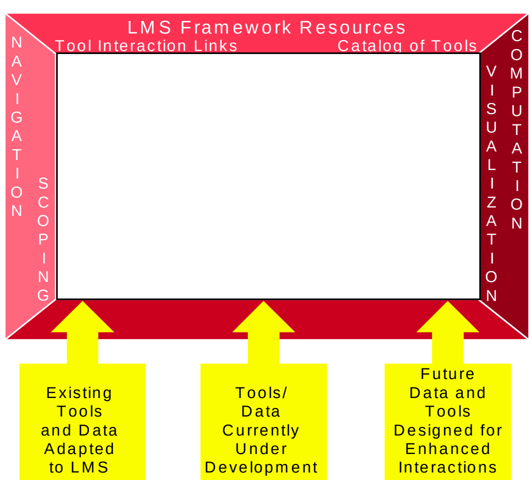


Figure 13. The LMS framework.

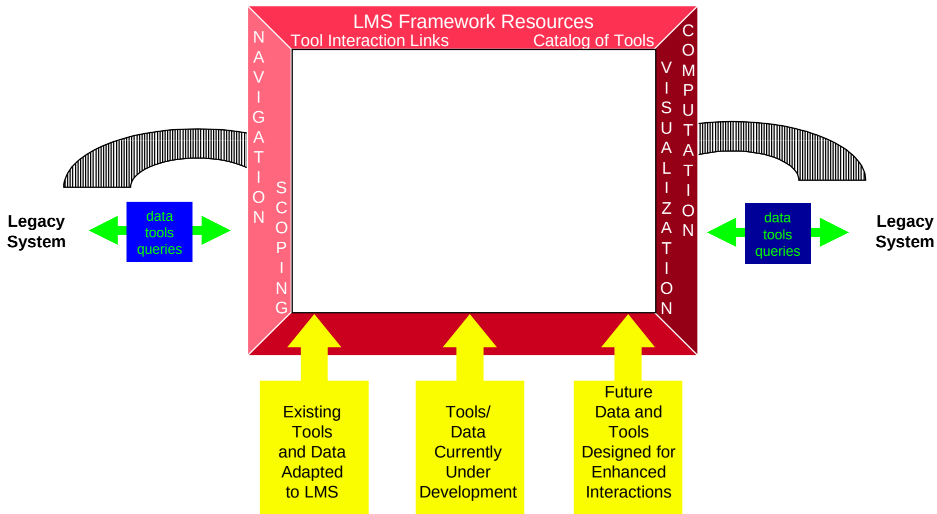


Figure 14. The LMS framework plus legacy links.

For technologies currently under development, there is a requirement to evaluate each tool in terms of how it may fit into LMS. Some efforts may be so far along toward operational fielding that reshaping them back into LMS may not be cost effective and may unnecessarily delay fielding. Such determinations would be the exception, however, putting the resultant products into the legacy category. For all other computer-based tools in the technology development pipeline, a reshaping toward LMS will be undertaken. Future technology developments will follow the LMS integration steps.

8 Technology Transition Planning

The LMS Protocols and Technology Transition

The LMS protocols will define the evolving LMS environment and how component capabilities will integrate into this environment. They will also help prepare organizations for LMS. Organizations that will potentially be affected by LMS will have a voice in shaping LMS through input into and review of the protocols. Through engagement in the protocol process, each participating organization will have opportunities to identify possible problems or issues with LMS, and to plan for the integration and coevolution of legacy capabilities with LMS. Thus, the protocols themselves become part of the LMS technology transition process. By inviting broad participation with the LMS protocols process, LMS developers have two goals: (1) to engage a broad community in shaping LMS, and (2) to engage the potentially affected communities in preparing for new capabilities and linkages when LMS (or LMS results) are available within their organizations. The protocols are intended not only to define LMS, but also to lay the groundwork for broader LMS implementation and to provide a mechanism for how LMS evolution will dovetail with agencies and industry's evolution related to information technology.

LMS Linkages to Legacy Systems

In addition to the protocol development effort, each version of LMS capabilities will be developed to enable model-to-model linkages and system-to-system interactions. Before these linkages are created, LMS developers and the target "linking" system developers will design the linkage goals, the kinds of information and data transactions desired, and how these transactions will be developed, tested, and implemented.

Documentation of these linkages will become important technology transition aids. Each linkage will be developed with the engagement and leadership from the proponents and developers of the systems targeted for linkages. Further, these linkages will be formally agreed upon by the affected organizations before the planned linkages are developed and tested.

The first version of LMS has two targeted linkages. For military land management, the ATTACC model (currently being fielded as a means to link land use and land rehabilitation efforts as part of a module within the Integrated Training and Testing Area Management [ITAM] Program and the Range Facility Management Support System (RFMSS), which is used across the Army (and by the Marine Corps at MCAGCC) to schedule range and maneuver area usage. In Civil Works, the first system targeted for linkage is the Water Control Data System (WCDS), used throughout the Corps Districts for water control operations. In each case, a design document will be developed that describes the method of linkage, the types of transactions, and the process for development, testing, and linkage between these systems and LMS. Whenever possible, these documents will identify potential "coevolutionary paths" for LMS and these legacy systems, to minimize overlap and maximize the value of the capabilities and investments of each system. For each subsequent version of LMS, additional bridging strategies will be developed to other legacy systems.

LMS Field Application Program Transitions

The field application program for LMS both shapes the development of new LMS capabilities and tests these LMS capabilities to help solve resource management and landscape analysis problems in the field. Like the protocol development process, the field application program has an element that links back to the technology programs, by defining desired capabilities and problems relevant to specific user sites. Equally important, these field application efforts provide opportunities to test, evaluate, modify, and document how LMS capabilities help to address specific user problems and how LMS results and capabilities fit into (or alter) decision processes at user sites.

Field site in-progress reviews are designed to ensure that the evaluation, modification, and documentation occur for each project associated with LMS. These reviews also allow other interested parties to review the projects and evaluate the value of applying LMS investments and results at other sites. One component of each project, discussed at in-progress reviews, is "technology transition and implementation."

LMS Implementation Planning

Overall implementation planning for LMS will be addressed from a life cycle analysis perspective. There are two major considerations (1) the cost and value to the organization in developing and fielding LMS, and (2) organizational processes affected by the implementation of LMS. These issues are closely related, as the cost and value of LMS will be altered significantly based on how aggressively organizations alter and evolve their business processes to exploit the LMS investment.

One of the primary purposes of this life cycle analysis will be to evaluate different approaches to LMS implementation. How rapidly should organizations target implementations? What will be the effects on legacy systems, and when should organizations plan to shift resources from stand alone legacy systems toward integration of these systems with LMS? What will be the enduring costs to sustain LMS as a framework resource, and how will these costs be reduced, over time, by collaboration and coevolutionary paths with industry?

From both a technology developer's and a technology user's perspective, one of the key issues related to LMS is: "Will delivery of my capability be constrained or delayed by LMS?" LMS will, over the next several years, shorten the interval between technology investment and field application of a new capability. This is a key goal of LMS, and an important driver for the LMS Field Application Program. But another important question is: "How confident can I be in the use of this new capability?" Arguably, the LMS will be among the best verified capabilities fielded in the area of natural resources management by virtue of its validation at the field sites and the use of its components, throughout its development process, as discussed previously in this report. This high level of field-scale validation will instill confidence in LMS use by DOD, and will also increase acceptance by regulators of LMS results.

Supporting Organizations for LMS

The key for organizations that implement LMS in support of their customer requirements is simple: "Will LMS provide more effective and efficient resource management analysis and thus, a competitive edge for my organization in supporting customers?" Supporting organizations will provide tool integration, data population, training, and other services for LMS users, once they see that LMS provides them with part of the "competitive edge."

End User Impacts

LMS end users will greatly vary from those who receive products generated from applications that were performed with LMS tools, to those who operate daily in an LMS computational environment to perform their normal duties. At each level, users will have differing support requirements. Those who receive LMS-generated products will require not only the products but also documented information on the processes and the data used to develop the product, the "confidence" level of the results, and the metadata for the inputs. The LMS will be organized to capture, manage, and package this information as part of the customer results delivery process.

For those who access LMS in association with a pre-existing system, LMS will provide a new resource to their current environment. System proponents and end users will need to evaluate these new resources versus the costs (maintaining compatible linkages, training, coordinated planning). As more functionality becomes available through LMS, this cost/payback relationship will yield increasingly higher returns, and proponents and users will then need to evaluate the cost/payback of maintaining their former computational environment, or switching their specific functions into the LMS framework.

Users of newly emerging capabilities will be working directly in an LMS-structured environment. New systems like the Navy's Predictive System for Environmental Assessment (PSEA), the Army's Risk Assessment Modeling System (ARAMS), and the new DOD Sustainable Lands Defense Technology Objective (DTO) will maintain unique identities, but their capabilities will be embedded in LMS functions, and they will be dependent on LMS-upgrade cycles for many of their version enhancements.

Technology Transfer

One of the most-often discussed aspects of research and development is the transfer of new technology to the user community in forms amenable to the business practices and technical requirements of the users. The USACE laboratories have significant experience in successful technology transfer (TT). USACE has transferred the GMS to over 750 users within DOD, EPA, USGS, DOE, and state government organizations. The transfer of the GRASS GIS software, the Surface Water and Watershed Modeling Systems, and other programs by the USACE labs represents the transition of these land management/environmental quality technologies to thousands of users worldwide. From these experiences, the following points are deemed key to effective transfer of the LMS to its diverse user communities:

- Presentations at national and international conferences, publication of LMS capabilities within peer-refereed journals, and the conduct of LMS user workshops are necessary and important pieces of the global TT pie. Note, however, that these pieces are not, in and of themselves, sufficient for truly effective TT.

- Partnerships with Industry. One key to the successful transition of LMS, especially to contexts beyond DOD, will be the development of partnerships with commercial organizations that (1) connect LMS to their products, (2) implement products in LMS compatible formats, and (3) provide direct user services necessary for LMS users, such as technical assistance. These partnerships can easily be accommodated through Cooperative Research and Development agreements (CRADAs) and other mechanisms, and such agreements for LMS are already being created.
- Demonstration Program. The LMS demonstration program is key to technology transfer of LMS. This program takes the capabilities of the emerging system and puts them to the test of real problems at DOD user sites. In progress reviews at the sites will ensure wide exposure of the activities at these sites, and that problems associated with integrating LMS capabilities into DOD business practices are identified and addressed.
- Maintenance of websites that provide users with up-to-date information on new LMS developments, access to approved downloads of new LMS executable versions and user documentation, recent error fixes, and recent user experiences with the LMS is again a necessary and important TT component. And, again, this piece alone is not sufficient to facilitate most effective TT.
- Effective TT has been observed to be greatly facilitated when dedicated, centrally-funded personnel, who are themselves part of the LMS development team and/or experienced LMS users, are provided to support users in their LMS applications. An example of such support is the Army-funded Groundwater Modeling Technical Support Center. This center, located at WES but providing virtual support from other USACE and Army technical personnel as needed, conducted over 1,000 technical support activities in fiscal year 1998. These activities included GMS maintenance, demonstration, training, help-desk, documentation, and applications support. Beyond this, center personnel were funded (by USACE and the Army Environmental Center) to provide up to five person-days of support to individual users with needs to employ new groundwater modeling technology for specific Army site cleanups. Such support greatly accelerated GMS use, and resulted in significant project cleanup cost savings by: (1) employing superior modeling technology with greater confidence; (2) increasing the Army's capability to be a "smart buyer" of subsurface modeling technology during contract specification and negotiation; and, (3) improved regulatory acceptance of cleanup designs through use of a system, the GMS, on which they themselves were trained (by center personnel from EPA funding) to operate, and for whose development they, in part, funded.

9 Summary

The challenges of managing our nation's land and water resources will continue to increase in complexity. Because of increasing population and development, our land, air, and water resources will continue to experience increasing pressures and impacts. Some community members will push for more development, others for constraints on development; many will want to be heard whenever the Federal government (and partnering state and local governments) plan land and water resource use and management activities. Data, analytical tools, and technical expertise will be needed to better understand and communicate the potential impacts of any current or proposed actions. The investment in LMS will provide access to and integration of the necessary data, a framework to connect the evolving software tools (particularly predictive modeling and simulation and geospatial tools), and capabilities to support all groups seeking to participate in an informed dialogue about management actions and priorities.

As the nation's premier engineering organization, the Corps of Engineers must make strategic investments to develop, acquire and provide improved forecasting capabilities. LMS is one of these major investments. The investment in LMS is unique in many respects. LMS is not merely a better model or simulation or data type representing an improved understanding of a geoprocess or human system/natural system interaction. Rather, LMS is the integrating framework in which these improved models and data types will be knit together and provided to the field.

The LMS investment is significant not just in dollars, but also in people and capabilities. As a pioneering initiative, LMS has a key role in transforming the way the Corps of Engineers integrates emerging capabilities into our business processes and in narrowing the gap between our science investments and our state-of-the-practice. In part, this investment is necessitated by the exponential growth of modern modeling and simulation and information technologies, and the potential that growth represents to improve land and water resource management

The Corps of Engineers and others across government and industry are continuing to develop many impressive capabilities related to modeling and simulation of geoprocesses, and the management and integration of data, information, and knowledge. LMS represents an accelerated leap forward in putting these pieces together at the multiple levels in which they will be used, in improving the synergism of DOD's civil and military technology investments, and in extending the value of the Corps of Engineers to the nation and the international community in understanding the complex inter-relationships between human activities and natural systems.

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Websites

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Fort Hood Homepage, http://www.hood-pao.army.mil

Integrated Training Area Management, http://www.army-itam.com/main.htm

LMS Work Group DoD Website, http://www.denix.osd.mil/denix/DOD/Working/ LMS/lms.html

LMS Work Group Public Website, http://www.denix.osd.mil/LMS

On-Line Catalog, http://owww.cecer.army.mil/ll/landsimsurvey/homepage.html

Tri-Service CADD/GIS Center, http://tsc.wes.army.mil/intro.asp

Twentynine Palms Homepage, http://www.mcagcc.usmc.mil/index.htm

USACE Information Architecture 2000 Plus (A2k+), http://www.usace.army.mil/im/ceimp/arch.html

Appendix: Contents of Information Within the Catalog/Advisor, Version 2.0

General Heading of Information Gathered within On-Line Catalog	Catalog Data Entry/Population Captures One or More of the Following (corresponds to heading)
Part 1 of 7. General Information	
Title	Brief summary
Description	Brief summary
Product Category	Decision Support Ecological/Landscape Economic/Planning Erosion/Sediment Transport Hydrologic/Hydrodynamic Model Development Environment Water Quality/Contaminant Transport Other
Applicable Ecological Region	Artic Coastal Desert Estuary Floodplain Forest Grassland Groundwater Lake River Savannah Shoreline Tundra Wetland Other
Applicable Component	Animal Behavior Animal Populations Climate Economics Groundwater Human Activities Overland Water Plants Surface Water Weather

	Other
Product/System Description	Brief summary
Problems/Technical Issues Addressed	Brief summary
Technologies Employed	Brief summary, e.g. algorithm type, sensor, etc
Resulting Benefits	Brief summary
Current Status	Brief summary
Web Site URL	Example format, http: //www……
Part 2 of 7. Product Applicability and Audience	
Target Audiences	Decision makers Engineers Model Developers Operations Personnel Planners Policy Makers Scientists Software Specialists Others
Computer Knowledge Needed	Casual User Experienced User Programmer Other
Example of Successful Users	Brief summary, e.g. number of users, location of users
Product Cost (in $ 1,000s)	Brief summary, e.g. cost to obtain, cost to maintain
Frequency of use of product	Brief summary, e.g. monthly, annually, etc.
Length of time for model to run and provide outputs	Brief summary, e.g. range of run times
Length of time for product setup	Brief summary, e.g. range of time for setup
Part 3 of 7. General Features	
Assess current conditions	Yes or No, default is No
Future predictions compared to desired outcomes	Yes or No, default is No
Analysis of alternative outcomes	Yes or No, default is No
Test of alternatives and tradeoffs	Yes or No, default is No
Consensus building methods	Yes or No, default is No
Comparison of feedback to expected values	Yes or No, default is No
Analyze or display adjacencies	Yes or No, default is No
Provide audit trails	Yes or No, default is No
Part 4 of 7. Technical Product Features	
Relevant Technologies in Product	Deterministic Process Modeling Empirical Modeling Fuzzy Logic Inductive Reasoning

	Knowledge-Based Reasoning Optimization Simulation Technology Stochastic Process Modeling Symbolic Logic Other
Equations, Formulas Solved	Brief summary, e.g. empirical, Navier-Stokes, etc.
Literature Citations, References for Product	Brief summary
Sharing with other systems at other locations in real-time	Yes or No, default is No
Automatic Error Detection	Yes or No, default is No
Performs Sensitivity Analysis	Yes or No, default is No
Works with Incomplete Data	Yes or No, default is No
Part 5 of 7. Input, Processing, and Output	
A. Inputs	
List Inputs for Each Model/System	Brief summary to include: name of input, units of measure, valid data ranges, tolerance of uncertainty, frequency of input, other
Automated Ingest/Import Capabilities	Brief summary
Number and Type of Dimensions	Brief summary, e.g. 2-D space, 3-D space + time, etc
Computational Space to Store Model Representation	Brief summary, e.g. raster, vector, hexagon, TIN, point, line nets, etc
Time Intervals for Data Collection	Each second or smaller Each minute Hourly Daily Monthly Yearly or larger Other
B. Model Runs/Execution	
Runs Depend Upon Other Data/Models/Products	Brief summary
Spatial Scales Used During Runs	Centimeters or smaller Meters Hundreds of meters Kilometers Other
C. Outputs	
Data Outputs for Each System	Includes: name of output, units of measure, valid data ranges, tolerance of uncertainty, frequency of output, other
Automated Data Export Capabilities	Brief summary
Number and Type of Dimensions for Outputs	Brief summary, e.g. 2-D space, 3-D space, etc.

Computational Space Used for Export	Brief summary, e.g. raster, vector, hexagon, TIN, point, etc.
Other Information on Outputs	Brief summary
Graphical Output Formats	Charts Graphs Maps VRML Other
Reports Provided as Output	Yes or No, default is No
Part 6 of 7. Detailed System Status and Computer Platform	
A. Detailed System Status	
Current Status of Product	Conceptual Prototype Operational Prototype Partial Operation Operational
Levels of Verification, Testing, Current Fed-erations	Brief summary
Date of Most Recent Product Release	Date format as 01-Jan-1999
Product Version Number and Features	Brief summary
Date of Next Scheduled Release	Date format as 01-Jan-1999
Expected Version Number and Enhance-ments	Brief summary
Available Source Code	Yes or No, default is No
Product as Public Domain or Freeware	Yes or No, default is No
Year 2000 Compliance	Yes or No, default is No
B. System Platform Requirements	
Primary Operating System	DOS™ Windows 3.1™ Windows 95™ Windows 98™ Windows NT™ UNIX™ Other, explain
Minimum Target Computer Processor Speed	100 Mhz or lower 200 Mhz 300 Mhz Greater than 300 Mhz Other, explain below
Minimum RAM Required	16 MB or lower 32 MB 64 MB 128 MB Greater than 128 MB Other, explain below
Minimum Mass Storage Memory Required	250 MB 1 GB

	10 GB Greater than 10 GB Other, explain below Additional comments
Additional Information on Computer Platforms	Brief summary
Part 7 of 7. Help Features, Technical Support and Training	
A. Documentation	
On-line User Help System	Yes or No, default is No
References or Explanations on Products	Yes or No, default is No
B. Technical Support	
Support Hot-Line	Yes or No, default is No
Discussion Group or Automated Bulletin Board	Yes or No, default is No
Support through Academic, Commercial, or Other Sources	Yes or No, default is No
C. Training	
Classroom Training Available	Yes or No, default is No
Other Types of Training	Brief summary, e.g. on-line or paper tutorials, on-site training, etc

Acronyms

AEC	Army Environmental Center
ARAMS	Army's Risk Assessment Modeling System
ATTACC	Army's Training and Testing Area Carrying Capacity
CADD	Computer Aided Design and Drafting
CAX	Combined Arms Exercise
CERD	Corps of Engineers Research and Development Directorate
CERL	Construction Engineering Research Laboratory
CHL	Coastal and Hydraulics Laboratory
CRADA	Cooperative Research and Development Agreement
CRREL	Cold Regions Research and Engineering Laboratory
COTS	Commercial Off-the-Shelf
CTT	Conservation Technology Team
DENIX	Defense Environmental Network Information eXchange
DIAS	Dynamic Integrated Architecture System
DMSMART	Dredge Materials Smart Management System
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DRD	Director of Research and Development
DSS	Decision Support System
DTED	Digital Topographic Elevation Data
DTO	Defense Technology Objective
EDYS	Ecological Dynamics Simulation Model
EIS	Environmental Impact Statement
EL	Environmental Laboratory
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ESRI	Environmental Systems Research Institute
FHASM	The Fort Hood Avian Simulation Model
FY	Fiscal Year
GIS	Geographic Information System
GOTS	Government Off-the-Shelf
GMS	Groundwater Modeling System
GRASS	Geographic Resources Analysis Support System
GUI	Graphical User Interface
HEC	Hydrologic Engineering Center
HLA	Higher Level Architecture
HMS	Hydrologic Modeling System
HPC	High Performance Computing

ICBM	Individual Cowbird Behavior Model
IDLAMS	Integrated Dynamic Landscape Analysis and Modeling System
IPR	In-progress Review
ISTAB	Installation Spatial Technology Advisory Board
ITAM	Integrated Training and Testing Area Management
ITL	Information Technology Laboratory
IWR	Institute for Water Resources
LMS	Land Management System
MACOM	Major Command
MCAGCC	Marine Corps Air Ground Combat Center
MGE	Microstation GIS Environment (Intergraph)
M&S	Modeling and Simulation
MVP	Mississippi Valley Division, St. Paul District
NATO	North Atlantic Treaty Organization
NEPA	National Environmental Policy Act
NEXRAD	Next Generation Weather Radar
OGDI	Open Geospatial Database Interchange
OGIS	Open Geodata Interoperability Standards
O&M	Operations and Maintenance
ORNL	Oak Ridge National Laboratory
PDM	Product Development Manager
POC	Point of Contact
PRISM	Planning and Resource Integration Stewardship Modules
PSEA	Predictive System for Environmental Assessment
RAS	River Analysis System
RDBMS	Relational Database Management System
REEGIS	River Engineering and Environmental Geographic Information System
R&D	Research and Development
RFMSS	Range Facility Management Support System
RUSLE	Revised/Universal Soil Loss Equation
S&T	Science and Technology
SED2D	2-Dimensional Sediment Transport Numerical Model
SERDP	Strategic Environmental Research and Development Program
SIMWE	Simulation of Water Erosion
SME	Spatial Modeling Environment
SMS	Surface water Modeling System
SWARM	A simulation modeling environment (models objects as a swarm)
TEC	Topographic Engineering Center
TES	Threatened and Endangered Species
TT	Technology Transfer
TUDS	Training Use Distribution Model
UMRS	Upper Mississippi River System
USACE	United States Army Corps of Engineers
USACERD	United States Army Engineer Research and Development Center
USDA	United States Department of Agriculture

USGS	Unites States Geological Survey
VRML	Virtual Reality Modeling Language
WCDS	Water Control Data System
WES	Waterways Experiment Station
WMS	Watershed Modeling System
WRSC	Water Resources Support Center

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