APPLICATION OF REMOTE SENSING TECHNOLOGY TO MONITORING THE SHORE-LINE DYNAMICS OF SEASHORE PARKS

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1. Introduction

This paper presents the basic elements of a study design for investigating the applicability of remote sensing technology to a complex task: monitoring the status of and changes to the marine and terrestrial environments of seashore parks. Major components to be considered in the formal study and subsequent, associated testing and evaluation activities are:

a) A large-scale system for monitoring spatial shore line dynamics;

b) Appropriate base-line data to support the development and application of critical indicators in a shore-line hazards management system;

c) A coarse system to evaluate oceanic and meteorological disaster warning signs; and

d) A geographic information system with multiple source imputs, including remote sensing imputs, to support a seashore park monitoring (and management) system.

Included in the design package are indications of the resources (projects/studies, personnel) required to elaborate and execute the proposed study. The resources estimates are intended to provide the U.S.

National Park Service with a basis for considering the design study proposal in the context of such evaluation criteria as costs(fixed and variable), technologic and scientific utility, and personnel (operational)and management obligations required to conduct the project[1].

2. Feasibility of Using Remote Sensing Technology (RST) to Monitor Shore-line Dynamics of Seashore Parks

Remote sensing technology (RST) has been the subject of research in a variety of contexts and situations, and has been successfully introduced as a sole, complementary or corroborative source of data for many applications[2]. However, based on the literature, and information obtained from practitioners, very little research has been undertaken that bears specifically on the study design task under consideration. With regard to the feasibility of using RST to monitor shore-line dynamics, therefore, the proposed study design is advanced more in terms of principles and surrogates than tested, direct precedents.

Shore-lines are the interface or interaction zone between water and land, and their constituent parts. As a result, both the feasibility assessment and study design must reflect the presence of two very different study area environments.

In general, the major off-shore or water-oriented agents or factors of shore-line dynamics include currents, drifts and wave action, and their impacts are reflected in large part by the movement of materials.

As noted in the literature, and particularly in the Manual of Remote Sensing, each of the above agents of shore-line change has been considered in terms of susceptibility to analysis and monitoring of activity and impact by remote sensing means. Although the reported investigations vary significantly in terms of focus, scope and depth, type of sensor used, location of test sites and other features, it is regarded as demonstrated that the off-shore or water-oriented aspect of shore-line change can be analyzed and monitored by RST.

With regard to the on-shore or land-oriented aspect of shore-line dynamics, primary agents or factors of change are associated with human activity. This activity is expressed through recreational use of the seashore park area proper, as well as near-park residential, commercial and industrial activities which have park impacts. While there are apparently few (if any) reported attempts to monitor this aspect of seashore park dynamics, numerous surrogates exist. Most noteworthy in this regard are remote sensing research and applications related to urban and regional environments, land, forest, and range resources, and coastal environments[3]. It is regarded as demonstrated, therefore, that both the on-shore or land-oriented aspect of shore-line change can be monitored by RST.

The final consideration in terms of the feasibility of monitoring shore-line dynamics by remote sensing methods concerns the natural and built environment of the parks, that is, the various marine and terrestrial communities and structures which comprise the parks. Again, as thoroughly summarized in the Manual of Remote Sensing, the coastal zone environment and its constituent parts have been subjected to considerable remote sensing-based analysis. It follows, therefore, that the shore-lines of seashore parks, as parts of the larger coastal milieu, are susceptible to inventory, assessment and monitoring by RST.

With the foregoing observations as grounds for concluding that the proposed investigation is a feasible enterprise, the elements of a study design to examine the applicability of RST to monitoring the shore-line dynamics of seashore parks are presented.

3. Study Design - General Considerations, Specific Concerns

An organizing framework for the study is provided by Figures 1 and 2. Figure 1 deals with the total system; Figure 2 illustrates the detail work that will be involved in elaborating the data base development/shore-line monitoring capability which ties together the remote sensing and field survey/observation methods of data acquisition and change detection, analysis and monitoring.

All of the "boxes" and "flows" (shown as directed arrows) in Figure 1 and many of the boxes and flows in

Figure 2 require detailed elaboration before the study mission is launched. However, a number of the key design and major resource allocation concerns can be covered off by discussing a selected set of the boxes and flows.

First, because of the variety which characterizes coastal environments in general, the areas of study should be multiple. In particular, the sites should reflect major differences with respect to their marine and terrestrial communities, oceanic and meterological factors, kind and degree of recreation use, and the situational aspects of the parks vis-a-vis extra-park land use activities which have current (and potential) impacts on the parks' shore lines.

Second, the full range of RST should be considered in terms of contributions (known and potential), to the monitoring system. History has taught us (if belatedly) that the process of data base development at the data specification stage proceeds most rationally over the long-term when the data base evolves in a manner which has real-time sensitivity to the data acquisition capability. Since the data base (elements,items, formats) for the monitoring system (including the spatial dynamics, hazards management and disaster warning sub-systems) remains to be defined, the systems design should include consideration of all RST options. As a result, during the preliminary stages of investigation at least, the design framework should incorporate photographic systems, electro-optical remote sensors, imaging and non-imaging sensors and microwave sensors operating from the full range of sensor platforms.

Third, problem formulation and articulation will determine the data specification (requirement) element of the monitoring system; the capability to acquire data by remote sensing and other means will determine (as the converse to point two above) the extent to which data needs are satisfied. As a result, investigation of the intimate relationship between methods of data acquisition and their respective "yields" (in terms of meeting data needs) must be reflected in the systems design.

As shown in Figure 2, there are at least two distinct (but not mutually exclusive) methods of data acquisition, that is, the "non-contact" method of RST, and the "contact" method with enumerators, surveyors, etc. making field observations. Since the data base will be fluid at the outset of the study and data characteristics (timeliness, accuracy, reproducibility,etc.) yet to be confirmed in terms of necessity or relative importance, it will be necessary to design into the study evaluation of both methods in terms of their respective and combined contributions to the monitoring system and sub-systems.

The fourth major study design concern involves a classic systems problem: establishing the trade-off envelopes and decision points for choosing between or combining alternative data sources (remote sensing, conventional) for a geo-based information system which may be function-oriented, provision-oriented or a combination of the two. In this case, since both monitoring (of spatial shore-line dynamics) and evaluation (of oceanic and meteorological disaster warning signs) are part of the overall system design, it appears that a dual capability (functional/provisional) may be required.

Further, and with regard to the data processing capability, it will be necessary to relate the characteristics of the capability to the different types and quantities of data which can be obtained from the respective data source methods. Clearly, in relative terms, the data processing (extraction/receipt, storage, retrieval, manipulation) load of the RST approach has the potential to be far in excess of the load associated with the conventional approach of field observation. By way of illustration, a single 24 x 24 cm photo frame with 64 distinguishable tones for resolution elements of .01 mm^2 has an information capacity of roughly 35 million bits[4]. It is highly unlikely that any field observation activity in a seashore park would, in an operational sense, even begin to approximate the data processing burden that could be associated with even one photographic image.

As noted earlier, all of the boxes and flows in Figure 1 and most of them in Figure 2 would require elaboration during nuts-and-bolts stage of study design. The proceeding discussion sets out in an illustrative manner several of the major design issues that characterize and influence the possiblities and constraints which can be designed into and out of the system. The next section of the paper adds a "reality" dimension to the design study by identifying key chunks of resources (projects/studies, personnel) required to carry out the systems design activity.

4. Resources Required To Conduct The Study

In order to allocate resources in a system sense it is necessary to isolate the major design components, and to then bring components and costs together as a coherent whole. Given that the success of the mission will be very much dependent upon how well and how vigorously the project is managed, a lesson from prior design studies warrants attention: numerous systems efforts in principle quickly and irrevocably deteriorate into a bundle of unrelated initiatives and activities in practice. As a caveat of sorts, therefore, and this situation was observed in previous papers[5], proposed expenditures of financial and personnel resources should be undertaken on the understanding that there are interdependencies which, if not respected, will seriously jeopardize the mission.

In very brief terms, the design effort must recognize the interdependencies between the conceptualization, design, development, implementation, and maintenance stages of an evolving (spatial) information system. Further, there are five (5) phases of activity to be explicitly acknowledged within each of the stages: data specification; data acquisition; data processing(imput, storage, retrieval, manipulation, output); data dissemination; and data application. (Figure 3)

A key element of the study design, therefore, is a management and oversight unit which is charged with ensuring the systems integrity of the study, including the preparation and application of project evaluation criteria and procedures.

In terms of primary components of the design study,the following are those which will require major allocations of resources (funds, equipment, and personnel):

a) Specification of the data base or bases (elements, items, formats) in terms of uses and priorities for which data are intended for management, planning, operation and research purposes;

b) For multiple seashore park situations, and based on data requirements from (a) above, development of procedures for comparing the field observation and RST methods of data acquisition in terms of unique and relative advantages in the context of inventory, monitoring and assessment requirements for both dedicated and general-purpose systems;

c) Starting with the data base characteristics (type of data, quantity of data, data medium, etc.) from (a) and (b), and utilizing lessons learned from previous research and applications which have merged conventional and remote sensing source data in spatial information systems, documentation of the technical and operational possibilities and constraints (for both hardware and software) which will most likely characterize the several monitoring systems capabilities that will arise as options for accomodating the applications ((e) below) that might be designed into the system;

d) For the provision-oriented dimension of the monitoring system, including the delivery of data (dissemination) in a jurisdictional and/or functional environment, identification of users, users' needs, and alternative and appropriate mechanisms and media for the transmission of data information to users;

e) Since the purpose and utility of the entire exercise is bound up in what the system yields in terms of benefits to the management, planning, operations and research functions, the intended or anticipated data applications must be rigorously considered with regard to why and how they will impact on policy, program, plan or project evaluation, initiation and/or modification.

It is essential, therefore, that the systems design include identification of clients for and uses of system outputs, and also incorporate procedures for determining, measuring and evaluating benefits and costs which accrue as a consequence of moving beyong design to the development, implementation and maintenance stages.

5. Conclusion

The systems design framework presented in this paper provides "talking points" and questions to be raised and answered before positions are hardened and the formal systems design study is launched. In particular, and this design consideration cannot be over-emphasized, the paper established that the task at hand is more to build on what is known than to work new ground(research, in its pure sense), and that too much rather than too little choice will pose a challenge throughout the design effort.

Finally, an overriding concern throughout the paper is to establish a basic design principle: the "machinery" or technology (hard and soft) component must be appropriate to policy, program, plan or project needs explicitly expressed by the client(s) for system outputs.

It was argued early in the paper that the research and applications track records speak favourably of the feasibility of incorporating multiple data source imputs in seashore park monitoring systems. It was also argued, explicitly and by implication, that in terms of achieving effectiveness, efficiency and economy during the design (and any subsequent) stage, undue attention to technical and technological detail will contribute more to the failure than to the success of the mission. That is, it is imperative, and there are many past and present evidences to support his contention, that elaboration of the purpose of the design effort in whole and in part receive at least as much continuing consideration by project sponsors as the "capability" will by technicians, technologists and researchers.

[1]The contents and thrust of this invited paper for Auto-Carto IV are based on general terms of reference contained in a communication from Robert Aangeenbrug, Symposium Chairman

[2]See, for example, Manual of Remote Sensing - Volume II - Interpretation and Applications (Falls Church, Va.: American Society of Photogrammetry, 1975); Proceedings, International Symposium on Remote Sensing of Environment (Ann Arbor, Michigan; Institute of Service and Technology, University of Michigan); Photogrammetric Engineering; Proceedings of the Urban and Regional Information Systems Association; and Papers, American Society of Photogrammetry.

[3]ibid

[4]Manual of Remote Sensing, op. cit., Vol. I, p.653

[5]B. Wellar, Data Standardization: Wichita Falls Consortium Phase II Report, Vol.7, Conceptualization Themes. (Springfield, Virginia: National Technical Information Service, 1970) and B. Wellar, "Data Acquisition: Base of Information Systems Development?" in Urban and Regional Information Systems: Past, Present and Future (Chicago, Illinois: URISA/Municipal Finance Officers Association, 1971).

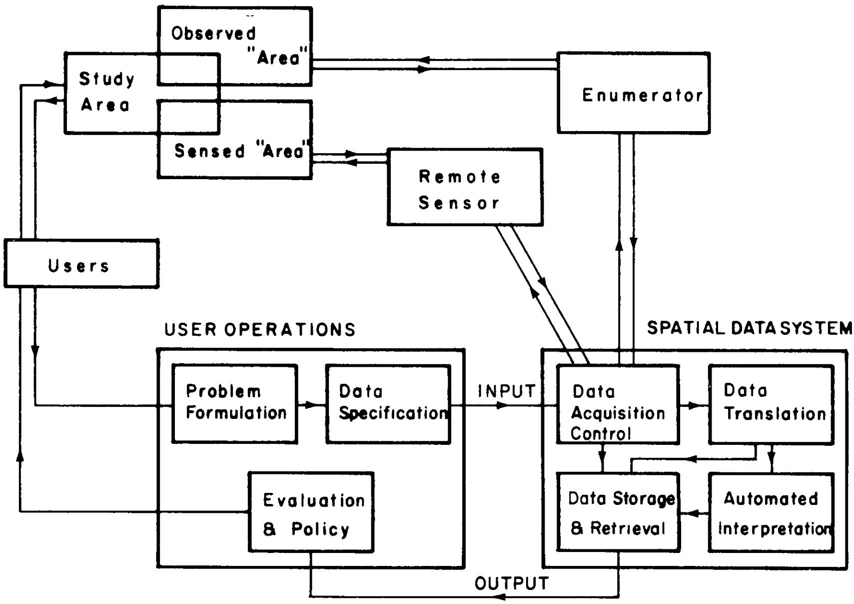

FIG. 1. A framework for the collection and processing of multi-source spatial data. (Adapted from E. Moore and B. Wellar, "Urban Data Collection by Airborne Sensor", Journal of the American Institute of Planners, 35, January, 1969, p. 38).

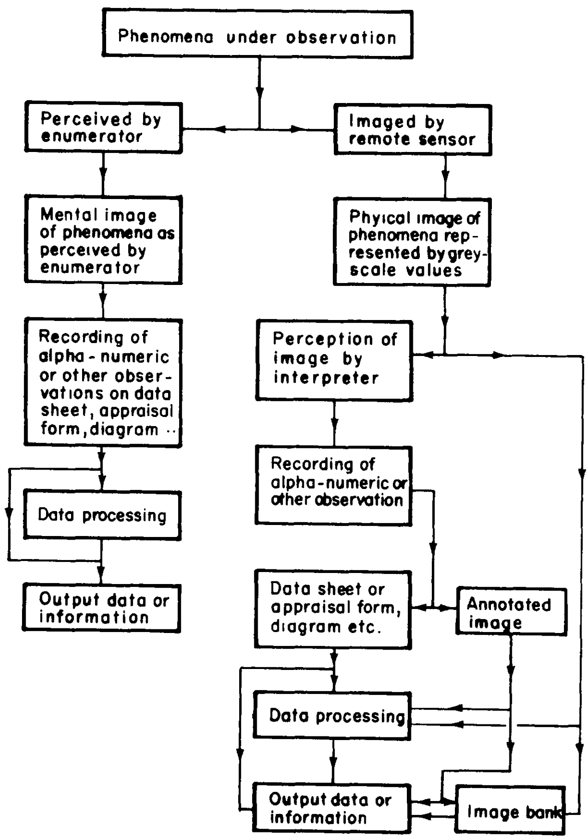

FIG. 2. Flowchart depicting relationships between contact and non-contact methods of data acquisition and development. (Source: B. Wellar, "Remote Sensing and Urban Information Systems", Photogrammetric Engineering, 1973, p. 1043).

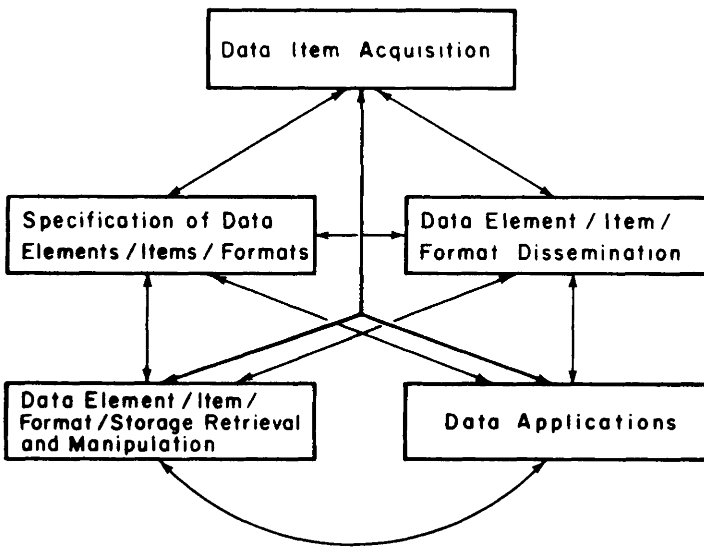

FIG. 3. Schematic Representation at an aggregate level of the bi-directional relationships between phases of data base development and maintenance.