# ASSESSING THE ROLE OF REMOTE SENSING INFORMATION FOR STREAMLINING ENVIRONMENTAL ASSESSMENT IN TRANSPORTATION

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## ABSTRACT

The U.S. Department of Transportation seeks to determine if remote sensing can contribute to streamlining the environmental assessment process. Environmental protection is accomplished through Environmental Assessments and Environmental Impact Statements (EIS) that seek to prevent adverse environmental effects from taking place rather than mitigating problems caused by past activities or practices. EISs are conducted in the context of an overall decision-making process that is inexact and fluid leaving significant latitude for the application of remote sensing as a supplemental or alternative source of environmental information associated with transportation development. Of the 25 environmental impact areas the FHWA recommends addressing in an EIS, 13 are good candidates for remote sensing in some capacity. In many cases, current "off-the-shelf" techniques can be utilized directly. In other cases, the assessment requirements dictate using newer data sets for which experience is limited or for which image processing techniques need to be refined or developed. However, these issues do not appear to be insurmountable obstacles. Perhaps the greatest challenge is in obtaining broad utilization and acceptance of remotely sensed imagery. Skepticism, unfamiliarity, cost, capital equipment and human resource needs are just of few of the anticipated impediments that must be addressed before broad utilization and acceptance can be achieved. In some cases, these impediments are real and substantial, but in many instances, they are fairly trivial. The NCRST-E is appropriately postured to provide the research and development and outreach services needed to raise remote sensing to the forefront of environmental assessment in transportation. The lessons learned over the last fifteen years with the implementation of GIS and GPS technology in transportation planning and engineering should be applied to remote sensing technology as well. A broad array of demonstration projects are needed, not simply to provide examples of remote sensing capabilities, but to engage the stakeholders in the process, assess the costs and benefits relative to performance indicators, and demonstrate overall the intrinsic value in accepting change.

## INTRODUCTION

Federal Highway Act of 1970 placed responsibility on the U.S. Department of Transportation (US DOT) Federal Highway Administration (FHWA) to fully consider adverse effects of transportation on community cohesion; public facilities; employment; tax and property values; displacement of people, businesses, and farms; and community and regional growth. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) requires transportation interests to recognize environmental values and incorporate environmental protection and enhancement measures into programs to develop and improve the nation's surface transportation system. In response to ISTEA, FHWA broadened its mission to reflect increasing interest throughout the nation in developing an environmentally sensitive transportation system. The renewed emphasis on the environmental and community impacts of transportation changed the framework of transportation planning and decision-making and vastly expanded the number of stakeholders who have an active interest in the FHWA's programs and policies.

A pervasive perception followed that the environmental process results in extensive delays and additional costs in completing transportation projects. Given widespread concerns about delays, duplication of effort, and additional costs associated with NEPA and other environmental review processes, under the heading of "Environmental Streamlining," Section 1309 of the Transportation Equity Act for the 21$^{st}$ Century (TEA-21, http://www.fhwa.dot.gov/tea21/) enacted in 1998 directed the US DOT to develop and implement a coordinated review process for construction projects. This review process applies to projects that require environmental assessments under NEPA, or any other environmental review, analysis, opinion, or issuance of an environmental permit, license, or approval by operation of federal law.

In response to Section 5113 of TEA-21, which requires the US DOT to establish a remote sensing applications program in the context of streamlining (http://scitech.dot.gov/reeng/sensmsrm/rmtsense/rmtsense.html), the US DOT, in cooperation with the National Aeronautics and Space Administration (NASA), sponsored a National Forum on Remote Sensing Applications in Transportation in May 1999 (Brecher, 1999; http://scitech.dot.gov/reeng/sensmsrm/rmtsense/sbrsmstr.html). The Forum defined five transportation priority areas with high payoff potential from remote sensing applications were identified: transportation planning, environmental impact assessment, hazard and disaster response and recovery, infrastructure management, and flow assessments (Brecher, 1999). In a follow-up workshop in August 1999, these priority areas served as the basis for a research framework for developing technology and applications focusing on commercial remote sensing products that can be implemented in transportation practices (http://www.cfm.ohio-state.edu/info/summary.html).

In order to determine potential applications of remote sensing as a source of measurements, however, we must carefully examine the context in which these measurements are applied. The context is comprised of environmental laws, the agencies that provide guidance in interpreting these laws, and the agencies that regulate and enforce the laws, and historical inertia. Inclusion of remote sensing measurements in the environmental assessment process requires some understanding of the responsibilities and organizational structure of agencies involved and the information from remote sensing must be in some way "better" than traditional sources of information before it will be embraced by planners, decision-makers, and other members of the transportation community. In this paper, I identify the environmental areas where remote sensing has the greatest potential as a supplemental source of geospatial information and characterize some of the obstacles that presently impede its full utilization.

## ENVIRONMENTAL ASSESSMENT

### NEPA

The National Environmental Policy Act of 1969 (NEPA) (42 USC § 4321, http://www.fhwa.dot.gov/environment/nepatxt.htm) marked the beginning of the environmental review process for all federal actions. The intent of NEPA is to ensure informed decision-making pertaining to environmental management by requiring the federal government to use all practical means and measures to create and maintain conditions under which people and nature exist in harmony. NEPA requires consideration of all relevant environmental consequences of proposed actions and involving the public in the decision-making process. Under NEPA, applicable projects are assessed in relation to the environmental conditions of the area, and the impact that various project alternatives would have upon those environmental conditions.

The Council on Environmental Quality (CEQ) was established by NEPA to oversee its implementation (40 CFR 1500-1508), and develops and recommends to the President national policies that further environmental quality, analyzes trends in the national environment, and appraises federal programs. The CEQ established detailed requirements for agencies to consider environmental impacts in their decision-making process (Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act, 40 CFR 1500-1508, 1986). The CEQ, however, is not a full regulatory body because it can neither veto nor control another agency's projects. Presidential Executive Orders (11514 and 11991), however, authorize the CEQ to issue regulations governing the EIS process and the procedural requirements for compliance with NEPA. Thus, CEQ regulations provide the basic framework for EIS regulations and the procedural requirements for compliance with NEPA. The regulations also required that federal agencies develop their own regulations to ensure that the agencies' decisions are made in accordance with the policies and purposes of the act. Consequently, agencies at the federal, state, and local levels have internal procedures, regulations, or ordinances that may have specific requirements that go beyond NEPA. CEQ has also issued several nonregulatory guidance publications on NEPA: Questions and Answers about the NEPA Regulations (1981), Scoping Guidance (1981), and Guidance Regarding NEPA Regulations (1983).

### Environmental Policy of the Federal Highway Administration

The FHWA's mission is to continually improve the quality of our nation's highway system and intermodal connections. One of its five strategic goals is to responsibly consider and evaluate all aspects of the environment throughout the highway planning, design, and development process. Accomplishments of the FHWA in environmental matters of the past decade are summarized on the FHWA web site (http://www.fhwa.dot.gov/environment/accomp/toc_intro.htm). In 1987, the FHWA's Office of Environmental Policy issued "Guidance for Preparing and Processing Environmental and Section 4(f) Documents" (T6640.8A, http://www.fhwa.dot.gov/

environment/nepa/ta6640.htm). This document is still the principle authority on environmental assessment today. During the 1990s, the FHWA's role broadened to reflect increasing interest throughout the nation in developing an environmentally sensitive transportation system. This shift occurred for several reasons, most importantly were the enactment of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21) in 1998. In enacting ISTEA and TEA-21, the U.S. Congress emphasized the need for an integrated and multimodal transportation system that reflects environmental sensitivity and community values. In 1998, the FHWA published a Strategic Plan for Environmental Research (1998-2003) that summarizes the key environmental research goals of the FHWA's Office of Planning, Environment and Real Estate Services (http://www.fhwa.dot.gov/environment/env_resh.htm). One of its strategic goals is to "protect and enhance communities and the natural environment affected by transportation."

## Other Agencies with EIS Responsibilities

The Environmental Protection Agency (EPA) was created to coordinate effective governmental action on behalf of the environment. The objective of the EPA is to control pollution through research, monitoring, establishing standards, and enforcement. The EPA also reinforces efforts among other federal agencies with respect to the impact of their operations on the environment, and is specifically charged with publishing its findings when it is determined that a proposal is unsatisfactory from the standpoint of public health or welfare of environmental quality. EPA has many responsibilities under several environmental laws. Agencies that most frequently deal with EIS processes are those that have planning and environmental responsibilities, such as land and natural resource management agencies, agencies involved in construction, permitting and licensing, and those that are a source of funding. Agencies that manage land or natural resources include agencies at the federal level, such as the Bureau of Land Management, U.S. Forest Service, National Park Service, American Indian tribes, and the military branches. Agencies involved in construction include the Army Corps of Engineers, Bureau of Reclamation, and the U.S. Department of Transportation. Agencies that issue permits and licenses subject to NEPA review include the land management agencies, U.S. Army Corps of Engineers, U.S. Coast Guard, and the Federal Energy Regulatory Commission. Agencies that provide funds include the Department of Transportation, Department of Housing and Urban Development, Economic Development Agency, and Federal Housing Administration. Although agencies with similar responsibilities comply with the same environmental laws, the internal policies and procedures for a particular environmental concern may differ from agency to agency.

## The Environmental Impact Statement

The terms "environmental assessment" (EA), "environmental impact assessment" and "environmental impact statement" are often used interchangeably to refer to the analysis of environmental impacts. An EA or EIS is both a process and the document that results from the process. An EA is prepared for proposed actions when it is not known *a priori* whether the proposal would result in significant impacts to the environment. An EIS serves as an evaluation of whether a proposed project is consistent with the objectives of the regulatory agency whose responsibility it is to manage the resource. The EIS process is forward-looking and seeks to prevent adverse environmental effects from taking place rather than mitigating problems caused by past activities or practices. The process requires us to take a hard look at the benefits and consequences of our actions on the environment. The EIS process is part of governmental planning and is affected by environmental laws and regulations that control land use (including air and water), the use of natural resources, and pollution, such as the Endangered Species Act, the National Historic Preservation Act, the Clean Water Act, etc. An EIS discloses the laws and regulations that are applicable to a proposed action and states whether and to what degree a proposed action would comply with these laws. Compliance with regulations, however, does not take place via the EIS. The only law an EIS complies with is NEPA or a comparable state law (a SEPA). Environmental regulations are written broadly because they apply to a wide range of agencies. Thus, they provide agencies wide latitude in their EIS methodologies and processes. Most agencies with EIS responsibilities have detailed EIS procedures. Since 1970, guidelines and regulations have provided the basic requirements for preparation of an EIS, but a great deal of flexibility, as well as ambiguity, is also in the regulations. Inconsistencies between plans and policies are disclosed in an EIS, but it is more beneficial if the inconsistencies are resolved. The EIS, therefore, provides motivation for dialogue among interested parties. EISs are prepared early in the planning process, so that modifications can be made to the project based on findings resulting from the assessment phase that would reduce the impacts of the proposed action to the point where further modifications would become difficult to accommodate. The courts have provided interpretations of the regulations, clarifying some parts while leaving other parts ambiguous. In some cases the courts have made conflicting decisions. Thus, over the course of the last 25 years, individuals who have managed and prepared EISs have developed their own style and method of EIS preparation that work best for them (Kreske, 1996).

EIS's have been produced since the early 1970's and one of the largest collections of environmental impact statements is available at the Transportation Library of Northwestern University (http://www.library.northwestern.edu/transportation/ searcheis.html). EIS's are also listed on the EPA Office of Federal Activity's web site by date of distribution (http://www.epa.gov/oeca/ofa).

## STREAMLINING THE EIS PROCESS WITH REMOTE SENSING

Environmental streamlining is the term used for a new way of doing business that brings together the timely delivery of transportation projects with the protection and enhancement of the environment. Because major transportation projects are affected by dozens of Federal, State, and local environmental requirements administered by a multitude of agencies, improved interagency cooperation is critical to the success of environmental streamlining. Streamlining initiatives have been conducted at the state, regional, and national levels. A memo describing FHWA action on streamlining is available at http://www.fhwa.dot.gov/environment/strmlng/eismemo.pdf and an overview of FHWA streamlining efforts can be found at http://www.fhwa.dot.gov/environment/strmlng/ overview.htm where information is also available about efforts going on at the individual state level.

### Remote Sensing as an Information Source

Although there is limited information to form a basis, it is generally assumed that greater efficiency in acquiring and analyzing data used in EIS preparation, and better data standards, would reduce EIS preparation time and possibly results in less controversy over the report's findings. EISs are dependent on geospatial information in order to make an assessment. High-quality databases that are maintained with current or frequently updated geospatial information would streamline road development projects. Data from remote sensing systems on aircraft or satellite platforms is a potential source of geospatial information. Remote sensing has numerous advantages over traditional data sets. Determining whether or not remote sensing can be used requires a thorough understanding of what information is needed.

Whereas geographic information system (GIS) data and aerial photography have been a staple for environmental assessment for two decades or more, digital imagery from aircraft- and satellite-based sensors is a relatively new source of information to the transportation industry. Remote sensing has numerous advantages over traditional data sets—it is unobtrusive; one can collect information simultaneously over a broad range of the electromagnetic spectrum; it is capable of making biophysical measurements; information can be acquired through clouds at long wavelengths; data can be collected in a very short timeframe with aircraft platforms and frequently with satellite platforms; data collection procedures are systematic thereby eliminating sampling bias introduced in some investigations; and analysis methods are relatively robust, objective, and repeatable. This is not to say that remotely sensed data necessarily replaces existing data sets, but in many cases it provides supplemental information that can lead to improved assessments. Comprehensive planning required to implement "smart growth" initiatives at local and state levels, road design that uses land cover data and digital terrain models, and emergency management are all enabled by archived and/or current satellite data. Temporal analysis of imagery data allows the calibration of transportation policy alternatives and identification of future trends using modeling.

The extent to which remote sensing can be used for transportation-related assessments requires a thorough understanding of what information is needed. Transportation projects proceed through several phases that require four distinct levels of accuracy and the nature of the information required in each phase is quite different. Planning and environmental assessment are transportation priority areas with high payoff potential for remote sensing. Imagery, in general, can aid in informing the public of the proposed action and facilitate engaging the public in the EIS process during the scoping phase. The pre-construction planning, siting, and design phase of any project requiring an EA or EIS is conducted in the context of environmental laws, agencies that provide guidance in interpreting these laws, and agencies that regulate and enforce the laws. There are no rules *per se* as to how to conduct an environmental assessment. The particular objective of each assessment dictates on a case-by-case basis what information and analyses are required. The FHWA has identified the expected content of environmental documents. There are no requirements defining how the evaluation must be conducted or what data sets and analyses must be utilized for the assessment. It recommends, however, that "the information should have sufficient scientific and analytical substance to provide a basis for evaluating the comparative merits of the alternatives," and should contain "sufficient supporting information or results of analyses to establish the reasonableness of the conclusions on impacts." The decision about which data sets to use in an assessment is initially left to the discretion of the consulting firm or lead agency that conducts the assessment. Ultimately, in the case of transportation projects, the decision rests with the FHWA, which must approve the EA or EIS.

**Use of Remote Sensing in the Planning Phase**

Planning is based on knowledge about the current state with some prediction as to how the state will change in the future. For long-range transportation planning by Federal, State, or metropolitan planning organizations, the information requirements may be less stringent as the focus is on characterizing general trends. Predicting the future is more precise if it is based on the historical trend projected through the present (Figure 1). The outcome of this process is to obtain a metric on trends and to steer thinking and planning activities internal to the organization. The accuracy of the prediction depends on the analysis method employed. Linear trends can be defined based on the difference between maps at two points in time. Alternatively, computational models can be employed to define more complex trends as well as the interaction among variables. Generally, however, data used for planning purposes is not required to meet precise accuracy standards.

Environmental or development planning requires geospatial information about the distribution of landscape features. Maps, and to some extent aerial photographs, are the traditional sources of this information. Remote sensing offers tremendous potential for planning purposes because it not only affords a picture of the current state, but unlike aerial photographs, multispectral data can be used to provide information classes, such as land cover and land use. Continuity in temporal classification of land cover and its extension to land use could play a significant role in preparation of a comprehensive development plan and would be invaluable in the planning stage of road development projects.

Data from the Landsat satellite program are invaluable sources of information for regional- and some local-scale planning. The Multispectral Scanner (MSS) on Landsat-1 began collecting data in 1972 and was followed by the Thematic Mapper (TM) on Landsat-4 in 1982 and the Enhanced Thematic Mapper Plus (ETM+) on Landsat-7 in 1999. These instruments have provided a continuous record of the terrestrial globe throughout this period. At 80 m (MSS) and 30 m (TM, ETM+) resolution, it is appropriate that these data only be used to map the distribution of features larger than about 100 m in size. As such, they are quite suitable for mapping natural resource features, such as evergreen and deciduous forests, pasture, cropland, residential and industrial areas, water bodies, etc. Unprocessed, “raw” Landsat data going back to 1972 can be purchased over the internet from the U.S. Geological Survey. There are also a number of public domain land cover data products available via the internet. High resolution commercial remote sensing data at 4 m resolution or less is extremely valuable for local scale planning. Although these data do not show as much detail as aerial photography, their multispectral characteristics can be fused with higher resolution panchromatic data resulting in information classes with high interpretive value.

**Use of Remote Sensing in Environmental Assessment**

The bulk of the FHWA’s “Guidance for Preparing and Processing Environmental and Section 4(F) Documents” (FHWA, 1987) comprises a list of 25 areas with "potentially significant impacts most commonly encountered by highway projects." A number of these areas were identified at the December, 2000 Transportation Research Board Conference on Remote Sensing and Geospatial Technologies as high priority areas in need of improved or alternative information sources. Many of these application areas are discussed in some detail below.

***Land Use Impacts***. FHWA guidelines require that proposed actions be put into the context of current development trends. The EIS must also identify the state and/or local government plans and policies on land use that will be impacted. These plans and policies are normally reflected in the area’s comprehensive development plan. The EIS land use discussion should address the consistency of the proposed alternatives with the comprehensive development plans and other plans used in the development of the transportation plan required by Section 134.

Partitioning of spectral information into land cover classes has been a long-standing application of remote sensing with multispectral sensors. Trends are defined with multitemporal geospatial information. Although it is not a trivial task, land cover information can be married with socio-economic information so that it can be translated into land use information. Landsat data at 30 m resolution is suitable for relatively general natural resource classes, such as softwood and hardwood forests, pasture, cropland, residential and industrial areas, water bodies, etc. The U.S. government has funded the Landsat program continually as part of an on-going mapping program and data are relatively very inexpensive. New commercial remote sensing data providers have targeted a market for high resolution multispectral data. These data are therefore better suited for mapping more detailed land cover/land use classes. Unlike Landsat data, commercial data is available through targeted acquisitions, i.e., acquisitions must be scheduled in advance for acquisition on a particular date for a specified area. Consequently, there is no archive of historical data from which to develop trends. Given the newness of commercial remote sensing data, there is still some uncertainty among image analysts who have little experience with these data as to whether existing image processing software has the tools necessary to extract the feature information of interest. Improvements in image analysis techniques may be required to take full advantage of these data.

The Army Corps of Engineers plans to utilize remote sensing in the Joint Rapid Airfield Construction project that the military intends to implement by 2003. This program seeks to use remotely sensed land cover and digital elevation model (DEM) data for rapid runway development. Remote sensing will be used for rapid site selection, quick assessment of runway stabilization issues, define opportunities to improve existing sites, and for better slope characterization. Other applications of land cover information include characterizing impervious surfaces. The distribution of impervious surfaces is valuable to hydrologic studies and analysis of storm water runoff.

***Farmland Impacts.*** The Farmland Protection Policy Act of 1981 has as its purpose "to minimize the extent to which Federal programs contribute to the unnecessary and irreversible conversion of farmland to nonagricultural uses…" Identifying farmland is partially based on defining what is not farmland by noting areas designated as urban on U.S. Census Bureau maps, U.S. Geological Survey topographic maps, and U.S. Department of Agriculture (USDA) Important Farmland maps or where USDA Natural Resources Conservation Service (NRCS) soil survey maps have designated the area as developed having low farmland potential. Farmland must be characterized as 1. prime, 2. unique, 3. other that is of statewide significance, and 4. other that is of local significance, and EIS preparers are instructed to consult with the NRCS where farmland may be impacted. If farmland may be impacted by a proposed project, the EIS should contain a map showing the location of all impacted farmland, discuss impacts associated with each alternative, and identify avoidance or reduction measures. The characterization of farmland quality is a designation made by the NRCS based on topography, soils, and lack of development. Land use information from classified remote sensing data would be useful in developing maps of the impacted farmland (base map) in relation to adjacent land and proposed alternatives (vector overlays).

***Coastal Zone and Barrier Impacts***. The Coastal Zone Management Act requires states to develop a Coastal Zone Management Plan approved by the U.S. Department of Commerce to protect coastal zones. Likewise, the Coastal Barriers Resource Act (FWS, 1983; http://www.fhwa.dot.gov/environment/guidebook/vol1/ doc2b.pdf) protects coastal barriers. When coastal zones are impacted by proposed projects, the EIS must show evidence that there is coordination with the State Coastal Zone Management agency or appropriate local agency. If the preferred alternative is inconsistent with the Coastal Zone Management Plan, the project can be federally funded only if the Secretary of Commerce determines that the proposed action is consistent with the purpose or objectives of the Coastal Zone Management Act or is necessary in the interest of national security. Where coastal barriers may be impacted by proposed projects, the EIS should include a map showing the relationship of each alternative to the barrier units (FWS, 1983).

Coastal environments are very dynamic and virtually any map is likely to be out of date in a short amount of time. Remote sensing offers the ability to rapidly update maps of the coastal environment with current information and to document the temporal history of coastal dynamics. These same data can provide a base map of current coastal zone configuration upon which management plan information, barrier delineation, and alternatives can be shown.

***Floodplain Impacts***. The FHWA floodplain encroachment standards were issued in 1979 and are regulated by 23 CFR 650A. The FHWA requires using National Flood Insurance Program (NFIP) maps to determine whether an alternative will encroach on the base (100-yr) floodplain. Three types of NFIP maps are available: a Flood Hazard Boundary Map, a Flood Boundary and Floodway Map, and a Flood Insurance Rate Map (FHWA, 1982a). If NFIP maps are not available for the project area, information developed by the lead agency may be used. This implies that NFIP maps are the standard for floodplain mapping; there is some uncertainty whether this language implies that the NFIP maps should be used regardless of whether the lead agency can produce more accurate information. Draft EISs should include exhibits of the base floodplain with alternatives. Flooding risk, impacts and efforts to minimize impacts should be defined. Encroachment on a regulated floodway as the only practicable alternative must comply with 23 CFR 650 and Executive Order 11988 (http://www.fhwa.dot.gov/environment/guidebook/ vol1/doc6f.pdf). The FHWA recognizes the NFIP standard that provides for up to a 1-foot increase in flood stages when designating a floodway or evaluating an encroachment where no floodway is designated. This standard is established as the Federal standard under Executive Order 11988, Floodplain Management, and is to be used in designating highways in NIFP mapped floodplains (FHWA, 1986a, b). Coordination with FEMA and appropriate state and local government agencies should be undertaken in situations where administrative determinations are needed involving a regulatory floodway or where flood risks in NFIP communities are significantly impacted (FHWA, 1982b). Floodway revision should include evidence from these agencies supporting the revision. Local hydraulic studies are required and usually involving some form of modeling.

Floodplain delineation relies on topographic information. Light Detection and Ranging (LIDAR) and Interferometric Synthetic Aperture Radar (IFSAR) are two relatively new remote sensing technologies that offer an alternative to *in situ* field surveys and photogrammetric techniques for the collection of elevation data. Although these techniques are relatively complex, they provide timely data with vertical accuracies better than standard topographic maps and comparable to or better than photogrammetric techniques (Flood and Gutelius, 1997). LIDAR and IFSAR are capable of vertical accuracies of about 0.1 to 2.0 m root mean square error. These systems operate from airborne platforms in which Global Positioning Systems (GPS) are an integral part. These data would meet basic requirements for floodplain mapping. A comprehensive Digital Elevation Resource Directory can be found in a recent supplement to Geospatial Solutions and GPS World (Barnes, 2001) and a new text provides a comprehensive guide to DEM technologies (Maune, 2001).

***Wetland Impacts***. The U.S. Army Corp of Engineers, Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Department of Agriculture Food Security Act of 1985, Emergency Wetland Resources Act of 1988, all have unique definitions of wetlands. Section 777.11(b) of 23 CFR states that the FHWA will use the definition adopted by the U.S. Army Corps of Engineers (33 CFR 323.2(c)) in its administration of the Section 404 permits. This definition of jurisdictional wetland requires the presence of hydric soils, hydrophytic vegetation, and periodic inundation or saturation. The Army Corps of Engineers (COE), U.S. Environmental Protection Agency (EPA), and other agencies using the Federal Manual (FICWD, 1989) or the COE Wetland Delineation Manual (USACE, 1987) use this definition.

The COE issued a national delineation manual in 1987 and revisions in 1989 and 1991. Because of controversy regarding the revised manual, the National Academy of Sciences through a committee formed by the National Research Council was tasked with reassessing the adequacy and validity of wetland definitions. The committees report is expected to have a role in changes to the Federal wetland regulatory program in the near future. In the meantime, the FHWA recommends using the methodology described in reports FHWA-IP-82-23 and FHWA- IP-82-24, "A Method for Wetland Functional Assessment Volumes I and II" in wetlands delineation and analysis. The FHWA is also considering a hydrogeomorphic approach to wetlands assessment being developed by the COE (http://www.fhwa.dot.gov/environment/guidebook/ vol1/doc14i.pdf).

Current practice in wetland assessment is to deploy a field team consisting of a biologist and soil scientist. These individuals assess hydrology, soils and vegetation while boundary positions are identified and recorded with a differential GPS. The upper root zone or top 30 cm of wetland soils must be saturated for 12% of the annual growing season (~14 days) on more than 50% of growing seasons. These numbers vary slightly with geography. Vegetation and soil moisture needs to be documented almost on a daily basis during a critical period in the phenological cycle to determine if the 12% criterion is met. Wetland boundaries are delineated to an accuracy of about 1 m and an areal accuracy of 1/100$^{th}$ of an acre (40 $m^2$). Use of aerial photography is common, but is used less for interpretation than as a reference base map. Digital orthophotographs may also used.

Application of remote sensing imagery for wetland assessment is a challenging problem. Water can be easily distinguished from adjacent terrain using multispectral imagery and synthetic aperture radar (SAR). Delineation requires 1 m resolution with 1 m positional accuracy. Presently, multispectral imagery is available at 2.5-4 m resolution. C band SAR data are presently available from satellite at 20 m resolution and X band SAR data are available from aircraft at 4 m resolution. Because water levels in a wetland fluctuate, the inundated area changes size and shape. The challenge is to acquire imagery early the growing season (preferably before complete canopy closure from leaf emergence) during maximum inundation. When wetland soils saturate from a slowly rising water table, there may not be any noticeable surface water. In this situation, multispectral remote sensing may not be of any utility. Significant progress has been made in past decade with regards to passive microwave remote sensing of soil moisture, but this technology is still too crude for application at the scale and sensitivity of this problem. In time, soil moisture remote sensing may become a significant resource. In some cases, wetlands are distinguished from the surrounding terrain on the basis of one to a few plant species. Even at 2.5 m resolution, imagery may be too coarse to characterize wetland vegetation. Where an assemblage of plant species characterize a wetland, multispectral or hyperspectral imagery at 2.5 to 4 m may be sufficient to aid in delineating the wetland. High-resolution digital elevation data may also play a role in wetland delineation. If the boundary of a wetland can be delineated at several points, a digital elevation model can be used to estimate the perimeter ("water line") of the inundated area or area of saturated soil. The most probable application is some combination of the above methods. Although remote sensing will not replace the need for field validation, it may significantly reduce the number of man hours required.

***Water Body Modification and Wildlife Impacts***. For projects that require modifications of existing water bodies, the Draft EIS should contain exhibits and discussion identifying the location and extent of water body modifications (e.g., impoundment, relocation, channel deepening, filling, etc.) and the resulting wildlife impacts. Coordination efforts with appropriate Federal, State and local agencies should be documented, i.e., Fish and Wildlife Coordination Act of 1958. Remote sensing images could be used as reference base maps showing current location/shorelines of water bodies overlaid with proposed modifications. These maps could contain land cover and/or wildlife habitat information derived from multispectral imagery.

***Threatened or Endangered Species Impacts***. Threatened or endangered species are regulated by 50 CFR 402.12(c) and 16 USC 1536, Section 7 of the Endangered Species Act. A project is not eligible for federal funding if it does not comply with the Endangered Species Act or obtain an exemption. The lead agency must consult with the Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) to determine the presence of listed and proposed threatened or endangered species, and designated and proposed critical habitat in the proposed project area. The information regarding these species may be from a published list of species or critical habitat, a project-specific notification of a list, or substantiated information from other credible sources. When a proposed species or a proposed critical habitat may be present in the proposed project area, a biological assessment is made on the potential impacts to identify whether any such species or critical habitat are likely to be adversely affected by the project. This should be done in cooperation with the FWS and NMFS. In accordance with the Endangered Species Act, if the project is likely to jeopardize the continued existence of any proposed species or result in the destruction or adverse modification of proposed critical habitat, the lead agency, in consultation with the FHWA, must confer with FWS and/or NMFS to attempt to resolve potential conflict. Also, if a listed species or a designated critical habitat may be present in the proposed project area, a biological assessment must be prepared to identify any such species or habitats which are likely to be adversely affected. The biological assessment must summarize data regarding, among other things, the species distribution, habitat needs, and other biological requirements; the affected areas, etc. The Draft EIS should include exhibits showing the location of the affected species or habitat.

Except for shallow water estuaries and coastal zones, remote sensing of marine habitat is limited. On the other hand, remote sensing of terrestrial habitats holds much promise. Where habitat can be identified as a biome or assemblage of vegetation species, multispectral remote sensing has significant potential. Remote sensing could then be used to map critical habitat and identify habitat continuity and wildlife movement corridors or potential habitat fragmentation as a result of proposed alternatives. Remote sensing will not eliminate the need for on-site verification, but may expedite the assessment process.

***Historic and Archeological Preservation***. In accordance with 36 CFR 800.4, the EIS should demonstrate that historic and archeological resources have been identified and evaluated. The information required for historic structures should be sufficient to determine their significance and eligibility for the National Register of Historic Places. The information required for archeological resources should be sufficient to identify whether each warrants preservation in place or whether it is important chiefly because of what can be learned by data recovery. Proposed use of land from an historic resource on or eligible for the National Register and all archeological sites also on or eligible for the Register and which warrant preservation in place will normally require an evaluation and approval under Section 49(f) of the DOT Act. Effort needed to evaluate and identify these resources will vary from project to project as determined by the FHWA.

All too often, the archeological impacts are dispensed with by an expert based on prior knowledge of the distribution of historical sites. In areas with prior expectations about the presence of sites of archeological significance, aerial photographs and remote sensing are used for search and analysis. High resolution imagery fused with DEM data could potentially be used to identify Native American ceremonial mounds and canals used to manage water, early American breastworks, etc. Remote sensing cannot replace site surveys, but can reduce the number of man-hours involved in on-site verification.

***Relocation Impacts***. When proposed actions require displacing existing structures and facilities, the EIS is required to estimate and report the number of displaced households, businesses and farms, and identify affected neighborhoods and public facilities. In addition, the EIS must identify available relocation sites, such as the availability of housing comparable to that of the displaced families, identify sites available in the area to which affected businesses can relocate. Relocation must be in accordance with the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970. Much of this information would be obtained from socio-economic databases. With the recent development of very high resolution multispectral remote sensors, it is feasible that imagery can be processed to distinguish between single-family homes, multi-family homes and businesses (Fig. 4). Although the technique may not be 100 percent accurate, it may reduce the amount of time required for validation on the ground. These techniques may also be used to identify comparable housing, but would not be able to determine their availability. It is likely that a combination of imagery and socio-economic data may be the most streamlined approach.

***Water Quality Impacts***. The Draft EIS must describe ambient conditions of streams and water bodies that are likely to be impacted by the proposed project. Under normal circumstances, existing data may be used. Use of water quality data spanning several years is encouraged to reflect trends. The EPA, under the Federal Clean Water Act, may provide assistance. Coordination with Federal, State and local agencies responsible for water quality should be included in the EIS. Three FHWA documents provide procedures for estimating pollutant loading from highway runoff and are helpful in determining potential impacts and appropriate mitigation measures. Locations where roadway runoff or other nonpoint source pollution may have an adverse impact on sensitive water resources should be identified. Principal or sole-source aquifers (defined and protected under Section 1424(e) of the Safe Drinking Water Act) impacted by the project should be coordinated with the EPA. The critical aquifer protection area should also be protected. EPA has regulatory authority and must approve any design that cannot avoid the aquifer area. Wellhead protection areas must be identified and avoided in accordance with the 1986 Amendments to the Safe Drinking Water Act. Coordination with the State agency responsible for the protection plan is recommended.

Remote sensing cannot be used to assess water chemistry directly. It can, however, be used to detect changes in temperature, water productivity and turbidity associated with chemical changes. Because vegetation and water have unique spectral signatures, multispectral imagery can be used to monitor changes in aquatic vegetation growth. Remote sensing can also be used to monitor changes in turbidity due to changes in erosion within the watershed and sedimentation in water bodies. The timeliness of remote sensing may be the greatest impediment in this application.

***Air Quality Impacts***. Air quality impacts are separated into mesoscale and microscale concerns. Mesoscale concerns include ozone, hydrocarbons, nitrogen oxide, whereas microscale concerns focus on carbon monoxide. Proposed projects should be described in the EIS in relation to the State Implementation Plan (SIP) for air quality. Either the project is or is not in an area that has transportation control measures in the SIP or the project is or is not in an air quality attainment area. An analysis of CO is necessary if it is judged on the basis of previous analyses for similar projects or published data that the contribution of the project will cause the area to exceed the 1- or 8-hour standards. Thus, measurements of CO are required.

Aerosols are a significant component of air pollution. Remote sensing of aerosols in the atmosphere is a mature science and continues to improve. Most of these measurements, however, focus on the upper troposphere and stratosphere and thus, contribute little to our understanding of urban air quality. Remote sensing of chemical constituents of air pollution is a new and emerging area. In most cases, the space-time dimensionality of aircraft- or satellite-based remote sensing is inconsistent with air quality measurements. However, recent research suggests that continuously monitoring ground-based sensor systems may provide valuable air quality information.

## ACCEPTANCE AND IMPLEMENTATION OF REMOTE SENSING

Some of man's best inventions have failed to get embraced by the public based on their merits alone. Conversely, some of the most useless widgets have gained at least temporary success because of an outstanding marketing strategy. Although remote sensing seems to hold great potential for streamlining some areas of environmental assessment in transportation, there are numerous impediments that must be addressed before it will be widely accepted as an alternative to existing techniques. For example, the FHWA has in some cases defined an assessment methodology. Because remote sensing is not a direct substitute for existing measurements, methods may need to be altered to take full advantage of a different type of information. There may be inertia among EIS preparers or stakeholders in voluntarily altering their approach. After all "that's the way it has always been done." The decision to embrace remote sensing assumes that the data provided by remote sensing is in some way better than existing information, but how do we define "better" information? Who must we convince that we may have a better widget? In the following text, we attempt to identify some of the issues that must be addressed to enhance the acceptance and implementation of remote sensing.

## Assessment Methodology

The methodology used in conducting an environmental assessment dictates what data, information, and analyses are required. The adequacy of the conclusions is a direct function of how well the methodology employed meets professional and scientific standards. CEQ regulations require the methodology used in EISs to have professional and scientific integrity and to identify sources used in forming a basis for the conclusions (40 CFR §1502.24). Trade-offs among these factors is required to arrive at a preferred method. The courts have determined that the "best" method, be it less costly or more scientifically sound, does not have to be used in an EIS (Kreske, 1996). The criteria for determining the best method should be based on whether the information is necessary to allow the decision-maker to make an informed decision. The purpose of EISs is not to generate scientific or technical data in spite of how useful it may be, but to generate informed decisions by a lead agency for a proposed action. EIS authors should describe the methods used in each environmental subject area so that this information is available for technical analysis as part of the review process. Whereas authors of EISs often describe the methods utilized in conducting the assessment, they neglect to explain why the particular method was used, what limitations affected the methodology, and why other methods were not used. This omission often leads to confusion and raises concern of reviewers of Draft EISs regarding the rationale behind the author's analysis. Furthermore, the reviewer may disagree with the choice of method due to their lack of understanding of *a priori* limitations. Thus, EIS authors must provide a thorough explanation of the rationale for the appropriateness of various methods and discuss limitations of each to avoid concerns by reviewers.

## Assessment Data

The data used in an assessment undergoes the same scrutiny for scientific and professional integrity, as does the methodology used in obtaining and analyzing data. Data sources should be referenced in a manner consistent with the professional or scientific discipline. Although there are no prescribed data sets to be used in an assessment, they should possess the following basic attributes: relevant, current enough to be useful, reputable or from a credible source, and in a usable format. Of these, obtaining usable data is often the most problematic. All too often, existing data sets are misrepresented and turn out to be something other than what they were represented or no one has any confidence in these data. Most data used in EISs comes from established sources--the most common of these are state and federal natural resource agencies and libraries. More recently, data clearinghouses have been a source of digital geospatial data.

In most cases, there is a preconceived idea among the EIS prepares and the regional FHWA as to what constitutes "best available data." There is, however, no official definition of best available data—this is principally a byproduct of experience. Consequently, this is rarely an issue for dispute. This does not imply, however, that there may not be a better way of acquiring or analyzing necessary information, but through years of experience, EIS preparers and lead agencies have become familiar with certain data sets and have grown accustomed to their application for various assessments. Behind many of the data sets used in environmental assessments are federal agencies that developed each of the data sets. Information from remote sensing must be in some way "better" than traditional sources of information before it will be embraced by planners, decision-makers, and other members of the transportation community. How then do we define data or information as "better"? Who makes the decision as to what is better? If we consider remote sensing as a marketable technology, then we can consider the consumer of this technology as the stakeholder. Who are they? What are their needs? On what basis would these stakeholders define better data? Utilizing a new data source requires identifying appropriate stakeholders and end users and educating them on the virtues of these alternative sources.

## End Users and Stakeholders

End users are the entities that apply remote sensing for assessment. To them, it is one of many assessment tools like a topographic map, Geographic Information System, theodolite, or Secchi disk. Consulting firms who perform environmental assessments under contract with the lead agency represent an end user. End users do not have a vested interest in remote sensing as a technology. They simply apply a proven technology for reasons of efficiency or competitiveness at the recommendation of the lead agency.

Stakeholders on the other hand, have a vested interested in remote sensing as a technology insofar as it can make measurements and discriminate among features accurately in support of or in lieu of other measurements.

This may be on a case-by case basis or through development of a product that would be valuable to multiple users. Federal and State agencies that have a mandate to manage and/or regulate natural resources would be one example of stakeholders. These agencies are often responsible for mapping or monitoring the state of resources, such as forests, rangeland, wetlands, parks, water quality, etc. These agencies would have a vested interest in remote sensing applications that would permit them to update or revise their maps more efficiently or more frequently thereby enabling them to better manage resources under their jurisdiction. Likewise, agencies involved in planning, such as metropolitan planning organizations, are stakeholders whereby remote sensing may provide them with a more up to date synoptic view of a region of interest or more detailed and current information about assets. The lead agency that must approve or reject an EIS is also a stakeholder. The lead agency may advocate using remote sensing as part of the EIS if they feel that it would allow them to make a more informed decision about a proposed action. The lead agency itself may also be an end user if it conducts some of the assessment using its own personnel. The agency requiring the EIS is also a stakeholder; this agency may or may not also be the lead agency. In some cases, the distinction between stakeholders and end users is unclear as a single entity may serve multiple roles.

## Regulations and Accuracy Standards

EISs are prepared in the context of environmental laws and regulations. These regulations define the "rules" by which EISs are prepared and regulatory authorities routinely interpret and enforce these rules. Such rules place restrictions on what is defined as acceptable methods. Having a clear understanding of the regulations, data accuracy standards, and what latitude is permitted is essential to defining potential remote sensing applications.

Despite broad statements in NEPA, unlike some environmental laws, NEPA has no "teeth"; that is, environmental considerations do not have to be elevated above other considerations; and there are no civil or punitive penalties, such as fines or imprisonment, for not complying with the law (Kreske, 1996). (Recently, however, the US DOT has threatened to withhold federal highway funds from states with metropolitan areas that fail to comply with EPA’s ozone standard.) The CEQ has regulations for implementing NEPA (40 CFR 1500-1508). The FHWA is the primary organization responsible for certifying that construction projects are in accordance with all applicable statutes, although it has little regulatory authority. The FHWA's Guidance on Preparing Environmental Documents is not regulatory. Instead, the FHWA makes recommendations as to which agencies should be consulted for interpretation of various regulations and encourages coordination among agencies at all levels of government. Regulatory authority resides with the agencies that manage the resources, issue permits and licenses are involved in construction, and grant funds. For example, the EPA has regulatory authority over aquifer protection and is responsible for approving any design that cannot avoid the aquifer area. The US DOT requires the COE to license construction activities associated with wetlands. Approval from the COE signifies that all applicable regulations have been addressed regarding wetland issues.

Many agencies like the USDA NRCS or the FWS that manage resources have developed national maps of these resources. A clear understanding of the accuracy standards to which the original information was obtained is required in order to identify applications where remote sensing information can supplement, replicate, or improve upon the information contained in these maps. NEPA and the FHWA do not mandate specific minimum data tolerance requirements for environmental assessment. The engineers in charge evaluate assessment activities on a case-by-case basis. "The level of analysis should be sufficient to adequately identify the impacts and appropriate mitigation measures…" (FHWA, 1987).

Likewise, for environmental assessment, the COE does not specify accuracy and tolerance requirements for data acquisition. The COE sees no value in requiring rather arbitrary tolerances for dynamic environmental phenomena. The COE allows engineers to choose acquisition techniques consistent with the project’s requirements. The presence of endangered species, political influences, and various other factors affect the level of accuracy that is required from site to site. On the other hand, for construction projects, the COE publishes a tolerance guideline used for determining what level of accuracy is required. The COE requires tolerance ranges for on-site GPS measurements of 2-3 cm for elevation accuracy and 1-2 cm for lateral positional accuracy. For floodplain mapping, FEMA has specified a standard that provides for up to a 1-foot increase in flood stages when designating a floodway or evaluating an encroachment where no floodway is designated.

## Adopting Innovation

A fundamental challenge of a new application is to overcome the inertia to change and adopt innovation. Inertia manifests itself for many reasons including skepticism, cost, newness, unfamiliarity, and lack of resources. ***Skepticism***. Can remote sensing do the job? Does remote sensing provide the information I need? Does it meet regulatory requirements for accuracy? Do metrics for existing data readily transfer to remotely sensed information? ***Cost***. How does remotely sensed information compare with traditional sources that may be available from a national data clearinghouse or library? ***Newness***. Methods become entrenched in society. There is a legacy within organizations that is difficult to overcome. Few agencies have the knowledge or latitude to change their procedures to attempt different approaches. ***Unfamiliar***. What data to do I acquire? Where do I get it? How do I specify what I need? How do I choose between two sources of information? How do I interpret the information? It just doesn't "feel" right! Lack of familiarity with a new way of conducting an assessment may result in confusion and impede acceptance. ***Resources.*** What do I need to use remote sensing data? How many man-hours will it require? What software do I need? Can I still use my existing computers? These are just some of the reasons that limit diffusion of an innovation like remote sensing into the environmental assessment process associated with transportation.

The speed with which an innovation is adopted is dependent on five factors: Relative advantage, Compatibility, Complexity, Trialability, and Observability (Rogers, 1983). ***Relative advantage*** is the extent to which the innovation is perceived to be better than the current practice. The perceived positives must outweigh the negatives. ***Compatibility*** is the degree to which the innovation is perceived to be consistent with current values, past experiences, and priority of needs. Remote sensing should be perceived as very compatible with existing practices. ***Complexity*** is the degree to which the innovation is perceived to be difficult to understand or use. As with any technical discipline, there is an associated vocabulary that is unfamiliar to the layperson. Those in the remote sensing field need to be conscientious about using terminology that is unfamiliar to persons from other backgrounds so as not to give the false impression that remote sensing is an insurmountable technical challenge. ***Trialability*** is the extent to which an individual or agency can try out one idea on a limited basis with the option of returning to previous practices. The NCRST-E is teaming with stakeholders in government and industry to conduct demonstration projects thereby allowing agencies an opportunity to learn more about remote sensing and gain greater familiarity with how it may impact traditional workflows. ***Observability*** is the extent to which the results of an innovation are visible to others. An innovation with highly visible, beneficial results is more rapidly assumed. Vendors and government agencies that have independent results are encouraged to share their successes with others. Some of this information is presented in professional journals, and trade magazines.

## CONCLUSIONS

One of the strategic goals of the Federal Highway Administration (FHWA) is to "protect and enhance communities and the natural environment affected by transportation." Environmental protection is accomplished through Environmental Assessments and Environmental Impact Statements that seek to prevent adverse environmental effects from taking place rather than mitigating problems caused by past activities or practices. EISs are conducted in the context of an overall decision-making process that is inexact and fluid. Despite the fact that EISs are conducted in accordance with Executive Orders, environmental laws, and regulations, the process is laced with subjective components, such as "significant impact," "best available data," and loosely defined accuracy requirements. Although the rationale for EISs is environmental protection, they are not in and of themselves regulatory. The cost to the environment is weighed against the benefits of the proposed project. EISs are simply a source of information on which to base informed decisions.

For the most part, there are no hard and fast rules or requirements in EIS preparation. The laws and regulations tend to address the process, not specific procedures. The courts have determined that the best method does not even have to be used. The information used, however, should have sufficient scientific and analytical substance to provide a basis for evaluating the comparative merits of the alternatives, and should contain sufficient supporting information or results of analyses to establish the reasonableness of the conclusions on impacts. Decisions regarding the adequacy of certain data or methods are up to the discretion of the engineer overseeing the assessment.

Although the data issue is a very small part of an overall streamlining effort, the U.S. Department of Transportation has sought to determine where remote sensing can contribute to streamlining the environmental assessment process. The framework noted above contains significant latitude for the application of remote sensing as a supplemental or alternative source of environmental information associated with transportation development. Of the 25 environmental impact areas the FHWA recommends addressing in an EIS, 13 are good candidates for remote sensing in some capacity. In many cases, current "off-the-shelf" techniques can be utilized directly. In other cases, the assessment requirements dictate using newer data sets for which experience is limited or for which image processing techniques need to be refined or developed. However, these issues do not appear to be insurmountable obstacles.

Perhaps the greatest challenge is in obtaining broad utilization and acceptance of remotely sensed imagery. Skepticism, unfamiliarity, cost, capital equipment and human resource needs are just of few of the anticipated impediments that must be addressed before broad utilization and acceptance can be achieved. In some cases, these impediments are real, but in many instances, they are fairly trivial. The NCRST-E is appropriately postured to provide the research and development and outreach services needed to raise remote sensing to the forefront of environmental assessment in transportation. The lessons learned over the last fifteen years with the implementation of GIS and GPS technology in transportation planning and engineering should be applied to remote sensing technology as well. A broad array of demonstration projects are needed, not simply to provide examples of remote sensing capabilities, but to engage the stakeholders in the process, assess the costs and benefits, and demonstrate overall the intrinsic value in accepting change.

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