New Approaches to Ecological Surveys

DETAILS

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NCHRP SYNTHESIS 400

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

New Approaches to Ecological Surveys

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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New Approaches to Ecological Surveys

A Synthesis of Highway Practice

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SUBJECT AREAS
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Cover Figure: Family of three deer on overpass (*credit:* Patricia Cramer).

FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

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This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail Staba
Senior Program Officer
Transportation Research Board

During all phases of the transportation planning, development, and operations process environmental data are needed to prepare environmental documents, obtain permits, design and construct road improvements, mitigate or avoid impacts, monitor mitigation, and conduct maintenance activities. The objectives of this synthesis were to survey transportation and natural resource professionals familiar with transportation systems to identify ecological survey needs related to transportation activities and to identify technologies, techniques, and innovative methods to fulfill those needs. These technologies, techniques, and methods, collectively called new approaches, include data collection, its analysis and delivery, how it can be used in planning and operations, and cooperative working relations. The audience for this synthesis includes transportation professionals responsible for planning, designing, constructing, operating, and maintaining transportation projects and the road corridor in an environmentally and fiscally responsible manner, as well as professionals in natural resource agencies and other organizations who work with departments of transportation (DOTs) on these issues.

The synthesis is based on an electronic survey conducted in early 2008 that was sent to all state departments of transportation and state fish and wildlife agencies, and concurrent literature and new initiatives searches. There were 103 respondents representing 49 states, 46 state DOTs (92% of all state DOTs), 37 state fish and wildlife agencies (74% of all states), 3 state Natural Heritage Programs, the U.S. Forest Service, and the Association of Fish and Wildlife Agencies.

The major themes of this synthesis, as developed from those responses and concurrent literature and new initiatives searches, are:

1. Transportation planners and their colleagues are moving beyond the traditional framework in the consideration of ecological resources. The 2005 Transportation Act (SAFTEA-LU) encourages and expects this. Long-range transportation planning will consider ecological resources to a greater degree than past actions.

2. The innovations that assist with the developing broad scale approach to transportation planning involve new ways of thinking; a paradigm is developing that encompasses broad biological and landscape scales of viewing the natural world and longer time frames to detect potential impacts and to create solutions.

3. These large spatial scale and long-time frame plans and potential solutions require increasingly higher resolution data. These data need to be increasingly in similar formats and easily accessible.

In summary, the future holds many promising new ways of gathering data, bringing them into common geographic information system formats, and improving working relations among agencies. The expanded scope of how far away from the roadway and how early in the planning process environmental concerns are considered is evidence of a new paradigm change for transportation agencies. This change began happening in the past decade as state and federal transportation departments became more responsible for the world outside of the road right-of-way.

Patricia Cramer, Research Assistant Professor, Department of Wildland Resources at Utah State University, Logan, Utah, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

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The author also recognizes the important work of those in transportation agencies and natural resource agencies and organizations. Credit is given to survey respondents in these organizations for their input into this work. They include the following:

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NEW APPROACHES TO ECOLOGICAL SURVEYS

SUMMARY

During all phases of the transportation planning, development, and operations process environmental data are needed. Whether the phase of planning involves long-range plans 20 years into the future, or day-to-day operations, information related to the environment is needed to prepare environmental documents, obtain permits, design and construct road improvements, mitigate or avoid impacts, monitor mitigation, and conduct maintenance activities. The objectives of this synthesis were to survey transportation and natural resource professionals familiar with transportation systems to identify ecological survey needs related to transportation activities and to identify technologies, techniques, and innovative methods to fulfill those needs. These technologies, techniques, and methods, collectively called new approaches, include data collection, its analysis and delivery, how it can be used in planning and operations, and cooperative working relations. The audience for this synthesis includes transportation professionals responsible for planning, designing, constructing, operating, and maintaining transportation projects and the road corridor in an environmentally and fiscally responsible manner, as well as professionals in natural resource agencies and other organizations who work with transportation professionals in departments of transportation (DOTs) on these issues. Environmental surveys in this synthesis are best described as ecological surveys; they do not consider archeological resources that are typically organized under environmental surveys. Ecological surveys taken as a whole convey a wide spectrum of information on the natural world from species to climate change.

The synthesis is based on an electronic mail (e-mail) survey conducted in early 2008 that was sent to all state DOTs and state fish and wildlife agencies, and concurrent literature and new initiatives searches. Personnel in DOTs and fish and wildlife agencies who were most familiar with environmental survey needs of transportation agencies were asked to describe the most pressing unmet environmental survey needs, and the recent advances they were familiar with to help meet these survey needs.

A rich response of ideas came from 103 respondents representing the following: 49 states; 46 state DOTs (92% of all state DOTs); 37 state fish and wildlife agencies (74% of all states); three state Natural Heritage programs; the U.S. Forest Service; and the Association of Fish and Wildlife Agencies. In this report, responses concerning ecological survey needs and new approaches were paired under the most appropriate phase in the transportation planning, development, and operations process in which they would be used. The phases and their concurrent needs and new approaches presented in chapter two include: (1) Systems Long-Range Planning, (2) Project Development, (3) Construction, and (4) Maintenance and Operations. Within each of these transportation phases, an ecological hierarchy was used. Simply put, survey needs for species, and then ecosystems and landscapes were addressed in a standard manner for each phase of transportation planning, development, and operations.

Systems Long-Range Planning

The ecological survey approaches for the systems long-range planning level address broad-scale planning in space (landscape scale) and time (20 to 30 years before projects). Ecological survey needs and approaches at this stage are typically those organized and identified in formats that look at natural system features in broad terms, cover large areas, and possess features whose time limits do not expire quickly so they can be referenced for years. Data in the form of maps, models, tables, and research reports are helpful during these coarser scales of long-range planning. Planning professionals have a need to understand the patterns of plant and animal distributions in the general planning areas, what the natural vegetative communities may be, and whether wetlands and other sensitive ecosystems are present. There are also needs to look at overall ecosystem-level effects of the proposed transportation plans, such as fragmentation of habitat and potential pollutants and climate change. In this report, potential species' effects, landscape connectivity, landcover mapping, and overall ecological effects are addressed at this phase.

Species Presence Survey Needs and New Approaches

Long-range planning needs for species' surveys include species maps, potential distribution models, and overall planning documents that can assist with general wildlife and plant distribution information. The greatest needs mentioned by respondents for this phase of planning were those for early planning of surveys and guidelines that help prompt surveys years ahead of schedules. Early planning helps surveys to be scheduled at the correct time of year to detect the species of concern, and can produce results that are available to transportation planners with enough time before project development to include conservation measures.

New approaches to species survey needs during long-range planning revealed during this study included the following:

- Considering ecological systems (and thus species) earlier than traditional approaches in long-range planning in accordance with the 2005 Transportation Act SAFETEA-LU;
- Predicting wildlife and plant distribution through maps, models, and the use of existing reports such as State Wildlife Action Plans; and
- Predicting wildlife and plant distribution and biotic and abiotic interactions to better understand what is happening on the landscapes where these distributions and interactions occur, typically using geographic information systems (GIS) tools, and often in approaches related to the *Eco-Logical* planning model.

Ecosystems and Landscapes Survey and Analyses Needs and New Approaches

An overall theme among responses was the need for understanding what ecological attributes are present at the ecosystem and landscape scale before project-level planning. Surveying at these larger scales is difficult, and relies heavily on mapping analyses that seek to extract data from satellite and aerial data, surveying and monitoring in scientific manners that allow for greater representation of a larger area, and on GIS-based modeling approaches to predict potential occurrences as well as impacts. These approaches highlight the change in the scale of ecological surveys from concerns limited to a specific area before potential development to the analyzing the landscape over greater time scales far in advance of a potential project.

New approaches that directly address the ecosystem-level needs and that were learned about in the course of this study include those that either address cumulative impacts or tools to address the ecological effects of potential projects. A new approach to cumulative impacts—a cumulative effects analysis method—was developed by the Colorado DOT. The University of Massachusetts–Amherst approach to conservation planning with the Conservation Assessment and Prioritization System is another new approach to assess connectivity and fragmentation of potential projects. New approaches to climate change include several state initiatives, reports, and books, such as the 2008 National Research Council's Committee on Climate Change and the U.S. Transportation's *Potential Impacts of Climate Change on U.S. Transportation*.

GIS data are tremendously important to long-term planning and all other stages of the transportation planning, development, and operations process. GIS ecological survey needs and new approaches were a major part of this synthesis. A common method in GIS is landcover mapping which displays vegetation on the ground by means of GIS technologies. The data are commonly used to predict ecosystem and species occurrences. The GIS data needs that respondents of the survey indicated were important to long-range planning included:

- The need to coordinate and cooperate on data sharing, such as the exchange of landcover maps among agencies.
- The need for uniform, nationwide survey methods for gathering and storing remote-sensed data.
- The need for methods of data sharing that enhance accessibility to data with relative ease of use.
- The desire to have data in one central location.
- The desire to have data that are kept current and are maintained.
- The desire to have a one-stop place on the Internet for permitting processes as well as basic data.

Coordination and cooperation among state agencies are occurring across the United States and in several states where examples were given in the survey responses. These examples included but were not limited to Michigan's cooperative approaches, and how Maryland's working relations have been aided by the development of the GIS-based Green Infrastructure Project. Examples of GIS-based Internet sites to assist with environmental data and methods of integration include the FHWA's website on Planning and Environmental Linkages, which assists in strengthening planning while protecting ecological concerns. Standardized approaches to data collection and storage typically are developed by agencies and organizations working at the national level, such as NatureServe, the GIS software company Environmental Systems Research Institute (ESRI), and the U.S. Geological Survey (USGS).

Connectivity analyses can provide important data on areas where aquatic and terrestrial wildlife need to move over short- and long-range distances. Twenty state agencies responding to the survey expressed the need to identify landscape linkages or wildlife corridors (largely for mammals) to avoid, minimize, or mitigate transportation corridors that may bisect these linkages. This was the second most often quoted need of the entire survey. Aquatic systems connectivity is another important environmental concern for long-range plans. Seven agencies identified the need to examine and plan for aquatic connectivity. Early planning for ecological systems also involves understanding the local and regional efforts conducted to map and plan for conservation and development. New approaches involving connectivity mapping include the following:

- State efforts to map wildlife linkages statewide and not only along transportation corridors, such as Arizona's Wildlife Linkages Assessment;
- Efforts to assess options under different planning scenarios with a GIS-based system, such as the Conservation Assessment and Prioritization System;
- Efforts to standardize data collection and sharing, such as a western states initiative to map wildlife corridors over 19 states through the Western Governors' Association; and
- Statewide approaches to identifying, prioritizing, and replacing blocked aquatic passages such as Washington State's program.

Local and regional planning efforts that use new approaches include consensus-building methods to bring people together to plan for conservation and make the data fully available, such as the Linking Conservation and Transportation Planning Workshops, sponsored by the FHWA, NatureServe, and Defenders of Wildlife.

Project Development

During project-level planning and development, ecological survey needs and new approaches become more specific than in long-range planning. Ecological survey needs in large part have been identified by the regulatory requirements of the National Environmental Policy Act, which are initiated at this stage. Regardless of the regulatory reasons, any project development initiates the need for environmental surveys that evaluate a specific area for potential occurrences and effects to species, ecosystems, and landscapes. These surveys address specific places where plant and wildlife species may occur to determine their presence and distribution, refer to maps of terrestrial and aquatic linkages for species and process movement, and identify areas where specific ecosystems are located, such as wetlands and sensitive areas.

Species Presence, Distribution, and Health Survey Needs and New Approaches

The project development phase is when the highest level of need exists to understand species presence, distribution in specific places, population numbers, and the overall health of present populations. Survey respondents most often described survey needs for species at the project level than at any other time during the transportation planning process. Needs included the need to determine species presence or absence in a timely manner, as well as methods to better determine a population's size and how the population is distributed on the landscape.

Many new approaches to address species presence include standards for gathering data, such as:

- The Association of Fish and Wildlife Agencies' new handbook on monitoring for amphibians and reptiles
- Analyses of the genetics of populations on either side of a road, such as Arizona's studies of pronghorn isolation among roads
- Technologies to detect species, such as sonic tag detectors in fish
- Population studies of wildlife near roads.

Some states have environmental or ecological survey manuals and guidebooks to help standardize such methods.

Broad-Level Ecosystems and Landscape Survey Needs and New Approaches

At the project development phase, data needed to address ecosystems and landscapes include:

- Data on the presence of sensitive ecosystems such as wetlands
- Specific connectivity areas for terrestrial wildlife and aquatic connectivity of streams and wetlands
- Methods of bringing together plans, maps, and data from local and regional scales.

Wetlands appear to be the most important ecosystems for consideration of data during project development and probably all planning phases. Eleven agencies identified their concerns for wetland ecosystem survey needs. These comments included the need for better mapping, better understanding of the entire ecosystem function of a stream or lake, better methods for restoring wetlands, the need to assess chemical alterations to aquatic systems from roads, and the needs for surveys for streams and wetlands that are somewhat unusual compared with the typical definition, often those that are more ephemeral or unique to a certain area. Pollution considerations were also important; 14 agencies discussed the need to better evaluate the effects of noise or salt on species, and waterborne pollutants in aquatic systems, all stemming from the transportation system, its construction, traffic, and maintenance.

Connectivity considerations were also important to respondents. The need for the installation of more wildlife crossings and research to determine the effectiveness of these crossings was mentioned by 27 agencies. This was the most often quoted need of the entire survey. Eleven agencies noted the need to map fish connectivity and install fish passages.

New approaches to these ecosystem and landscape-level survey needs include several studies, syntheses, and approaches. Scientists are developing methods to use aerial photos and remote-sensed imagery to evaluate ecosystems, including wetlands, for specific attributes. Such a method was developed by Booth et al. in 2007 using software analyses of aerial photos of riparian areas. Two noise syntheses have been conducted to help explore approaches to deal with noise pollution on wildlife [Kaseloo and Tyson's *Synthesis of Noise Effects on Wildlife Populations* (2006) and Dooling and Popper's "The Effects of Highway Noise on Birds" (2007)]. New approaches to dealing with wildlife connectivity and the concurrent problem of animal–vehicle collisions (a-v-c) include several NCHRP reports recently released that address both wildlife crossings and a-v-c data collection and storage (*NCHRP Synthesis 370 and NCHRP Report 615*). A new approach to aquatic connectivity includes the use of Passive Integrated Transponders tags to monitor fish movement through culverts. A new regional planning approach includes research at Mississippi State University using remote sensing and spatial information to assist in streamlining environmental and planning processes (National Consortium for Remote Sensing in Transportation Streamlining and Planning Processes at Mississippi State University).

Construction

In the construction phase of transportation planning, the need for environmental data is at a fine scale, measured in just a few meters, typically to understand what animals and plants may be affected by construction activities.

Species Survey Needs and New Approaches

During construction, the need to learn of species' presence is typically for wildlife with nests or movement near the area to make sure they have not entered the area since construction began, and for sensitive and invasive species of plants. The need to track wildlife movement or detect their presence in the area is the same as those for species' detections at the project level (this is also true for the newly developing approaches). One difference with previous transportation phases is the need to track vegetation and sensitive species' locations.

A recent publication sponsored by AASHTO, "Environmental Stewardship Practices, Policies, and Procedures for Road Construction and Maintenance," presented new approaches for environmental considerations during construction and is the most appropriate research publication for these concerns. New innovations also include tracking the locations of rare species or invasive species (particularly plants) through the use of Global Positioning System (GPS) technology. These GPS monitors mounted on equipment can alert operators to times when species are approaching an area of concern. For more information, see chapter three, Case Study 5.

Ecosystem and Landscape Scale Needs and New Approaches

Most ecosystem and landscape-scale needs for environmental information at the construction phase are for information pertaining to wetlands nearby. Respondents mentioned three ecosystem-level environmental survey needs that could be applied to the construction phase. These needs related to the following: (1) streams and their inhabitants affected by noise and pile driving, and the effects of in-water work; (2) jurisdictional wetlands and their documentation; and (3) water quality related to in-stream flows and pollutants. The new approaches presented in this section address water connectivity (flow), construction and engineering for fluvial geomorphology characteristics, a thermal imaging approach, and a way to track a project's ability to comply with commitments. Hydroacoustic monitoring of aquatic ecosystems is a recent method used to help determine construction impacts on aquatic systems. Water quality and hydrology can also be addressed through analyses conducted by computer programs such as GISHydro.

Maintenance and Operations

In the operations and maintenance phase, wildlife, plants, ecosystems, and the greater natural processes that are affected by things as small as lawnmowers and as large as climate change need to be evaluated with respect to daily operations and maintenance of transportation systems. The ecological survey needs and approaches in this phase typically address the following:

- Evaluate whether wildlife is using transportation infrastructure, such as bridges
- Evaluate whether wildlife is using the mitigation created for it
- Evaluate whether mitigation areas are functioning as expected
- Identify locations of sensitive species of plants to avoid mowing, herbicides, and de-icing impacts
- Identify environmental changes in species, ecosystems, and processes as a result of climate change

Species Survey Needs and New Approaches

Species survey needs during daily operations include the need to determine whether wildlife are located near transportation structures, such as bridge nesting, and to assist in managing wanted and unwanted plants, such as endangered and invasive species. Wildlife and fish mitigation structures need to be monitored to ascertain their effectiveness during these everyday stages. Vegetation management accounts for a large part of maintenance activities. Agencies need to be able to ascertain the extent of invasive plant species, manage for them, and determine the presence of rare species and manage for them also. New approaches for wildlife and plant detection include survey technologies such as Anabat (a system designed to help users identify and survey bats by detecting and analyzing their echolocation calls), remote cameras, and aerial images combined with software analyses. Additional new approaches are often used in conjunction with cutting-edge technologies, such as GPS units in handheld devices and mounted on equipment (such as mentioned previously in construction), as well as GIS modeling to predict potential impacts.

Ecosystems and Landscapes Survey Needs and New Approaches

The maintenance and operations phases of transportation planning are the long-term stages during which everyday actions such as care for infrastructure and mitigation occur, and potential large-scale impacts are carried out and concurrent mitigation is conducted. The operations phase is when mitigation sites and structures are monitored for their performance. Five agency responses mentioned the need to assess restoration mitigation. In general, these needs pertained to the ability to determine the effectiveness of wetlands that were created for mitigation, and their ability to function and perform similarly to nearby wetlands that had not been affected. Under new approaches to ecosystem-scale concerns in everyday activities, several studies are presented that track progress in mitigation areas, such as the NCHRP publication, *Developing Performance Data Collection Protocol for Stream Restoration*. Agencies also need to be able to address pollution and climate change effects. The effects of pollution that come with road runoff from vehicles and de-icing agents need to be monitored for changes to populations of aquatic and terrestrial species and ecosystem effects. New approaches to address pollution issues are presented in research reports, such as the NCHRP report, *Short-Term Monitoring for Compliance with Air Quality Standards*. Climate change approaches were presented in the section Systems Long-Range Planning.

Matrix of New Approaches

The large number of new approaches investigated in this synthesis makes for a document that requires some time to access the needed information. A matrix of new approaches was created so users can quickly reference at what point in the transportation planning process they need information, and then cross-reference the types of new technologies that address species, and ecosystems, landscapes, and processes. Those references are then more fully detailed, referenced, and linked to appropriate websites when available, in References: Literature and Website Review. The matrix is presented in the following table.

MATRIX OF STAGE OF TRANSPORTATION PLANNING, OPERATIONS, AND MAINTENANCE AND THE TYPES OF TECHNOLOGIES, METHODS AND COOPERATION THAT COULD ASSIST WITH ECOLOGICAL SURVEYS AT THAT STAGE

Type of Technology/Methods/Cooperation	Species/ Taxa	Ecosystems, Landscapes, and Processes
Long-Range Planning		
Cyber Tracker	x	x
Florida Efficient Transportation Decision Making Tool for GIS Data Sharing (under GIS and Case Studies)	x	x
NatureServe (under GIS)	x	x
Satellite Imagery (under GIS)	x	x
Predictive Modeling (under Species)	x	x
Google Earth (under GIS)	x	x
FHWA Website on Planning and Environment Linkages (under GIS)	x	x
Trust for Public Land GreenPrinting Web Service (under GIS)		x
National Geospatial Program (under GIS)		x
The National Map (under GIS)		x
USGS Landover maps (under GIS)		x
Wetlands Geodatabase (under GIS)		x
CAPS—Conservation and Prioritization System (under Ecosystems and GIS)	x	x
USDA Natural Resources Conservation Service (NRCS) Soil Mapping (under GIS)	x	x
ESRI (under GIS)	x	x
National Spatial Data Infrastructure (under GIS)	x	x
Dr. Paul Beier's Corridor Design for identifying Wildlife Linkages (under GIS)	x	x
Maryland's Green Infrastructure (under GIS)	x	x
Washington Fish Passages (under Maps and Connectivity Plans)	x	x
California Fish Passages (under Maps and Connectivity Plans)	x	x

Type of Technology/Methods/Cooperation	Species/ Taxa	Ecosystems, Landscapes, and Processes
Massachusetts Fish Passages (under Maps and Connectivity Plans)	x	x
USFWS iPac Decision Support System Tool (under Local and Regional Planning)		x
Climate Change book: *Potential Impacts of Climate Change on U.S. Transportation*	x	x
Goddard Space Flight Center Global Change Master Directory Website (under Climate Change)		x
LIDAR Technology to Measure Topographic Change Data Along Shorelines (under Climate Change)		x
Landscope America (under Local and Regional Plans)	x	x
CRAFT (under Local and Regional Planning)	x	x
Community Viz (under Local and Regional Planning)	x	x
"Eco-Logical" (under Local and Regional Planning and Case Study 6)	x	x
NCHRP SHRP 2 (under Local and Regional Planning)	x	x
Natural Capital Project (under Local and Regional Planning)		x
Ecosystem-Based Management (EBM) (under Local and Regional Planning)		x
NatureServe Vista (under Local and Regional Planning)	x	x
Metro Quest (under Local and Regional Planning)		x
Trust for Public Lands GreenPrinting (under Local and Regional Planning)		x
Project-Level Planning		
Trail Cameras (See Maintenance and Operations—Species)	x	
Anabat (See Maintenance and Operations—Species)	x	
VERTRAD (See Maintenance and Operations—Species)	x	
Cyber Tracker	x	x
GPS—PDA Handheld Devices w/Data (under Species and Case Studies)	x	x
Visual Elastomers for Fish (under Species)	x	x
Hydrophones for Fish and Streams (see Construction—Ecosystems)	x	x
Sonic Tag Detectors (under Species)	x	x
DNA Analyses (under Species)		
eBird (under Species)	x	x
Amphibian and Reptile Monitoring Handbook (under Species)	x	x
Occupancy Estimation Modeling Book (under species)	x	
Thermal Imaging (under All Types of Biological Organization)	x	x
VERTRAD—Vertical Beam Radar (under Species)	x	x
Florida's Efficient Transportation Decision Making Tool for GIS Data Sharing (under GIS and Case Studies)	x	x
Google Earth (under Species)	x	x

Type of Technology/Methods/Cooperation	Species/ Taxa	Ecosystems, Landscapes, and Processes
Northwest Habitat Institute (under Species)	x	x
Utah's Geographic Transportation Environmental Assessment—GTEAS (under Species)	x	x
NatureServe and Natural Heritage Programs (under Species)	x	x
GPS Data on Wildlife Movement in Arizona (under Species)	x	x
USGS National Fish Passage Program	x	x
USFWS Service Fish Passage Support System	x	
USFWS Fish Crossings	x	x
Website www.wildlifeandroads.org, for Wildlife Crossings and Other Mitigation (under Landscape Connectivity)	x	x
PDA Device for Animal–Vehicle Collisions to Help Identify Placement of Wildlife Crossings (under Landscape Connectivity)	x	x
Deer–Vehicle Collisions Clearinghouse, www.deercrash.com (under Landscape Connectivity)	x	
Digital Photograph Analyses [see Booth (under Ecosystems)]		x
Noise Effects Syntheses (under Ecosystems)	x	
NCHRP Report 615 on Wildlife Crossings (under Landscape Connectivity)	x	x
Passive Integrated Transponder (PIT) Tags (under Landscape Connectivity)	x	x
Oregon Guidelines for Stream Crossings	x	x
Maine Fish Passages Policy and Guidelines	x	x
Massachusetts River and Stream Continuity Project	x	x
U.S. Forest Service Fish Xing	x	x
National Consortium for Remote Sensing in Transportation Streamlining (under Planning—Local and Regional)		x
Construction		
Cyber Tracker	x	x
GPS—PDA Handheld Devices w/Data (Case Studies)	x	x
GIS Hydro—Hydrologic Models (under Ecosystems)		x
Hydro-acoustic Monitoring (under Ecosystems)	x	
Report—Environmental Impact of Construction and Repair (under Ecosystems)		x
Dave Rosgen's fluvial geomorphology (under Ecosystems)		x
Environmental Stewardship, Practices, Policies, and Procedures for Road Construction and Maintenance (under Species)	x	
Maintenance and Operations		
Trail Cameras	x	
Cyber Tracker	x	x
GPS—PDA Handheld Devices w/Data (under Case Studies)	x	x

Type of Technology/Methods/Cooperation	Species/ Taxa	Ecosystems, Landscapes, and Processes
Google Earth (under GIS) for Changes in Vegetation, Hydrology, and Boundaries over Time	x	x
Goddard Space Flight Center's Global Change Master Directory		x
VERTRAD to Detect Birds (under Species)	x	
Anabat for Bat Surveys (under Species)	x	
DNA Analyses for Wildlife Crossings (under Species)	x	
Citizen Scientists (under Species)	x	
Studies on Mapping Invasive Species in Roadway (under Species)	x	
Guidelines for Vegetation Management (under Species)	x	x
Study on Alternatives to Herbicides (under Species)	x	x
Aerial Photo Analyses Blumenthal (under Species)		x
Study on Monitoring for Air Quality Standards (under Ecosystems and Landscapes)		x
Report on Protocols for Stream Restoration (under Ecosystems and Landscapes)		x
Wisconsin Tracking Environmental Mitigation Projects (under Ecosystems and Landscapes)		x
Washington's *Gray Notebook for Performance Measures* (under Ecosystems and Landscapes and Case Study 7)		x

Note: See References for literature and website review.

Case Studies

Eight case studies were selected to showcase some of the varied means of obtaining, standardizing, sharing, and evaluating ecological survey data. Case studies represent different regions of the United States, different agencies and organizations involved in environmental data collection and management, and varied needs along the transportation planning, development, and operations process. These case studies are presented in chapter three.

Conclusions

In chapter four, the synthesis is summarized. Respondents to this synthesis' survey gave thoughtful responses as to how state DOTs and natural resource agencies are coping with the challenges of protecting natural resources. The rich diversity of responses from more than 100 survey participants provided a wide spectrum of biological and ecological survey needs and new approaches to those needs. The major themes of this synthesis, as developed from those responses and concurrent literature and new initiatives searches, are as follows:

1. Transportation planners and their colleagues are moving beyond the traditional framework in the consideration of ecological resources. The 2005 Transportation Act (SAFTEA-LU) encourages and expects this. Long-range transportation planning will consider ecological resources to a greater degree than past actions.

2. The innovations that assist with the developing broad-scale approach to transportation planning involve new ways of thinking; a paradigm is developing that encompasses

broad biological and landscape scales of viewing the natural world and longer time frames to detect potential impacts and to create solutions.

3. These large spatial scale and long-term plans and potential solutions require increasingly higher resolution data. These data increasingly need to be provided in similar formats and need to be easily accessible.

In summary, the future holds many promising new ways of gathering data, bringing them into common GIS formats, and improving working relations among agencies. The expanded scope of how far away from the roadway and how early in the planning process environmental concerns are considered is evidence of a new paradigm change for transportation agencies. This change began happening in the past decade as state and federal transportation departments became more responsible for the world outside of the road right-of-way. New ways of doing business that take into account resources beyond the road, such as Context Sensitive Solutions, and the provisions of SAFETEA-LU Sections 6001 and 6002 are becoming more standard. The dozens of responses to this synthesis' survey are reflective of how those within and outside DOTs expect these organizations to operate. A more holistic and greater landscape scale of looking at the environment outside the roadway and over longer time scales than traditionally have been considered will be more common in transportation planning and projects across the United States. This expanded vision of responsibility will necessitate greater interaction among DOTs and state fish and wildlife agencies and an increased need for these agencies to be more proactive about identifying areas that state, regional, and local organizations have targeted for development as well as those areas to avoid, minimize, or mitigate because they are conservation areas. The current initiatives such as the *Eco-Logical* approach to long-term planning, and the Western Governors' Association Wildlife Corridors Initiative are examples of how states and regions of the country and agencies are coming together to develop an interagency approach to transportation planning, development, and maintenance. These new ways of doing business will be supported by more standardized GIS data that will be synchronized among data layers and across agencies. Technological advances in survey methods will become better developed and disseminated. A promising sign of how ecological survey data will be used proactively to help avoid, minimize, or mitigate environmental impacts is the wealth of survey responses received. The DOT and fish and wildlife agency professionals who replied to the survey are doing an admirable job at protecting the natural world and finding ways to work together. The general consensus is that it is important for these professionals to understand what the ecological resources are before they are gone. Judging from the wealth of knowledge and commitment from the survey respondents concerning the natural world, the United States is well on its way to defining how it will protect and restore its ecological legacies.

CHAPTER ONE

INTRODUCTION

BACKGROUND

During all phases of the transportation planning, development, and operations process, environmental data are needed. Whether the phase of planning involves long-range plans 20 years into the future or day-to-day operations, information related to the environment is needed to prepare environmental documents, obtain permits, design and construct road improvements, mitigate or avoid impacts, monitor mitigation, and conduct maintenance activities. The objectives of this synthesis were to survey transportation and natural resource professionals who were familiar with transportation systems to identify environmental survey needs related to transportation activities and to identify technologies, techniques, and innovative methods to fulfill those needs. These technologies, techniques, and methods, collectively called new approaches, include data collection, its analysis and delivery, how it can be used in planning and operations, and cooperative working relations in data delivery and analyses. The audience for this synthesis includes transportation professionals responsible for planning, designing, constructing, operating, and maintaining transportation projects and the road corridor in an environmentally and fiscally responsible manner, as well as professionals in natural resource agencies and other organizations who work with departments of transportation (DOTs) on these issues.

State DOTs need data from environmental surveys. Environmental surveys in this synthesis are best described as ecological surveys; they do not consider archeological resources that are typically organized under environmental surveys. Ecology is the study of the interactions of organisms and their environment. Surveying specific species' locations or other information involves knowing how the animal or plant interacts with its environment and understanding what environmental factors are important. Surveying a community within an ecosystem, such as a wetland, also entails understanding its relationship with other components of the ecosystem. Ecological surveys need to convey and review a wide spectrum of such information on the natural world that can include data ranging from species to climate change. Surveys need to be conducted in a timely and cost-effective manner, and need to use up-to-date technologies and methods. Appropriate survey design must balance biological considerations, such as the time of year, detectability, migratory movements, and life history characteristics, with the operations considerations of transportation, such as project schedule, costs, and regulatory requirements. Every year, advances in technologies and knowledge allow for greater sources of information and the ability to more effectively glean the data from nature and databases. Progress in these advances sometimes occurs in different regions of the country or among certain agencies because of specific pressing needs. Thus, innovative approaches can occur without national knowledge of such advances. One of the main objectives of this synthesis is to use this opportunity to share those experiences and methods with others to help meet DOTs' environmental survey needs in effective and efficient manners.

Ecological surveys are used at all levels of the transportation planning and operations phases and for different reasons, yet they have several common attributes. Surveys need to be undertaken at the correct space and time scale for the specific data needs. The data need to be available to all agency and related organization personnel who are involved in transportation planning in easy-to-read formats and need to be stored in places that are easily accessible in a timely manner. Finally, useful ecological survey data are gathered in a quantifiable manner that allows for their comparison with other data over larger spaces and time scales to help with environmental compliance and performance measurements.

Ecological survey data possess a wide spectrum of attributes. In this report, those differences are partially reconciled by organizing ecological survey needs and new approaches according to when they may be used during the various phases of transportation planning: Systems Long-Range Planning, Project Development, Construction, and Maintenance and Operations. Within those phases, the natural world is organized first by species and then at broader scale ecosystem and landscape levels. Both levels are presented with survey needs and new approaches.

Data on natural systems are needed at different scales and in different formats according to these transportation phases. Ecological survey needs and approaches for the systems long-range planning typically are those provided in formats that look at natural system features in broad terms, cover large areas, and possess features whose time limits do not expire quickly so they can be referenced for years. Data in the form of maps, models, tables, and research reports are helpful at these coarser scales in long-range planning.

Project-level planning and development-phase ecological survey needs and new approaches are more specific. They address specific places where plant and wildlife species need to be surveyed to determine presence and distribution, reference terrestrial and aquatic linkages for species and process movement, and identify areas where specific ecosystems are located, such as wetlands and sensitive areas locations. Species presence can be critical if the species is of special concern; an endangered species' presence may prompt a shutdown clause, and alternatively if the species is not documented, a project may continue.

During the construction phase of transportation planning, ecological survey needs are typically identified to understand what animals and plants and sensitive communities such as wetlands may be affected by construction activities in a specific area (usually measured in meters). Equipment movements in relation to plant communities, wildlife populations, and aquatic systems need to be evaluated.

In the operations and maintenance phase, wildlife, plants, ecosystems, and the greater natural processes that are affected by things as large as climate change need to be evaluated with respect to daily operations and maintenance of transportation systems. The ecological survey needs and approaches in this phase typically include evaluating whether wildlife is using transportation infrastructure such as bridges, whether wildlife is using the mitigation created for it, and whether mitigation areas are functioning as expected; identifying areas where sensitive species of plants are located to avoid mowing, herbicides, and de-icing impacts; and determining the environmental changes in species, ecosystems, and processes as a result of climate change. The needs identified in these different phases are paired with ecological survey needs and new approaches in this manner in this report.

OBJECTIVE, SCOPE, AND AUDIENCE OF SYNTHESIS

U.S. state DOTs need to collect biological resource data to assist in transportation planning, development, and operations, but those data can be difficult to obtain and process in a timely and cost-effective manner. The objectives of this synthesis were to survey transportation and natural resource professionals who are familiar with transportation systems to identify ecological survey needs related to transportation activities, and to identify technologies, techniques, and methods to fulfill those needs. These new approaches included data collection, data analysis and delivery, the ability to use data for planning and operations needs, and cooperative working relations. The common theme for these new approaches is that they are being used as acceptable methods for data gathering and analyses.

Methods of collecting and analyzing environmental data are available at the national, state, and organizational levels. For example, a plethora of websites can be accessed at the national, state, and local levels just concerning geographic information systems (GIS) data. An exhaustive summary of these hundreds of methods and websites is not the goal of this synthesis. Rather, the scope of this report covers specific methods, technologies, and websites mentioned by participants in the survey and Topic Panel members overseeing this survey. It is assumed that the combined interests of more than 100 individuals representing 49 states who participated in the survey, along with the NCHRP Topic Panel of experts who helped guide this study, and the primary investigator's interests were sufficient to give a fair representation of the ecological survey needs and new approaches in the United States. If readers are interested in how and when to conduct environmental analysis for the transportation planning phases, several sources provide recommendations, including the FHWA Memorandum, *Integration of Planning and the NEPA Processes* (Federal Highway Administration 2005). Federal, state, and local agencies also have developed checklists and operating manuals of environmental concerns for early planning. For example, see Florida's Early Rapid Assessment Process in the National Research Council's Committee on Ecological Impacts of Road Density (2005). Such checklists are not part of the objective of this report.

ORGANIZATION OF REPORT

This synthesis is organized into four chapters, a glossary, references, and two appendixes. This first chapter is a basic introduction to the synthesis.

Chapter two is the main body of the report. It details survey methods used in this synthesis, the e-mail responses of needs for environmental surveys, innovative new approaches to environmental surveys, and a matrix of these new approaches. The needs and new approaches are organized in subsections within the results section according to the stages of transportation planning for which their use would be most appropriate. Within each of these transportation phases, an ecological hierarchy was used. Simply put, survey needs for species, ecosystems, and landscapes were addressed in a standard manner for each of these phases of transportation planning. A species is defined as a group of organisms capable of interbreeding and producing fertile offspring. Other species definitions have been used in conservation biology. For instance, more precise or different measures can be used, including DNA or appearance similarities, or the geographic range of the species. An ecosystem is a system of interdependent organisms, processes (such as water movement), and physical factors (such as soil and geologic features). The actual lines where humans may draw the boundaries of an ecosystem can be somewhat varied based on what factors are important. A landscape is an aggregation of ecosystems. It is composed of visible features, such as landforms and water, and is measured in size in miles or kilometers. Figure 1 displays the transportation planning and operations phases and illustrates how these phases run parallel to the ecological levels of an organization from which data are needed to inform that phase of the process.

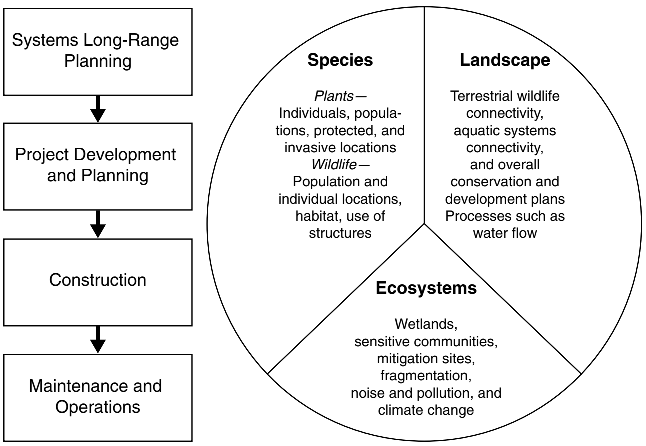

FIGURE 1 Flow of the transportation planning, development, and operations process. This flow parallels the natural world from which these planning phases need to gather data to inform the transportation process of species, ecosystems, and landscapes possibly affected.

This synthesis presents needs and new approaches in a format that follows the transportation planning process. This format allows for timely access of information in a manner similar to when it is needed. At the same time, this organization breaks up the natural world into convenient pieces that present a more fragmented view than they occur. For instance, water flows over watersheds and is influenced by the terrestrial ecosystems and activities that occur there, all varying in time scales longer than human lives and in a three-dimensional manner. Trying to maintain and restore aquatic connectivity and quality involves viewing the aquatic and terrestrial systems as a working whole entity, in a holistic manner. To present this complex dynamic in a structure that fits human planning constraints means presenting a somewhat-disjointed view of a large ecological phenomenon. New ways of conducting transportation business, such as Context Sensitive Solutions and the *Eco-Logical* planning approach, encourage a holistic view of the natural world, expanding the spatial and temporal scales of analyses. This report tries to bring a common thread of similar ecological systems by organizing the information under each section of transportation planning in the same ecological hierarchy: species, and ecosystems and landscapes. The reader should follow the ecological-level survey needs and new approaches across all phases of transportation planning, with an eye toward a holistic approach, which is preferred to better understand how everything is connected. The matrix of new approaches is presented in the Summary and at the end of chapter two. This matrix of new approaches was created so that users can quickly reference the point in the transportation planning process at which they need information, and then cross-reference the types of new technologies that address species, ecosystems, landscapes, and processes. Those references are fully detailed, referenced, and linked to appropriate websites, when available, in References: Literature and Website Review.

Chapter three presents eight case studies of innovative technologies, techniques, and strategies used successfully in specific states to address the top ecological survey needs most often mentioned by respondents in chapter two. Chapter four provides a summary and conclusions. The References section (References: Literature and Website Review) presents literature, names of initiatives and organizations, and relevant websites that provide information on innovative technologies and methods that show promise in new approaches for environmental surveys. A glossary of common terms used in this report follows the references. Appendix A is the original survey instrument. Appendix B is a summary of new ideas about organizational changes that invoke ecological surveys that are centered on cooperation. This is a special section that documents dozens of respondents' ideas on a developing a new strategy for transportation agencies: thinking and working toward approaches beyond the road right-of-way and beyond the current regulatory framework to integrate conservation into transportation planning.

CHAPTER TWO

RESULTS OF SURVEY: NEEDS AND NEW APPROACHES

In this chapter methods used and survey results are presented. The results are presented in the order typical of the transportation planning, development, and operations process: (1) Systems Long-Range Planning; (2) Project Development; (3) Construction; and (4) Maintenance and Operations. Each phase is ordered according to the ecological hierarchy: (1) species and (2) ecosystems and landscapes. Within these ecological levels, ecological survey needs and new approaches are presented.

METHODS

Literature and Website Searches

Sources of potential information on studies, software, websites, and collaborative approaches were investigated during 2007–2008 before and after the electronic mail survey. Resources to locate ecological survey data gathering, analyses, and sharing sources included the following:

- Transportation Research Information Services (TRIS)
- Proceedings from the International Conference on Ecology and Transportation (ICOET)
- Sources provided by the NCHRP Topic Panel of this synthesis, including requests for information to Natural Heritage program listserv members, the Plant Conservation listserv members, and U.S. Forest Service personnel involved with transportation ecology
- Presentations and papers from the 2007 and 2008 TRB annual meeting
- Advisory committee meetings in preparation for the NCHRP SHRP 2 projects titled, "Integration of Conservation, Highway Planning and Environmental Permitting Using an Outcome-Based Ecosystem Approach" and "Integration of Conservation, Highway Planning, and Environmental Permitting Through Development of an Outcome Based Ecosystem Approach and Corresponding Credits System"
- Meetings of the committee on Wildlife and Transportation for the Western Governors' Association (WGA) Wildlife Corridors Initiative
- The author's contacts with those involved in transportation and natural resource management and research.

Searches for innovative methods were refined once respondents' needs and innovative initiatives were revealed.

Survey Questions Format

Survey questions were formulated through discussions and testing among panel members and two general open-ended questions were decided on:

1. What are the most pressing *unmet needs for environmental surveys* that are necessary to assist in transportation planning, design, construction, and maintenance? These include data collection needs, analyses, and the ability to transfer the information to professionals. (Further details of questions are included in Appendix B.)

2. This survey will also bring together information on *recent advances in environmental survey methods*, such as new uses of GIS data and such technologies as using genetic markers in scat to identify presence of sensitive species. Could you please tell us about recent advances and innovations that show promise in helping transportation planning and other arenas to better consider ecological resources? These methods may be in use or under exploration.

The full survey instrument is presented in Appendix A. These questions were electronically mailed as a Microsoft Word file attached to the e-mailed requests. Responses were returned by email and hard copy through the postal service.

Analysis of Responses

The open-ended nature of the survey made definitive analysis of exactly what the respondents intended regarding a specific consideration somewhat arduous. To better analyze the nature of the replies, each respondent's responses were broken into subject areas related to the following: wildlife and plant species, ecosystems, processes, and new initiatives. These areas were the subsections presented under questions 1 and 2 in the survey instrument. These subsection responses were transferred to an Excel spreadsheet and were organized under columns titled in the same manner (wildlife and plant species, ecosystems, processes, and new initiatives). Each response was read and entered and key words were extracted and entered in a key word column adjacent to the subject area column. When a specific consideration was analyzed, such as the need for better GIS tools, key word searches were used on those key word columns (such as "GIS") to collect all responses that pertained to that subject. Responses were reviewed in the corresponding subject area column, and tallied for presentation in this final report. In an effort to give a fair representation of all states, the number of agencies responding to a need was tallied rather than the actual number of respondents. This was done because some agencies' single response represented feedback from multiple individuals, whereas other states had several individuals submit separate responses.

Survey Recipients

Every U.S. state DOT and state fish and wildlife agency was approached to participate in this survey. Each agency was asked to submit one response per agency, with the option to ask multiple employees to contribute. State DOT potential survey respondents were first selected based on AASHTO state representatives for the Standing Committee on the Environment (SCOE), of which each state DOT has at least one member. Representatives' contact information was taken from the AASHTO SCOE website. The initial e-mail request to participate was sent on February 15, 2008, and a follow-up e-mail was sent on March 13 to these individuals. A third attempt was made on April 23. After three "no responses" (no reply to the survey request) from e-mails sent to these individuals, DOT professionals were selected from those who participated in a previous NCHRP survey as part of the project, (NCHRP 25-27) *NCHRP Report 615: Evaluation of the Use and Effectiveness of Wildlife Crossings* (Bissonette and Cramer 2008). In cases in which no response was received from these contacts, phone calls were made in May to the specific DOT environmental office to identify the person most likely to know ecological survey needs of the agency. Every DOT environmental office that had yet to respond by each of the request dates mentioned previously was contacted through these efforts.

State fish and wildlife agency potential participants were selected from the Association of Fish and Wildlife Agencies' contact list of all state fish and wildlife agency directors. Panel member Ron Regan, the resources director for this association, sent the initial e-mail to these directors asking for participation in the survey on January 31, 2008. In March, wildlife professionals in states with no responses were selected from those who participated in the previously mentioned NCHRP survey (NCHRP 25-27). In cases in which no response was received from these contacts, phone calls were made in April and May to the specific state wildlife agency to identify the person most likely to know ecological survey needs of their DOT. Every state fish and wildlife agency that did not respond by the dates of request mentioned earlier was contacted through these efforts.

Natural Heritage program professionals were contacted to participate in this survey at a later stage. On May 14, panel member Bruce Stein, at the time NatureServe's vice president and chief scientist, sent an e-mail to Natural Heritage employees through a listserv e-mail service, asking for participation in the survey. The final deadline for participation in the survey was May 23, 2008.

RESULTS—RESPONDENTS

Forty-nine states had at least one agency respond to the survey. There were 103 respondents who sent replies to the survey: these people represented 46 state DOT agencies, 37 state fish and wildlife agencies, three Natural Heritage state programs, two replies from the U.S. Forest Service, and one reply from the Association of Fish and Wildlife Agencies. The response rate can be calculated in several ways. If one looks at the overall state response rate, 49 of 50 states participated, for a 98% response rate. The survey was presented to 50 state DOTs and 50 state fish and wildlife agencies or Natural Heritage programs. The overall response rate for those 100 requests was 83%. State DOTs' response rate was 92%. State fish and wildlife agencies' response rate was 74%. It is unknown how many state Natural Heritage programs received the request to participate, so their responses are included with the state wildlife agencies. State agencies that responded are represented in a map in Figure 2. Agency response was often a result of multiple professionals responding within an agency with their ideas brought together in one file. A single response was the result of the thoughts and work of anywhere from one person to as many as, in the case of Florida, 11 people within the agency, environmental resource agencies, or consulting companies that work with the DOT. Respondents were assured their responses would be anonymous. Their comments are presented in this document, at times quoted directly, but only with the individual respondent's identification given as a resident in a region of the United States. Permissions were requested and granted from state agencies that were directly identified.

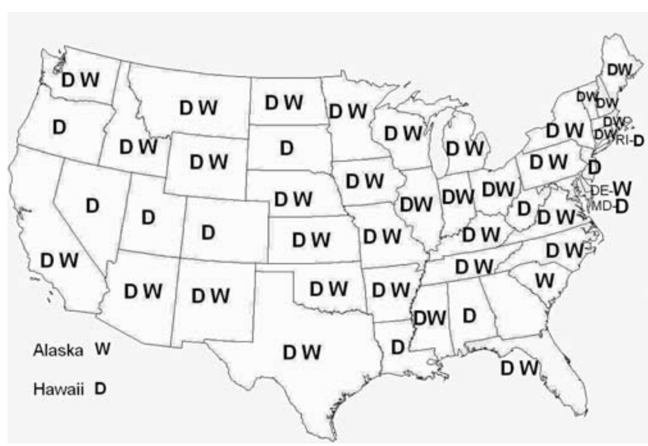

FIGURE 2 Map of agency respondents by state.
Note: D = response received from state department of transportation; W = response received from state fish and wildlife agency or Natural Heritage program office. There were 46 state DOT agencies and 37 state fish and wildlife agencies that responded.

RESULTS—NEEDS AND NEW APPROACHES

This section is divided into four subsections according to the transportation planning, development, and operations process. This organization allows users involved in transportation planning to quickly reference the appropriate phase of planning in which they need specific ecological survey information. These subsections are as follows:

1. Systems Long-Range Planning
2. Project Development
3. Construction
4. Maintenance and Operations.

Within each of these transportation phases, an ecological hierarchy was used. This was organized according to survey needs and new approaches for species, and ecosystems and landscapes. Each was addressed in a standard manner for each phase of transportation planning. This organization allows readers to be able to locate similar ecological levels in all levels of transportation planning.

Systems Long-Range Planning

The ecological survey approaches during systems long-range planning address broad-scale planning in space (landscape to climate change scale) and time (20 years prior to projects). Planning professionals have a need to understand the patterns of plant and animal distributions in the general planning areas, what the natural vegetative communities may be, and whether wetlands and other sensitive ecosystems are present. They also need to look at overall ecosystem level effects of the proposed transportation plans, such as fragmentation of habitat, potential pollutants, and climate change. Often the local-level scale of species distribution points can be too fine, and a broader, more predictive approach over larger areas is most appropriate. Because long-term planning is conducted years in advance of projects, the understanding is that these environmental surveys are conducted to gain a general understanding of the species and ecosystems in an area, and that over time the dynamic nature of ecosystems may change those components. This is especially true when predicting ecological changes and transportation adaptations to climate change. Ecological surveys for long-range planning are typically those of predictive models, potential habitat analyses, maps of species distribution and landscape linkages, and analyses of potential long-term cumulative impacts to ecosystems. This is the stage at which state-level GIS often are used. In this section, these needs and new approaches for environmental surveys at the long-range planning stages are presented in two subsections.

Species Distribution includes the following:

- Predicting Wildlife and Plant Distribution through Maps
- Predicting Species Distribution through Models
- Predicting Species Distribution and Biotic and Abiotic Interactions
- Transportation Act 2005 Legislation and Early Planning.

Broad-Level Ecosystems and Landscapes Surveys and Analyses include the following:

- Ecosystems Overall Effects
- Ecosystems Long-Term and Cumulative Impacts
- Ecosystems Expanding Temporal and Spatial Scales
- Ecosystems Climate Change Causes and Effects
- Landcover Maps and Wildlife and Aquatic Linkages Overview
- Landcover Maps and Wildlife and Aquatic Linkages GIS Analyses
- Landcover Maps and Wildlife and Aquatic Linkages Maps and Connectivity Plans
- Landcover Maps and Wildlife and Aquatic Linkages Overall Local and Regional Planning.

Species Distribution

Long-range planning needs for species surveys often require the availability of maps, potential distribution models, and overall planning documents to assist with general wildlife and plant distributions. This level of planning requires an understanding of the distribution of species of concern so that routing decisions can avoid or minimize conflicts with such species and their habitats. Wildlife species of concern can include plants and animals legally protected under federal or state statutes (e.g., threatened or endangered). Additionally, rare or declining species that are not formally protected by law often receive particular attention by resource management agencies. For example, species regarded by NatureServe and its state Natural Heritage program partners as imperiled or vulnerable at a range wide (G1–G3) or state (S1–S3) level frequently are taken into account in both long-range and project planning. Other wildlife species that may be of concern in long-range planning efforts include locally or regionally valued game species, and species with specific management issues related to specific places, such as wading birds or deer herds with specific wintering areas of habitat.

Species survey needs often include maps of documented occurrences (especially for rare species), occupied or potential habitats, or general distributions for the species of interest. Although many respondents detailed needs for species location information in the context of project-level planning, the long-range planning-level timing of surveys also was identified as an issue. Specifically, respondents indicated a need to better distinguish between areas that potentially may support a species of concern and areas that actually are occupied by the species. Survey work to distinguish this often must be planned and carried out well in advance of actual project design work. Nine respondents mentioned the need to better plan surveys with respect to time. The two major themes of these responses were as follows:

1. Guidelines need to be established to prompt timing of surveys to plan years ahead of the actual survey so these surveys can be conducted in a timely manner and the information can get back to planners with enough time to plan a project long enough in advance to possibly avoid or minimize transportation impacts.

2. Planning should occur at longer time scales ahead of projects to better plan for surveys so that they can be conducted for species at the correct time of year.

One dilemma associated with the early timing of surveys is the expiration of survey data. If the ecological survey is conducted too many years in advance of a project, the resource agencies may require up-to-date surveys. Another quandary is the project funding for surveys may not materialize with enough leeway to conduct timely surveys. These needs are partially addressed in the next section on new approaches under timing of surveys.

New approaches to help determine wildlife and plant locations for systems long-term transportation planning involve the use of existing maps, aerial photographs, software and models to analyze these data, and reports and tools developed by natural resource agencies and organizations to assist in early development planning. The previously cited needs focused on how to approximate species locations through distribution maps and models, and appropriate timing of calls for surveys to better document species presence or absence. These new approaches involve the following:

- Predicting wildlife and plant distribution through maps
- Predicting species distribution through models
- Predicting species distribution and biotic and abiotic interactions
- Following Transportation Act 2005 legislation and ensuring early planning.

Predicting Wildlife and Plant Distribution through Maps Current sources of species survey data that involve maps for use in long-range planning include the following:

All states have a Natural Heritage program, which maintains databases of documented locations for sensitive plant and animal species. The NatureServe Explorer website provides a summary of which species at risk are known from each state, county, or watershed (NatureServe).

All 50 states have Wildlife Action Plans that identify species of greatest conservation need. Many of these plans present some form of maps for these species, their priority habitats, or important conservation areas. Some also provide information on invasive species that could be useful in long-term transportation planning. State Wildlife Action Plans outline the steps that are needed to conserve wildlife and habitat before they become rarer and more costly to protect. Taken as a whole, these plans present a national action agenda for preventing wildlife from becoming endangered. For listings of every state wildlife action plan, see "State Wildlife Action Plans" in the References.

Predicting Species Distribution through Models One area of technological advance in recent years has been the development of the use of computer models to predict areas where suitable habitat for particular species may occur. Because long-range planning usually requires more generalized regional information on the distribution of sensitive resources, such predictive models can distinguish among places with potential conflicts and those with no known conflicts. These models can better target more efficient and cost-effective field survey work for at-risk species and provide an early warning of areas where ecological conflicts may exist for potential transportation projects.

A number of predictive species distribution models, which combine known occurrences of species with underlying environmental data layers, are now in use within the scientific community. NatureServe, for instance, has developed a GIS-based Predictive Distribution Modeling (PDM) method to produce probability maps of areas where elements such as species and ecological community types are likely (or not) to occur. Advantages of this method include that predictive maps make field inventories more efficient and effective; they also show where to commit limited inventory resources for the highest likelihood of documenting the specific species or ecosystem component that is the target of the survey. These maps predict multiple ecological elements, including wildlife, plants, natural communities, and water resources, allowing for a more comprehensive holistic approach to ecological surveys. Several state Natural Heritage programs are using variants on this PDM method to guide inventory work and identify new populations of rare species and natural communities. They include Oregon's Natural Heritage Information Center, New York's Natural Heritage program, and Wyoming's Natural Diversity Database (NatureServe Predictive Distribution Modeling). In New York, for instance, the Department of Environmental Conservation's Natural Heritage program is using a local version of these predictive modeling tools to provide New York State DOT with statewide predictive distribution maps for priority species for use in its transportation planning and review.

The Northwest Habitat Institute developed a habitat assessment method that quantifies habitat value in a consistent format. A habitat (HAB) value is calculated for each site based on species, habitat types, and functions for each polygon. This method is used by Oregon, Washington State, and British Columbia (Northwest Habitat Institute).

Although aerial photography and satellite imagery are not new technologies, considerable advances have been made in the level of spatial and thematic resolution of these imagery sources. These advancements are improving the ability of these technologies to determine the location and extent of vegetation communities and wildlife habitats. In addition, the emergence of web-based mechanisms to access imagery (e.g., Google Earth, MicroSoft Virtual Earth) is transforming the way in which planners are able to interact with this information.

In North Dakota, the DOT intends to begin examining the use of infrared aerial photography to identify plant communities with little ground-truthing required.

Booth et al. (2006a) describe software packages that take digital aerial images over large scales (Very Large Scale Aerial Imagery—VLSA) and accurately (90% accuracy) predict specific objects such as streams, animals, logs, plant canopies, riparian habitat, and vegetative communities from large-scale images down to images as fine as 1 millimeter per pixel. The authors recommend these software packages to expand the utility of aerial image data.

Other methods are developing of using satellite and aerial imagery to determine species and community locations. Local offices of the Nature Conservancy and Natural Heritage programs are some of the best resources for learning about the methods being developed in their region.

Predicting Species Distribution and Biotic and Abiotic Interactions Approaches that use multiple layers of data and present them to users to better understand ecological interactions across the landscape are presented in this section. These approaches typically are developed by natural resource agencies and organizations that have a deep understanding of biotic and abiotic conditions and interactions as well as an understanding of how these interactions result in the species distributions on the landscape. This more in-depth ecological approach to species distribution is a development that is typical of how resources will be assessed in the future. Both the transportation community's Context Sensitive Solutions and the more recent *Eco-Logical* planning approach embody this larger context view. This view includes expanding the temporal scale of considering ecological resources in long-term planning undertaken 20 or more years before potential projects and over longer time scales of considering effects and mitigation, measured in decades. It also means that the spatial scale of ecological considerations extends far beyond the road right-of-way to areas not normally considered for effects or for potential mitigation banks. This approach embraces greater interagency cooperation to facilitate these considerations and actions.

The Florida Fish and Wildlife Conservation Commission recently developed the Wildlife Conservation Planning Tool, an innovation to help the collaborative process in Florida to prioritize wildlife conservation. Planning strategies for successful large-scale wildlife protection and habitat management can require coordinating information and resources from many sources. Tracking down the most appropriate materials can become time-consuming, even overwhelming. To expedite this process, the Wildlife Conservation Planning Tool provides an interactive, computer-based manual that includes links to hundreds of conservation resources. These resources guide project planning from evaluating existing natural resource conditions from a regional perspective to developing habitat management plans for specific properties or projects. Links guide users to a broad range of information—including literature and database hyperlinks, guidelines for multispecies habitat management and initial site assessments, survey protocols for protected wildlife species, conservation opportunities for private landowners, and conservation design options for transportation and development projects. The manual assists those requesting or reviewing a permit application for a development project for which wildlife may be adversely affected, or for those planning to conserve an area with wildlife conservation as a priority. The Wildlife Conservation Planning Tool became available in 2009 (Rousso and Hoehn 2009).

The Northwest Habitat Institute (NWHI) created the Interactive Biodiversity Information System (IBIS). It is an informational resource to promote current conservation efforts in the U.S. Northwest. IBIS contains the typical information about fish, wildlife, and habitats, and also analyzes relationships among these species and their habitat. The data have been developed for 5 years, and NWHI may use this information as a base for adoption for other areas as well.

Delaware DOT uses a system to rank the value of habitats; this ranking is based primarily on the location of known state and federal threatened and endangered species. The ranking system may be developed to include other ecological values of a given site, such as size and diversity of habitat, connectivity to other resources, and indirect costs of fragmentation (including increased road mortality, noise pollution, etc.).

Transportation Act 2005 Legislation and Early Planning Respondents reported the need for better long-term timing to include consideration of environmental variables in the long-range planning process. This longer time period approach allows for more thorough ecological consideration of potential projects before plans are drawn, and it gives greater opportunity than project-level consideration does to avoid, minimize, and then mitigate for the transportation development. In a 2006 survey, Cramer and Bissonette (2007) reported that 28 of 50 state DOTs surveyed reported beginning ecological considerations at the project level, and only 14 states reported any consideration of these resources at the long-range planning (20 years) level. The remaining states' respondents reported that they began ecological consideration at the State Transportation Improvement Plan (STIP) level. Developments in the 2005 transportation bill require early planning for environmental resources. The passage of the 2005 Transportation Act (known as SAFETEA-LU, the acronym for the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users) Section 6001 mandates that long-range plans be created with the consultation of natural resource agency personnel through the review of resource maps and inventories to identify potential environmental conflicts and mitigation activities. It requires states to develop long-range transportation plans with a minimum 20-year outlook and a reasonable opportunity for public comment. Section 6001 of the act requires 20-year plans to include the following:

- Consultations with resource agencies, such as those responsible for land-use management, natural resources, environmental protection, conservation, and historic preservation, which shall involve, as appropriate, comparisons of resource maps and inventories
- Discussion of potential environmental mitigation activities and potential areas to carry out these activities, including activities that may have the greatest potential to restore and maintain the environmental functions affected by the plan
- Participation plans that identify a process for stakeholder involvement.

Section 6002 of SAFETEA-LU establishes a new environmental review process for highways, transit, and multimodal projects. This new process, mandatory for all environmental impact statements (EIS), requires a new public comment process on the purpose and need of the project. The range of alternatives encourages greater participation from more agencies and organizations, as well as the public (SAFETEA-LU).

Broad-Level Ecosystems and Landscapes Surveys and Analyses

An overall theme among responses was the need for understanding what ecological attributes are present at the ecosystem and landscape scale before project-level planning begins. At least six respondents explained that without knowledge of the species, landscape linkages, and sensitive ecosystems presence in an area before transportation development, we risk losing these ecological attributes without even knowing they are gone. Surveying at these larger scales is difficult and relies heavily on mapping analyses that seek to extract data from satellite and aerial data, surveying and monitoring in scientific manners that allow for greater representation of a larger area, and allow for GIS-based modeling approaches to predict potential occurrences as well as impacts. These approaches highlight a change in the approach from surveying a specific area before potential development to looking at the greater landscape over longer time scales in advance of a potential project. This even includes looking for transportation causes of climate change and managing for potential changes from this global phenomenon. For survey needs and new approaches at this long-range planning phase, the large-scale approach is sectioned into (1) ecosystem concerns, and (2) landcover and linkage mapping and analyses in the following manner:

- Ecosystems Overall Effects
- Ecosystems Long-Term and Cumulative Impacts
- Ecosystems Expanding Temporal and Spatial Scales
- Ecosystems Climate Change Causes and Effects
- Landcover Maps and Wildlife and Aquatic Linkages Overview
- Landcover Maps and Wildlife and Aquatic Linkages GIS Analyses
- Landcover Maps and Wildlife and Aquatic Linkages Maps and Connectivity Plans
- Landcover Maps and Wildlife and Aquatic Linkages Overall Local and Regional Planning.

Ecosystem Overall Effects Ecosystems need to be surveyed for large-scale impacts over time, such as cumulative impacts, and over larger areas, such as fragmentation effects. At the same time, predictions need to be made regarding base conditions and how potential transportation activities would affect them. Ecosystems sustain a multitude of effects from transportation corridors that traditionally have not been assessed at the regulatory level, such as cumulative impacts and fragmentation. Today, a greater regulatory emphasis is placed on assessing these impacts than in the past and there is more interest in these findings. A minimum of 13 respondents identified the need to survey the impacts of roads on ecosystems and their processes. These include effects not regulated in the past but that are now part of regulatory consideration, such as current, future, secondary, and cumulative impacts. Fragmentation effects on terrestrial and aquatic ecosystems are also an ecological survey need, according to six survey responses. Respondents also noted a need to survey baseline natural conditions to assess and understand what the desirable conditions would be, and where core areas and corridors are needed to sustain different species, such as neotropical migrant birds, carnivores, and large ungulates, to better prevent fragmentation.

The current environmental regulations call for a review of the ecosystem effects resulting from transportation predominantly for construction phases. Some states look at long-term maintenance impacts as part of biological assessments undertaken during the environmental review phases in accordance with National Environmental Policy Act (NEPA) regulations. Other states are also looking to reduce maintenance and operations impacts to ecosystems and species by assigning environmentally trained professionals to maintenance units, as done by the California DOT (Caltrans). The current systems of studying and estimating ecological impacts typically address short-term effects from transportation activities and traditionally have not addressed the long-term and cumulative effects resulting from increases in traffic volume maintenance activities such as herbicide spraying, the urbanization that occurs with the development of roads, and other changes to the water, air, land, and overall connectivity of the landscape. The traditional approach could be improved and enhanced by looking at broader spatial and temporal effects.

Several respondents thought that modeling could be used to assess ecosystem-level impacts. One respondent mentioned that better models could be developed to identify ecologically significant areas or to predict impacts and minimize or mitigate for losses. Others throughout the survey mentioned the need for predictive modeling. Predictive modeling used to identify features that are important in avoidance and mitigation is becoming widespread, and respondents voiced a need for its increased use. A southeastern respondent noted a need to develop more efficient methodologies to locate potential wildlife crossings by comparing existing models of landscape permeability and connectivity, to create a reserve network design, and to identify sightings of wildlife crossing. Several respondents mentioned the need to calculate the value of ecosystems to determine the cost-effectiveness of mitigation measures. Such assessments were mentioned eight times in survey responses. Ecosystem assessment was mentioned in the context of evaluating ecosystems for pollutants, including gravel, sand, and salt runoff into aquatic systems. A northeast response included the need for a rapid assessment technique to be developed on a watershed or ecosystem scale to better factor ecological resources into the planning and design of projects. Based on the results of the ecological survey, many needs for ecosystem-level impacts were identified. The needs expressed in this survey include the following:

- Conduct a survey for long-term, cumulative impacts to ecosystems
- Conduct a survey for indirect impacts, such as ancillary urbanization of road areas
- Conduct a survey for fragmentation effects of road on environmentally important areas and predictive modeling to minimize potential impacts
- Expand the scope of environmental surveys of ecosystems to include long-term and large spatial areas that could be affected
- Evaluate the potential effects that climate change will have on transportation systems, and how those systems contribute to this change.

Ecosystems Long-Term and Cumulative Impacts There are regulatory reasons for assessing long-term impacts, including the Endangered Species Act. To help meet these requirements and go beyond the scope of the law, there are new approaches to examining the effects and potential effects of transportation on ecosystems and processes. Some of these approaches are presented under GIS tools in the landscape-level sections later in this report. Those approaches that directly address ecosystem-level needs and that were discovered in the course of this survey include those that address cumulative impacts or the ecological effects of potential projects. Following are a variety of examples.

The Colorado DOT recently (2008) released a cumulative impacts analysis document, "Area Wide Coordinated Cumulative Effects Analysis." The project evaluated whether and how a spatial accounting approach can be used to identify the cumulative impacts on the environment that result from the incremental impacts of multiple transportation and other projects, and related urbanization at a regional scale. Spatial accounting methods were employed to inventory improvement or decline in the quality of key resources over multiple time periods, jurisdictions, and projects. The tools of spatial accounting include the following: (1) data typically housed in a GIS; (2) models for the evaluation of environmental effects resulting from transportation projects and programs; and (3) metrics such as indicators or thresholds, which can be used to assess the importance of change in resource qualities. This type of analysis is close to what the survey respondents voiced was a necessary approach (Muller et al. 2008).

The EPA sponsored a study at Colorado State University on approaches to cumulative impacts: *Hydrogeomorphic Wetland Profiling: An Approach to Landscape and Cumulative Impacts Analysis* (Environmental Protection Agency 2005). The study developed a synthetic, hierarchical, and scalable approach to landscape characterization and a cumulative impacts analysis of wetlands.

The EPA also prepared an online report, *Cumulative Impact Assessment: Synoptic Approach to Cumulative Impact Assessment: A Proposed Methodology* (Environmental Protection Agency 1992). The report provides resource managers and technical staff with an approach to evaluate the cumulative environmental effects of individual human impacts on the environment, particularly with respect to wetlands.

The Integrated Wildlife Habitat Ranking System (IWHRS) is a GIS-based habitat model developed by the Florida Fish and Wildlife Conservation Commission composed of 10 statewide data layers that represent important ecological aspects for wildlife species in Florida. The IWHRS is used to conduct environmental reviews of development and transportation projects and to perform impact assessments, including direct, indirect, and cumulative impacts to important habitat systems and wildlife resources in the state. The IWHRS is especially useful in performing larger, landscape-level assessments of linear projects, such as highways, and has been incorporated into Florida's Efficient Transportation Decision Making (ETDM) web-based tool. For a detailed discussion of these tools, see chapter three, Case Study 1.

The University of Massachusetts–Amherst is developing a system of GIS analyses for ecosystems called Conservation Assessment and Prioritization System (CAPS). The model will assess connectivity to natural areas, evaluate mitigation efforts, and inform the design of new roads. This is one of the few models that attempt to address the fragmentation impacts from proposed transportation projects (Massachusetts Conservation Assessment and Prioritization System). For more information, see Massachusetts CAPS below, under *Landcover Maps and Wildlife and Aquatic Linkages Maps and Connectivity*.

Ecosystems Expanding Temporal and Spatial Scales The issue of expanding the scope of transportation ecological surveys beyond the road right-of-way and over longer time scales to better assess transportation effects on ecosystems is being addressed in several national-level initiatives that are being adopted in different areas of the United States. For a detailed discussion of these methods and places they have been and are being used, see chapter three, Case Study 6. DOTs are expanding the environmental scope within their agencies. The environmental considerations are becoming important enough to agencies that some, such as Caltrans and New York State DOT (NYSDOT), have brought environmentally trained professionals into their maintenance and operations divisions. In this respect, the scope of environmental concerns has begun to expand across the transportation planning, development, and operations process.

Ecosystems Climate Change Causes and Effects Climate change causes and effects are so broad in space and time scales that traditional regulatory framework and transportation phases have not addressed them. Increasingly, though, states are taking the lead in finding ways to address these issues within the transportation planning, development, and operations process. Transportation choices, such as improving road lane capacity rather than investing in transit, or affecting intact ecosystems that buffer against carbon dioxide buildup, directly contribute to climate change. On the other side, climate change effects of longer droughts and more intense storms, sea-level rise, and greater spring runoff pulses affect transportation systems. Twelve participants described survey needs related to climate change. Respondents were concerned about the effects of climate change on existing species distributions and terrestrial and aquatic connectivity, the flow of water, loss of habitat and its degradation, and the timing of biological functions.

Some states such as California are already mandated by their legislatures to plan for climate change in projects and daily operations. Others have greenhouse gas reduction goals (see the Florida example discussed later). Legislated initiatives, as well as studies and technologies, can help with these and other goals of dealing with climate change. The following new approaches are presented as initiatives, studies, and technologies to address climate change at the ecological surveys level.

Florida is proactive in considering the reduction of greenhouse gases as one of the ways in which the government should be involved. The governor of Florida issued an executive order that establishes greenhouse gas emission reduction targets from 2017 to 2050. Additional direction is provided to develop rules to achieve the following: (1) reduce the maximum allowable emissions level of greenhouse gases for electric utilities; (2) adopt California motor vehicle emission standards; and (3) adopt a statewide diesel engine idle-reduction standard. Transportation models have been developed to measure the particulates that are considered to degrade the quality of the atmosphere. Although this is not a specific survey method, these standards will lead to quantifiable methods to evaluate changes from climate change and may lead to new ecological survey standards.

Another recent initiative calls for the potential inclusion of global warming impacts in environmental analyses documents. In February 2008, the International Center for Technology Assessment, the Natural Resources Defense Council, and the Sierra Club petitioned the chairman of the Council on Environmental Quality (CEQ), and the executive office of the president, requesting that the CEQ amend its regulations to clarify that climate change analyses be included in environmental review documents (see Climate change CEQ for more information).

Several respondents from across the United States mentioned a study funded by the U.S.DOT and U.S. Geological Survey (USGS): "Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I" (U.S. Department of Transportation and U.S. Geological Survey 2007). This study has dozens of authors. The ultimate goal of this joint U.S.DOT–USGS research is to provide the knowledge and tools that will enable transportation planners and managers to better understand the risks, adaptation strategies, and trade-offs involved in planning, investment, design, and operational decisions in the face of climate change.

A recently released book by the National Research Council, *Potential Impacts of Climate Change on U.S. Transportation* (National Research Council Committee on Climate Change 2008), was written by committee. This book consists of papers by 12 professionals from state DOTs, universities, the National Oceanic and Atmospheric Administration (NOAA), and consulting companies. Titles of chapters include Understanding Climate Change, Impacts of Climate Change on Transportation, Challenges to Response, Meeting the Challenges, and a Summary.

Goddard Space Flight Center's *Global Change Master Directory* (GCMD) website enables users to locate and obtain access to Earth science data sets and services relevant to global change and Earth science research. The GCMD database holds more than 25,000 descriptions of Earth science data sets and services covering all aspects of Earth and environmental sciences. Users can search using the search box or can select from the available keywords to search for data and services (see Goddard Space Flight Center).

In Wisconsin, models are being used to predict the change in stream locations of various fish species associated with increasing water temperatures. The question being addressed is: "Will warm water fish extend their range and cold water fish lose habitat?" The availability of these basic models, and the technology to run them, has provided some interesting scenarios in which to answer that question. Contact the Wisconsin Natural Heritage Inventory Program for more information.

A growing literature base is dealing with GIS-dependent ecological niche modeling. The potential may exist in this area to improve or develop biological surveys, impacts forecasting, and mitigation in landscapes that are changing because of normal fluctuations, development, and climate change (Dominguez-Dominguez et al. 2006).

Light Detection and Ranging (LIDAR) technology could have many applications to assist with measuring environmental considerations dealing with climate change. LIDAR is a remote-sensing system used to collect topographic data. This technology is being used by NOAA and National Aeronautics and Space Administration scientists to document topographic changes along shorelines making it a possible predictor and measuring device for climate change. It can measure distance, speed, rotation, and chemical composition and concentration. It is still being worked on to refine the methods. For instance, Schwartz (2006) reports the LIDAR technology has sometimes read treetops as ground level, skewing the results of the survey data.

Landcover Maps and Wildlife and Aquatic Linkages Overview Landcover maps and wildlife linkage maps and analyses can assist greatly with long-range transportation planning. They provide information on areas where ecosystems and species potentially and do occur, data on where landscape and aquatic linkages occur or need to be restored across a state, and information about what lands and waterways are important for conservation to local and regional citizen and agency efforts.

Landcover Maps and Wildlife and Aquatic Linkages GIS Analyses GIS data are tremendously important to long-term planning and all other stages of the transportation planning process. The GIS ecological survey needs and new approaches are a major part of this synthesis. It is instructive for readers to understand just how GIS data, also known as geospatial data, are important to transportation planning. In December 2007, the U.S. Forest Service, FHWA, and TRB sponsored the "Improving National Transportation Geospatial Information Workshop, New Applications: Environment and Planning." This workshop examined potential benefits and costs of initiatives to improve the national geospatial information infrastructure for transportation. Organizers Burns, Yanchick, and Perkins penned a white paper that provides an overview of the results (2007). The following paragraph (from that document) crystallizes the need for geospatial data in transportation planning:

> Geospatial data can assist transportation specialists in understanding the ecological implications of an individual transportation project. They can also be used by planners to understand the broader, more cumulative impacts of a larger regional or statewide transportation system on the natural and human environment. Increased understanding of ecological relationships and the implication of those ecological relationships can improve transportation designs that minimize impacts to the environment, reduce mitigation costs and project delivery delays. As individual environmental elements are influenced ultimately by ecological processes that are regional or even global in nature, data that provide a larger regional or national context may make it easier to understand how different transportation projects or systems can influence those ecological relationships and pathways that may pass through the project planning area. A better understanding of the relationships may make it easier to design projects that minimize or avoid disruptions to these pathways and ultimately minimize environmental impacts. And, since individual transportation projects are often part of a larger system, with implications beyond regional, state, and even national boundaries, this database [of geospatial data] can assist in providing the appropriate context to design more safe and efficient transportation systems appropriate to the needs of transportation users. Beyond increased safety and efficiency, these improved systems can also enhance the human and natural environment (Burns et al. 2007).

Survey respondents indicated that the following GIS data needs were important relative to long-range planning:

- Coordination and cooperation among agencies
- Uniform, nationwide survey methods for gathering and storing remote-sensed data
- Data-sharing methods that enhance accessibility to data with relative ease of use
- Data that are stored in one central location
- Data that are current and maintained
- A one-stop place on the Internet for permitting processes.

The use of GIS is now mainstream among transportation agencies and other land-use planners. Novel uses and applications of GIS continue to appear, and many of these new approaches focus on improving the access, integration, and visualization of various types of spatial data of relevance to biologists and transportation planners. Dozens of GIS approaches and websites could be considered as new approaches to the GIS needs required at the long-term planning scale. These systems typically show promise for more than one of the ecological survey needs addressed previously. For instance, the Florida example addresses the need for coordination and cooperation, while at the same time demonstrates the benefits of having a standardized system in one central place. A general classification of the GIS approaches in this report is somewhat arbitrary, but it is provided to enable readers to better organize how these approaches can assist in terms of ecological surveys. Each one of these approaches addresses several of the previously cited needs for GIS ecological survey data. Readers are encouraged to explore these programs and websites to determine which solution best represents their specific ecological survey needs. The three types of GIS approaches presented are as follows: (1) coordination and cooperation among agency partners in specific states, (2) general GIS sites with environmental data and methods of data integrations, and (3) standardized and uniform data collection.

Coordination and cooperation among agency partners dealing with GIS-based data occur at multiple levels of government in every state. GIS systems are now used by every state DOT as well as other agencies. Although the more advanced state GIS systems are better known from their coverage in reports, conference presentations, and FHWA awards (see discussion of Florida's ETDM Process in chapter three, Case Study 1), other advances are being made by states that are progressing along the continuum of GIS technologies. The following seven examples illustrate some of the different ways that states are bringing GIS data together for planning purposes. Although some readers may not view these examples as "cutting edge," they nonetheless provide an idea of what different states are doing with GIS to assist with environmental surveys in long-range planning.

In Maryland, the State Highway Administration (SHA) is continually building a working partnership with the state resource agencies, which has helped in the sharing of ecological survey databases. Their working GIS database is the Green Infrastructure, developed by Maryland's Department of Natural Resources (DNR) (see Maryland Green Infrastructure Development discussed in chapter three, Case Study 2, and References).

Michigan Department of Information Technology's Center for Geographic Information manages the Michigan Geographic Data Library. It is the state's repository for GIS and includes more than 60 unique statewide data sets, including the Michigan base map (Michigan Geographic Framework), aerial imagery, geology, hydrology, land ownership, topography, and other maps (Michigan Geographic Data Library).

In New Jersey, the New Jersey Department of Environmental Protection (NJDEP) GIS information and Landscape Project data are used as preliminary screening tools. The GIS layers encompass many different areas of interest, including threatened and endangered species habitat, wetlands, streams, water quality classifications, and so on. If it is warranted for a project, the NJ DOT uses NJDEP wetlands mapping and the Landscape Project data in preliminary screening to conduct a formal wetland delineation (New Jersey GIS).

In Tennessee, the Tennessee DOT is developing the Statewide Early Management System, which will encompass the Early Environmental Screening (EES) tool. The EES uses existing GIS data to make better planning decisions early in a project's life. Experts in various disciplines (e.g., ecology, history, and geology) were brought together to examine available data in their respective disciplines and to decide how those data should be used and displayed to best aid those decision makers. Based on these data, a scoring system has been developed that alerts stakeholders of potential roadblocks the project may face along the way. This enables stakeholders to avoid those roadblocks or to build extra time into the schedule to deal with the problems. Planners now have data that are accessible and easy to use but that still contain enough information to make effective decisions.

Florida is known for its ETDM web-based tool for handling GIS data and long-range and project-level planning. The Florida Department of Environmental Protection and the Florida Fish and Wildlife Conservation Commission have major data development programs and partnerships to enhance accessibility to environmental and ecological GIS data (such as threatened and endangered species, habitat mapping, land-use and landcover classifications, watersheds, wetlands, imagery), improve data-sharing capabilities, and promote interactive and effective interagency coordination (Florida Environmental Resource Analysis Tool). For more information, see chapter three, Case Study 1.

Michigan DNR is developing a lake and stream classification system with local-scale and catchment-scale characteristics. This system will assist transportation planning because it can identify areas with a large number of unsampled locations.

In Wisconsin, the DNR has a web-mapping function, The Surface Water Data Viewer. This tool gives special coverage to a variety of water resources. This tool collects information and makes it available for both developers and highway builders. Its mapping application provides water resources, monitoring, and water quality assessment data. Users can view and analyze watershed-related data for lakes and streams, monitoring stations, impaired waters, and Outstanding/Exceptional Resource Waters (see Wisconsin Surface Water Data Viewer).

Also in Wisconsin is the Aquatic and Terrestrial Resources Inventory (ATRI), which provides a central location from which general data can be retrieved. This information is available for planning agencies and also includes a strong citizen-monitoring program of a variety of resources (see Wisconsin ATRI).

General GIS websites that assist with environmental data and methods of data integration possess information and offer approaches that can help with some of the ecological survey needs listed for long-range planning.

FHWA's website on Planning and Environment Linkages contains information developed and compiled by the FHWA and its partners to assist in strengthening planning and environment linkages. It represents an approach to transportation decision making that considers environmental, community, and economic goals early in the planning stages and carries them through project development, design, and construction. This approach can lead to a more seamless decision-making process that minimizes duplication of effort, promotes environmental stewardship, and reduces delays in project implementation (see Federal Highway Administration, Planning and Environment Linkages in References).

The USGS maintains a landcover data portal containing federal lands, data from the Amphibian Research and Monitoring Initiative, landcover, Gap Analysis Program (GAP) analysis resources, water resources such as aquifers, rivers, topographic maps, and many more data layers and links (see U.S. Geological Survey Landcover in References).

The U.S. Fish and Wildlife Service maintains a GIS Wetlands Geo-database (see U.S. Fish and Wildlife Service, GIS in References).

The U.S. Department of Agriculture (USDA), Natural Resources Conservation Service maintains a soil-mapping GIS service online, linked with the Soil Survey (see U.S. Department of Agriculture in References).

Approximately six respondents mentioned the need to have national or statewide standards for data collection and storage of GIS data. The following software companies, organizations, and initiatives seek to standardize GIS data on natural resources. These efforts have assisted transportation planning across the country and potentially allow greater ease of interagency data exchange across the United States.

NatureServe, a nonprofit research organization, sets national standards for the collection and management of data on species and ecosystems used by the network of state Natural Heritage programs. As a result, Natural Heritage data are nationally consistent and can be used in regional and national-scale analyses. NatureServe has developed a U.S. National Vegetation Classification system, which has been adopted by the Federal Geographic Data Committee as an interagency standard for use in classifying and mapping vegetation communities. NatureServe has developed a midscale ecological systems classification that is serving as the basis for national-scale landcover mapping efforts of the USGS Gap Analysis Program and the USDA Forest Service–led LandFire initiative. NatureServe provides access to many of these nationwide species and ecosystem data through its NatureServe Explorer website (see NatureServe Vista). Also see chapter three, Case Study 3.

ESRI (Environmental Systems Research Institute) is a world leader in the development of GIS software and provides access to numerous standardized underlying geographic data sets. This company produces ArcGIS, the industry-standard GIS software program used around the globe. ESRI develops specific software applications for individual organizations and states. For instance, Utah's Geographic Transportation Environmental Assessment System (GTEAS) for analyzing data layers of species of concern was developed specifically by ESRI. Recently, the Western Governors' Association, a political organization of 19 western states, was advised by both ESRI and NatureServe on how to map wildlife corridors across the entire western United States. Both organizations develop software for individual states [ESRI (Environmental Systems Management)].

The National Geospatial Program was developed by USGS. This program developed the National Atlas, which contains topographic maps and stream coverages. The National Geospatial Program provides leadership for USGS geospatial coordination, production, and service activities. The program engages partners to develop standards and produce consistent and accurate data through its Geospatial Liaison Network (see U.S. Geological Survey Geospatial Liaison Network in References).

The National Map, developed by the USGS, is an online interactive map service based on a consistent framework. It provides public access to high-quality, geospatial data and information from multiple partners (a consortium of federal, state, and local partners who provide geospatial data) to support decision making by resource managers and the public (see U.S. Geological Survey, National Map in References).

The Western Governors' Association Wildlife Corridor Initiative involved a science committee that made recommendations for GIS data collection and storage for 19 western states (see Western Governors' Association, Wildlife Corridors Initiative in References). Also see chapter three, Case Study 4.

Landcover Maps and Wildlife and Aquatic Linkages Maps and Connectivity Plans Landscape-scale ecological connectivity and plans are critical to long-range transportation plans. Long-range transportation planning efforts need input on areas where landscape and aquatic linkages occur or that need to be restored across a state as well as which lands and waterways are important for conservation to local and regional citizen and agency efforts. Incorporating information from coarse-scale large area maps of areas where wildlife and aquatic species need to move helps planners determine whether potential long-range projects should avoid those affected areas, minimize potential impacts, or include mitigation efforts long before the project-level planning. The Context Sensitive Solutions approach enables transportation agencies to consider the ecological, historical, and human community values and attributes of an area under transportation development consideration. To best consider the ecological resources and the ecological attributes that local communities find important, ecological resources must be considered from the data perspective and community conservation priorities perspective. In this section, needs and new approaches are presented for terrestrial connectivity, aquatic connectivity, and overall planning for local and regional scales.

Twenty states expressed the need to identify landscape linkages or wildlife corridors largely for mammals, to avoid, minimize, or mitigate transportation corridors. These responses came from every region of the country. Respondents conveyed the sense that data are available for the individual animals studied, but they are not sufficient to map corridors for the majority of wildlife movement. As one respondent wrote, "GIS mapping that depicts important fish and wildlife habitat and wildlife crossings areas will assist in proactive planning to avoid impacts to valuable habitat, minimize vehicle/wildlife conflicts, and identify potential mitigation opportunities. This will support the requirements of Section 6001 of SAFETEA-LU." Although these maps are important, it is the data that create them that are lacking. Ecological surveys help planners understand different species' movements, which in turn can be combined across studies to create landscape-level maps. Although current maps are helpful, they are often based on consensus among biologists and created through GIS modeling efforts with usually only data for up to five species' needs and distribution. Data needs for terrestrial wildlife connectivity thus involve not only maps of potential landscape linkages, but also studies of multiple species to learn how animals use the landscape, especially with respect to roads.

New approaches include approximately 20 individual state analyses of terrestrial connectivity for wildlife or green infrastructure mapping. A general overview of these maps can be found under Wildlife and Roads—Landscape Linkages in the References. These analyses are developed using two methods: (1) consensus-building rapid assessments through a statewide meeting of concerned professionals, and (2) a GIS-modeling exercise developed specifically for a state that incorporates multiple GIS layers and models of the needs of approximately five keystone species. The resulting maps show where wildlife needs to move on public lands and on private land as well. Each state's maps have their limitations, but the critical attribute of each is that they are tailored to each state's needs. The states with greater human development have limited natural landscape linkages. A recent trend has been to combine several state analyses to identify areas where wildlife movement lands can be linked with other states. The Western Governors' Association Corridors Initiative is the most far-reaching example. Several different approaches give a view of the various maps available.

In Arizona, a GIS initiative called Areas of Conservation Priority is being developed to identify major areas of importance to wildlife, development threats, and connectivity. The program should engage transportation professionals and developers in maintaining some of the important areas that are identified (see Arizona Natural Infrastructure Data Sources in the References).

Since its release in 2006, Arizona's Wildlife Linkages Assessment has proven to be a valuable tool in alerting planners to potential conflicts with wildlife movement corridors. Although no formal adoption of the document has occurred, Arizona DOT (ADOT) has put wildlife linkages in their project checklist. ADOT has said that open preservation and wildlife linkages are one of the overarching principles to be considered in framework studies. The Wildlife Linkages Assessment was a collaborative effort between nine agencies and nonprofit groups to proactively address wildlife connectivity in Arizona. In conjunction with this effort, the Arizona Game and Fish Department funded site-specific Linkage Designs for eight of the identified linkages. The work was conducted by Northern Arizona University (NAU) and led by Dr. Paul Beier. These plans identify and map multispecies corridors that will best maintain wildlife movement between wildland blocks, as well as highlight specific planning and road mitigation measures required to maintain connectivity in these corridors. Through this process, NAU developed a GIS extension tool to aid in wildlife corridor planning. The downside of this project is that it works only with ArcView 9.1 or 9.2, a more recent GIS software that not all agencies may possess as a result of budgetary constraints. The completed Linkage Designs are extremely useful when completed before design of a transportation corridor (see Arizona Wildlife entries in the References).

Vermont Wildlife Linkage Habitat Analysis is a GIS database of core wildlife movement areas associated with state highways (Austin et al. 2006). For more information, see chapter three, Case Study 2.

The University of Massachusetts–Amherst and its partners in Massachusetts will build on the existing CAPS through a statewide landscape connectivity study. CAPS is a computer model developed by the University of Massachusetts that incorporates biophysical and anthropogenic data to develop an index of ecological integrity. This Landscape Connectivity Study will create a spatially explicit tool, including maps and scenario-testing software, to mitigate the impacts of roads on the environment and inform the design of new roads. This study will assess connections among natural areas and wildlife habitats; design strategies to protect existing connections among habitats (including rivers, wetlands, and forests); locate prime wildlife habitat and movement corridors, where the strategic use of mitigation techniques can be used to facilitate wildlife passage and reduce the risk of animal–vehicle collisions (a-v-c); and examine habitat connections that transcend political boundaries through regional analysis. This study has been used to site a new highway alignment in Connecticut (see Massachusetts Conservation Assessment and Prioritization System in the References).

The Maryland Green Infrastructure Project is a GIS mapping tool used to identify and prioritize the state's most important natural lands. For more information, see chapter three, Case Study 2.

In New Hampshire, the FHWA awarded a grant in 2008 to the Audubon Society of New Hampshire to develop a framework to identify transportation and wildlife conflict areas and potential mitigation strategies on an ecosystem scale that can be used before the design phase of state transportation projects begins (see New Hampshire Audubon Society).

In Arizona, GIS tools to identify wildlife connectivity on the landscape are available to multiple users, including the Least Cost Path Analyses Corridor Designer Toolbox developed by Beier of Northern Arizona University (see Arizona's Wildlife Corridor Planning GIS extension), and the newer Circuit Theory Model developed by McRae of Northern Arizona University (see Arizona's Circuit Theory Model). Agency expertise to use these programs in both state wildlife and DOT agencies are necessary to determine and prioritize wildlife corridors.

The Western Governors' Association adopted the Wildlife Corridors Initiative in 2008. An important component of this initiative is the standardization of data and its storage. A science committee that advised this initiative created a standards manual for future data collection and GIS systems for 19 states to be able to share data and create seamless maps. This is discussed in detail in chapter three, Case Study 5.

Aquatic systems connectivity is an important environmental concern for long-range and project-level planning. Several respondents replied how the hydrologic connectivity of rivers, streams, estuaries, marshes, bogs, and other wetlands and uplands is an important information need in long-range planning. For these systems to function, the water quality, quantity, exchange, and organism movement all need to be maintained or restored in ways that are comparable to what is found naturally. This is especially important in maintaining habitat connectivity for aquatic organisms, such as fish and mussels. Although long-range planning typically does not analyze specific infrastructure such as existing bridges and culverts, a general overview of a potential transportation project must determine whether the existing infrastructure is impeding the movement of water and aquatic organisms and needs to be redesigned or retrofit. In Washington State, this is mandated by state legislation. Retrofitting and realigning existing road infrastructure in long-term planning creates an ecological survey need to check existing databases and priority lists of blocked passages to determine what the aquatic connectivity retrofitting will entail. Long-term planning also entails evaluation of existing natural aquatic resources in a general area (1) to evaluate how potential transportation project would affect these areas' connections and (2) to avoid these areas or evaluate how bridge and culvert structures can be designed to reduce hydrologic impacts to aquatic species. Whereas wetlands in general are evaluated for other potential impacts, this part of the long-term planning addresses an ecological survey need to better understand the aquatic connectivity of a system. At this stage in the planning process, potential structures along a transportation corridor may need to be evaluated. As one respondent wrote, "Structure design should be analyzed by an inter-disciplinary team of professionals consisting of a biologist, hydrologist, and engineer to minimize risk of adverse impacts to all aquatic resource values." This ecological survey need also includes the identification of potential pathways for the possible spread of contaminants from a project area, and the spread of invasive species across an area by means of the waterways. The ecological survey needs for aquatic connectivity include the following: (1) maps of existing wetlands and hydrologic data, (2) priority lists and maps of blocked aquatic passage, and (3) a standardized methodology for determining what constitutes a blocked passage and how to prioritize these areas.

The new approaches to understanding aquatic connectivity include new classification systems of waterways, web-based mapping functions to better investigate aquatic resources, and fish passage programs that are well organized and allow efficient access to large databases of prioritized passages, as well as standardized methods for collecting blocked passage data.

Washington State DOT (WSDOT) recognized that many existing highway culverts are barriers to fish passage. WSDOT has managed a cooperative program since 1991 to inventory, prioritize, and correct these fish passage barriers on the state highway system statewide. Through an assessment process, WSDOT has identified and prioritized fish barriers for correction. Fish barriers are corrected as part of transportation improvement projects and also as part of separate stand-alone projects. Since 1991, more than 200 fish barriers have been corrected with project cost ranging from less than $100,000 for retrofitting existing culverts to several million dollars for replacing barrier culverts with bridges under major interstates. Access to about 500 miles of stream habitat has been improved through this effort. A fish passage website helps users scope fish passage barriers in the predicted area of future projects. Links to references are available on the process of installing and monitoring fish passages (for links, see Washington State Department of Transportation Fish Passage Program).

Caltrans has standardized methods for identifying blocked fish passages and how to design culverts for aquatic passage (see California Fish Passage).

In Massachusetts, Scott Jackson of the University of Massachusetts–Amherst has developed a system to help identify blocked fish passages and to install aquatic passages (Jackson 2004).

Additional information on fish crossings is presented under project-level considerations, *Landscape Connectivity—Streams and Fish Connectivity* .

Landcover Maps and Wildlife and Aquatic Linkages Overall Local and Regional Planning Conservation plans for local and regional scales can help inform the planning process to identify what the ecological resources and plans are at local and regional scales. Although the state transportation agency creates the long-range plans and brings them into a statewide long-term program, these plans are based on the direction that local Metropolitan Planning Organizations and Rural Transportation Planning organizations and communities have indicated they would like to follow in transportation and development. According to the Topic Panel for this project, the incorporation of local and regional plans was an important data need for ecological surveys.

The new approach to incorporate local and regional plans into broader-scale plans includes connecting stakeholders, prioritizing approaches to development and conservation, and entering these approaches into a computer model to predict outcomes. Following are the more highly used methods that have assisted with transportation planning.

The *Eco-Logical* guide to planning expands the scope of transportation planning to bring in landscape-scale and long-term time frames. It outlines a process of collaborative decision making (see *Eco-Logical* Performance Measures in the References). The next phase of implementing *Eco-Logical* will be based on the research results of two SHRP 2 projects. For more information, see chapter three, Case Study 6.

SHRP 2 Research Projects C06(A) and C06(B) are under way at the time of this writing. The anticipated results will help with long-term large-scale planning and future assurances that create a larger-scale assessment, mitigation, and working environment (see Integration of Conservation, Highway Planning and Environmental Permitting Using an Outcome-Based Ecosystem Approach in References). For a detailed description, see chapter three, Case Study 6.

The FHWA helped sponsor the "Linking Conservation and Transportation Planning Workshops 2006." These workshops were held to improve linkages between conservation and transportation planning, with an emphasis on long-range planning. Hosted by the FHWA Project Development and Environmental Review Office, NatureServe, and Defenders of Wildlife, the workshops emphasized the use of information, tools, and methods that can be shared between the transportation community, and the resource and regulatory agencies at the local, state, regional, and national levels. The workshops focused on using tools and information developed by NatureServe and its state Natural Heritage program members, as well as linking transportation planning to other conservation approaches, including State Wildlife Action Plans. The workshops demonstrated how the information and tools presented can save money and time by streamlining transportation projects and planning (see "Linking Conservation and Transportation Planning Workshops" 2006).

The Oregon Bridge Delivery Partners website showcases the new way that the Oregon DOT is replacing aging bridges by bundling several projects into a single set of environmental analyses (see "Oregon Bridge Delivery Partners" in References). This approach is conducted at the long-term planning scale to provide an overview of which bridges are priorities for replacement and which can be bundled.

Engineers' drawings were mentioned by one survey respondent as a means to connect people who are working on long-term plans. The respondent wrote,

> The transfer of information between transportation planners and biologists could be facilitated by providing engineering drawings referenced to landscape features. Where possible, drawings should include plan view perspectives on more biologically meaningful base such as a topographic map, ortho-photograph, or remote sensing imagery. This will allow for more meaningful and efficient biological reviews for potential impacts, as engineering line drawings and station numbers are time-consuming to cross-reference

This idea of connecting engineer drawings with topographic maps, ortho-photography, and remote-sensed images could bring to life transportation plans and be a means to unite different professionals and talk about potential plans. At the same time, the interested parties will be able to visualize the features that other participants may have assumed were understood.

Following are other tools and software that can assist with planning for ecological components of ecosystems affected by long-range planning.

Comparative Risk Assessment Framework and Tools (CRAFT) software was designed to assist in the planning and evaluating of management alternatives. It provides a structured approach to identifying objectives, developing and comparing alternative actions, and displaying the trade-offs and risks associated with different decisions. CRAFT uses a decision framework developed in the management sciences to compare decisions made under uncertainty. CRAFT is designed primarily for use in a facilitated team environment. Individuals can use CRAFT, but a planning team is more likely to have access to the range of resources and perspectives necessary to conduct an integrated risk assessment (see Comparative Risk Assessment Framework and Tools).

Community Viz is a software program that works as an extension to ArcGIS, a well-used GIS program. The software is designed for land-use planning and to help people visualize, analyze, and communicate about important land-use decisions. It can be used to site roads, predict future traffic volumes, and estimate environmental impacts.

NatureServe Vista is another software program that is an extension to ArcGIS. This decision-support system is designed to explicitly incorporate biodiversity into land-use planning processes and can be used in transportation planning. NatureServe Vista enables the user to identify the suite of resources of interest or concern (e.g., species, habitats, or other features) and to create scenarios that look at the potential effect of alternative alignments or plans on those features.

The Ecosystem-Based Management (EBM) approach considers the entire ecosystem (with humans) rather than managing one issue or resource in isolation. This is in accordance with a move among many federal natural resource agencies to consider more than species and look at entire ecosystems. In New York (through an executive order) and California, EBM is factored into decisions dealing with transportation. The EBM Tools Network maintains a website that connects developers and users of software tools focused on EBM. The EBM Tools Network is focused mostly on coastal and marine systems, but increasingly it is incorporating tools that have application to EBM for terrestrial and aquatic systems. The website provides access to a broad spectrum of software tools and analytical methods in this rapidly growing field (see Ecosystem-Based Management Tools Network in References).

Landscope America is a new web-based initiative of NatureServe and the National Geographic Society that is designed to provide easy access to conservation priorities that have been set by numerous agencies and organizations. Through the use of an Internet-based map viewer, the site provides users with the ability to zoom from national to state and local levels, and to view open-space protection priorities, existing parks and protected areas, and a variety of ancillary environmental information (NatureServe Landscope America). For more information, see chapter three, Case Study 5.

The Natural Capital Project, a collaboration among the Woods Hole Institute for the Environment at Stanford, The Nature Conservancy, and World Wildlife Fund, maintains a website called InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs). This tool places realistic values on ecosystems in today's markets. InVEST can model and map the delivery, distribution, and economic value of life support systems contributed by ecosystems into the future. The tool enables users to visualize the impacts of potential decisions, and identify trade-offs and commonalities among environmental, economic, and social systems (see Natural Capital Project's Integrated Valuation of Ecosystem Service and Tradeoffs).

Metro Quest software provides an approach for urban and regional planning that allows stakeholders to vote on what they would value in future scenarios. In early planning, participants in workshops can choose to incorporate ecological and build-out choices to determine what the area of interest would look like in the future. The program was developed in British Columbia, and a number of Canadian cities have used it in long-term planning (see Metro Quest).

The North Central Texas Council of Governments has created a website for Planning and Environment Linkages (see North Central Texas Council of Governments in the References). This site integrates environmental and natural resource conservation planning and transportation planning to enhance environmental considerations during the transportation planning process. The site is designed to provide information, gather feedback, and establish a forum for communication and collaboration to enhance the consideration of environmental impacts during the transportation planning process.

The Trust for Public Land (TPL) uses computer models created with GIS software to analyze community-based data. Their GreenPrinting service helps communities make informed decisions about land conservation. The service encourages partners to work toward common goals. The models combine layers of spatial information to guide growth management efforts, including the following: community-defined conservation priorities; mapping waterways in an effort to determine key lands critical to protect water quality; lands necessary to defragment the landscape of conservation lands; and land development forecasting (see Trust for Public Lands, GreenPrinting Service).

The following studies are available concerning ways that states can use broad-scale local approaches to address ecological resources during the long-range planning scale.

In Montana, the *Eco-Logical* approach was applied by an interagency group looking to conduct long-term planning and mitigation along US-93. Hardy (2007) documented how this approach worked. The state has taken lessons learned along this highway and started the next set of steps in projects along MT 83 to the east of US-93. A potential problem that the *Eco-Logical* approach has encountered in planning for MT 83 is that the process needs to be conducted somewhere between the time a potential project is nominated and when it becomes an approved project, which occurs between long-range planning and placement in the State Transportation Improvement Program. The MT 83 process began with projects that were being planned, but that were then pushed to future dates. These dates are so distant that the planning process becomes uncertain at best (see Hardy 2007). For more information, see chapter three, Case Study 6.

FHWA and NYSDOT are sponsoring an *Eco-Logical* grant in New York to provide an *Eco-Logical* perspective to transportation planning efforts and empower other agency partners to support the process. The research will result in the development of two draft Regional Ecosystem Frameworks (New York Study: Long-Range Planning).

Project Development

For purposes of the organization of the report, the project development stage includes corridor planning, State Transportation Improvement Projects, and project planning, design, and development. During the project planning and design phases, ecological survey needs in large part are identified by the regulatory requirements of the NEPA, which are initiated at this stage. Regardless of the regulatory reasons, project development initiates needs for ecological surveys that evaluate a specific area for potential occurrences and effects to species, ecosystems, and landscapes. As with the previous and following sections, project development survey needs and new approaches are presented in the species and ecosystems and landscapes formats. The survey needs and new approaches at this phase have in part been covered in the long-range section and in later sections of the report. Most of the focus of this phase in this report is the survey needs and new approaches for species. The section is organized in the following manner.

Species Presence, Distribution, and Health

- Presence and Distribution
- Population Abundance and Health.

Ecosystems and Landscapes
- Ecosystems—Wetlands and Sensitive Communities
- Ecosystems—Noise and Pollution
- Landscape Connectivity—Wildlife Crossings and Animal–Vehicle Collisions
- Landscape Connectivity—Streams and Fish Connectivity
- Overall Planning for Local and Regional Scales.

Species Presence, Distribution, and Health

The project development phase is when there are the highest level of needs for understanding species presence, distribution in specific places, population numbers, and the overall health of present populations. Survey respondents described survey needs for species at the project level more than at any other time during the transportation planning, project development, and operations process. This section of the report is where the majority of needs and new approaches are presented for species surveys in detail. Of particular concern during project development is the presence of any species that may have formal protections under federal or state endangered species acts, although many state DOTs are now working to identify and understand the needs of, and potential impacts on, a much broader array of species of concern.

Presence and Distribution Because of the nature of the project development process, more detailed and finer grained information on the location of species of concern is required than at the long-range planning level. In particular, there is a need to go beyond general distributional information, and have survey information available that is capable of distinguishing among potential habitat and occupied habitat for species of concern. In general, biological professionals are much better at verifying the presence rather than the absence of a species. Indeed, many of the survey needs identified have to do with improving the chances of detecting target species when they are present, and thereby improving understanding of presence and absence. Although only five agencies responded there was a need for presence-absence information on plant or animal species at the project level—all 50 state agencies need these data. The species survey needs respondents detailed involved sensitive species in general, aquatic species, reptiles and amphibians, listed species of cactus and other plants, presence-absence data on common species, and distribution and abundance for species of concern. Topic Panel members for this synthesis conveyed a strong need for agencies to have additional tools to address these presence-absence surveys of plants and wildlife.

State Natural Heritage programs are the major source for detailed locational (GIS-based) data on the presence of species of concern. They maintain georeferenced databases of the documented occurrences for most rare and endangered species. Consisting of documented occurrences, Natural Heritage databases explicitly strive to minimize errors of commission (indicating that a species exists where it does not), which is essential for use in regulatory processes. In so doing, however, they are subject to errors of omission (that is, they do not necessarily indicate all possible places a species may exist). As a result, a number of new approaches focus on using models to predict where, other than at documented localities, species of concern or their habitats exist. Other new approaches and innovations have to do with improved abilities to access and search species distributional data to determine whether potential conflicts with transportation projects may exist. New approaches include the following:

A number of Natural Heritage programs have begun converting their precise locational data on rare species and natural communities into mapping units that indicate not only the location of the species of concern, but also the surrounding lands and waters that are essential for the survival of the species at that location. The Massachusetts Natural Heritage program has carried this out for the entire state and produced a "BioMap" that is now being used by all levels of government in the state for avoiding impact to sensitive ecological areas. Virginia DOT is supporting the Virginia Natural Heritage program in the development of a similar data layer identifying sites of importance for sensitive species. The New York Natural Heritage program is also defining "important areas" based on their potential to support rare species.

Florida Natural Areas Inventory (FNAI, Florida's Natural Heritage program) created another tool visualizing where rare species in the state are found. The Rare Species Site: The Biodiversity Matrix Map Server (see FNAI—Rare Species Site in the References) is a new screening tool from FNAI that provides immediate, free access to rare species occurrence information statewide. This tool allows the user to zoom into the site of interest and create a report listing documented, likely, and potential occurrences of rare species and natural communities.

A reference to help practitioners and researchers alike is *Occupancy Estimation Modeling: Inferring Patterns and Dynamics of Species Occurrence* (MacKenzie et al. 2006). This book examines the latest methods in analyzing presence-absence data surveys. The authors use four classes of models: single-species, single-season; single-species, multiple seasons; multiple-species single season; and multiple-species, multiple seasons.

Donovan and Hines (2007) have developed exercises on the Internet to help develop methods described in MacKenzie et al. (2006). Donovan has also worked with researchers who use scat (feces) detection dogs to help determine forest carnivore species of wildlife. [For more information on these techniques see Long et al. (2007, 2008).]

Presence or absence information can also be obtained through initiatives that involve citizen monitoring. A program called eBird was launched in 2002 by the Cornell Laboratory of Ornithology and National Audubon Society. The goal of this program is to maximize the utility and accessibility of the large numbers of bird observations made each year by recreational and professional bird watchers who document the presence or absence of species, as well as bird abundance through checklist data. eBird provides data sources for basic information on bird abundance and distribution at a variety of spatial and temporal scales. In 2006, participants reported more than 4.3 million bird observations across North America, making this database a "must see" for those needing to survey bird resources for transportation planning. A simple web-interface engages participants to submit their observations or view results by means of interactive queries into the eBird database. A survey respondent mentioned how helpful this information has been and the potential value that these data may have at small scales in relationship to project development and resource evaluations (eBird in the References).

An alternative to comprehensive surveying for species is an approach that Wisconsin has embraced, according to one respondent, by assuming the species is present. A Wisconsin respondent replied that their DOT (WisDOT) does a reasonably good job of providing for surveys of species to determine presence and abundance. If surveys are not completed, the assumption is "the species of concern is present" and WisDOT avoids and minimizes impacts accordingly.

In Michigan, the Endangered Species Assessment is a new website to help agencies avoid adverse impacts to known ecological resources. The site gives a preliminary assessment of resources (Endangered Species Assessment—Michigan).

Predictive Modeling is one area of technological advance in recent years that has been developed to predict distribution of rare species. These models can be an aid in better targeting field survey work for at-risk species. The modeling can also help to identify areas that could be avoided by transportation projects. As described in the section Systems Long-Range Planning, NatureServe together with a number of its state Natural Heritage program partners, has been involved in putting these modeling methods to use in creating predictive maps for species of concern.

Population Abundance and Health Once a species has been detected or is assumed to be in an area (presence-absence), there are survey needs to understand how it is distributed and how large its population is. There are also needs to estimate the potential impacts of transportation systems on those species. Two general approaches to this need for species distribution and population sizes are to map habitats of those species and consider those areas as the places where the wildlife and plants are, or are potentially, and the other is to survey for the specific species with different technologies. Habitat or ecosystem mapping is a method that would typically be considered an ecosystem level of environmental surveys. This approach is typically conducted to help determine the distribution of the species *within* the mapped habitat, thus is presented as an ecological survey need for species. Five responses to the e-mail survey mentioned the need to have finer information (or other appropriate scale) from vegetation maps. It seems survey needs for species are defined at finer scales than the ecosystem level maps, which is the scale that is most available.

Survey needs for specific species distribution and numbers were typically given in relation to the type of taxa (taxa is a group of organisms of any taxonomic rank such as family, genus, or species). These included insects, birds, and amphibians and reptiles. Genetic methods to evaluate populations in general were also mentioned as a survey need. The needs mentioned specific to these taxa included the need to survey for specific insects, such as the Salt Creek tiger beetle (*Cicindela nevadica lincolniana*) and the American burying beetle (*Nicrophorus americanus*), to survey migrating bird populations so assemblages of birds can be assessed for population declines, and the need to consider the impacts of noise, light pollution, runoff, and road effects when the road runs in between wetlands and uplands and wetlands in general that are needed for amphibian and reptile populations on a day-to-day basis for seasonal survival and reproduction. Genetic needs were general. Respondents asked for methods to gain a better understanding of the genetic consequences of the road-fragmented landscape on animal populations (but this can also be assessed for plants).

The new approaches for estimating populations, their distribution, and health are organized according to four general methods:

- Data gathering (standards),
- Genetic analyses,
- Mapping species distribution, and
- Technologies to detect species presence and population information.

Data-gathering standards were rarely mentioned as either needs or new approaches to environmental surveys, yet they are tremendously important to the success of any program that shares data.

Respondents in Ohio stated that Ohio DOT (ODOT) is proficient in gathering and documenting ecological data. Ohio DOT has produced an Ecological Monitoring handbook that dictates data-gathering standards. According to one agency response, "Over the years the ODOT worked with all the state and federal agencies to develop standardized processes for data collection, data documentation, and coordination procedures. Overall, this consultation with the resource agencies has led to mutual agreement on techniques and procedures and an overall trusting environment." Other states have data standardization methods that were finalized within the agencies responsible for the resource, such as the fish and wildlife agency developed standards for wildlife data collection. An example of this can be found in a description of Florida partnerships, in chapter three, Case Study 1.

The Association of Fish and Wildlife Agencies is developing a monitoring handbook for amphibians and reptiles (see Association of Fish and Wildlife Agencies in References).

Five states indicated that genetic analyses were being conducted to better assess the presence of wildlife populations and potential impacts from the transportation corridor.

In Arizona, genetic samples are being taken during pronghorn (*Antilocarpa americana*) captures to help determine the level of isolation created by the highway that is acting as an almost complete barrier to pronghorn movement. This is being done by the Arizona Game and Fish Department.

In Connecticut, DNA analysis of rabbit scat is currently used to identify species.

In Delaware, hair catchers are being investigated to determine presence-absence and genetic identification of the federally listed Delmarva fox squirrel (*Sciurus niger cinereus*).

Purdue University in Indiana is conducting research on the genetics of squirrels to determine if roads are creating isolated populations.

North Carolina DOT is funding mussel genetics research (see North Carolina, research on genetics of mussels in References).

A recent genetic study of black bears (*Ursus americanus*) near Great Dismal Swamp using hair traps on wire transects provided information for mitigating highway upgrades in Virginia.

Mapping of species distribution is conducted in dozens of different ways. The following examples show the breadth of approaches.

NYSDOT is sponsoring a study (from 2008 to 2013) that will create complete and accurate digital maps of nearly 2,000 known rare species and significant ecosystem locations (which will build on the 1,500 already accurately mapped); create computer models that show the areas around known locations that are important for their persistence; and create online conservation guides for 327 rare species and ecosystem types on Long Island (New York Study: Biodiversity Information for Decision Makers).

Several state agencies mentioned Google Earth as a tool to analyze for species distribution. One respondent stated, "Google Earth imagery is useful in assessing land-use impacts where rare species have been documented in the past (old records)."

Texas DOT (TxDOT) and Texas Parks and Wildlife Department (TPWD) have developed a program to share the

TPWD's Natural Heritage database that contains all publicly available records of federally and state-listed species, species of concern, managed areas, and rare plant communities. This method is used in all states through the use of the Natural Heritage software program BIOTICS. TxDOT and TPWD have signed a Memorandum of Agreement that outlines the program, which includes training the TxDOT staff to use the database. The benefit of this program is to provide TxDOT with the most up-to-date information on protected species and resources that can be used in project planning, regional forecasting, and studies of the distribution of species that are affected by road projects. The TxDOT environmental staff is trained by TPWD and TxDOT to use the software and database and to interpret the information and incorporate it into project planning, particularly in preparing NEPA documents and addressing the Endangered Species Act.

The Utah DOT (UDOT) has sponsored the development of a GIS tool by ESRI (GIS leader) called GTEAS. This tool can be used to identify potential impacts to threatened and endangered species, state sensitive species, wetlands, and water resources. The data are from Utah's Automated Geographic Reference Center (see Utah GIS, Utah's Automated Geographic Reference Center). The Utah Automated Geographic Reference Center (AGRC) provides a wide range of GIS support to the state of Utah. AGRC strives to facilitate coordination among Utah GIS users and maintain effective, efficient use of GIS resources. Its GIS portal gives free access to many resources.

In West Virginia, the DOT used micro-pixel aerial photo software to perform desktop predictions for hemlock, red spruce, and yellow birch habitats to define suitable habitat for an endangered flying squirrel. This software differentiated the various tree and shrub layers to isolate the specific targeted habitat.

Florida DOT (FDOT) has formed an interagency partnership with the Florida Fish and Wildlife Conservation Commission (FWC). Together FDOT and FWC will implement the Florida Comprehensive Wildlife Conservation Plan and develop a new GIS tool for wildlife (see Florida Comprehensive Wildlife Conservation Plan). For more information, also see chapter three, Case Study 1.

The Northwest Habitat Institute developed a habitat assessment method that quantifies habitat value in a consistent format (see the discussion of NWHI, under Long-Range Planning, *Species Distribution* and Northwest Habitat Institute in the References).

NatureServe and its network of Natural Heritage programs in every state are the main source of information on rare, endangered, and threatened species and ecosystems (see NatureServe). For more information, see chapter three, Case Study 4.

Technologies to detect species presence include fish, bird, reptile, and mammal approaches for individuals. Population-level methodologies for ascertaining presence and road effects are also presented.

A survey respondent in the U.S. Southeast reported:

> Hydrophone surveys might be utilized to detect areas used by soniferous (sound-producing) fish for spawning or other activities. The hydrophone surveys need to be done at the right time of year, and right time of day/night for the species in question. Hydrophone surveys could also detect activity of other soniferous aquatic organisms, such as marine mammals (e.g., bottlenose dolphin—*Tursiops truncatus*).

A Southeast respondent also conveyed the following: "Sonic tag detectors (manual or automated) could be used to detect the presence of sonically-tagged fish (or other tagged aquatic organisms) in a survey area." These tags were used on a project to determine sturgeon locations, which in turned helped determine the construction schedule when they were not detected in the area.

California is sponsoring a study to develop a bird species identification and population estimation system. The system is based on an analysis of bird vocalizations and will be used for biological surveys (see Bird Species Identification and Population Estimation by Computerized Sound Analysis in References).

Radar technology has been used to determine flyway and counts of nocturnal avian species.

The Illinois Natural Heritage program is exploring a technique to monitor birds using radio-telemetry and microphones to pick up sounds in an area. The data are analyzed using computer software to identify target bird species and other specific activities, such as vehicles and people, in the area. Further analysis is used to explore the interplay among these factors—for example, changes in bird behavior in response to nearby vehicles or humans. In some cases, the birds are equipped with transmitting heart rate monitors to better assess their responses to disturbance. The outcome of these studies may provide (1) better methods of conducting bird surveys that are less dependent on skilled scientists visiting the sites, and (2) more complete information on the impacts of transportation routes (including roads and bicycle and walking paths) on avian species.

Vertical Beam Radar (VERTRAD) has been used in conjunction with Thermal Imaging (TI) to detect birds and bats using their thermal signatures as they fly. At this time, the equipment may be costly (reported to cost more than $50,000) and further developments are needed to translate the data into useable information that is cost-effective (see VERTRAD).

In Delaware, research dogs have been trained to find rare species in difficult situations such as pine snakes, which are largely subterranean, and bog turtles (*Glyptemys mulenbergii*) that spend much of their time in mucky, difficult-to-walk-through habitats.

A Montana respondent mentioned a novel survey method to identify areas where wildlife needs to move across roads. The United Parcel Service and Federal Express drivers are documenting wildlife occurrence near roads. In this way, it is a random sample of living as well as killed wildlife.

Personal data assistant (PDA) devices are being used by agency staff and consultants in the field to record plant, wildlife, and other natural resource locations that are accurately georeferenced. For more information, see chapter three, Case Study 5.

Connecticut is currently using radio-telemetry and mark-recapture surveys to track the movement of two state-listed species of special concern, the eastern box turtle (*Terrapene carolina carolina*) and the eastern hog-nosed snake (*Heterodon platirhinos*). This study is tracking the movement of both species before construction of a four-lane expressway and will continue post-construction to evaluate whether wildlife tunnels being constructed to allow movement beneath the roadway to get to different habitats are being used (Connecticut Reptile Research on Radio-Tracking Turtles and Snakes).

NYSDOT is sponsoring an integrated research and adaptive mitigation program (Amphibians and Reptiles. Effects of New York State Roadways on Amphibians and Reptiles: A Research and Adaptive Mitigation Program). The 2005–2009 study addresses three primary objectives: (1) document the impacts of transportation infrastructure on herptile populations; (2) determine the landscape, local habitat, and architectural attributes of effective herptile crossing structures; and (3) employ habitat analyses to identify "connectivity zones" where crossing structures would be most appropriately deployed along New York State roadways.

In Arizona, the use of GPS data from collared animals has been helpful in determining placement of wildlife crossing structures and fencing. This information has greatly aided the development process of transportation projects as well as the retrofitting of completed projects. Respondents mentioned that on both SR-260 and US-93, research projects are utilizing this technology. The placement of the bighorn sheep (*Ovis canadensis*) crossings on US-93 are based on GPS collar data. The main difficulty has been having sufficient time ahead of projects to implement the research. As of 2009, several projects are being conducted in partnership with Arizona Game and Fish. The projects will ascertain elk (*Cervus canadensis*) movements along I-17, pronghorn movements along SR-89 and SR-64, and mule deer (*Odocoileus hemionus*) studies on SR-64, among others. The data from these studies will be integrated into the design plans for the transportation corridor. GPS data also are being obtained from desert tortoise movements on SR-93 to determine the effectiveness of mitigation measures throughout that corridor (see Arizona GPS technology).

The Colorado Division of Wildlife gives lynx (*Lynx canadensis*) radio collar locations to the Colorado DOT. This enables DOT biologists to determine the locations of core populations and trends in movement.

Ecosystems and Landscapes

In this section, data needs and new approaches that reflect ecosystems and the greater landscapes are presented. First, the ecosystem-level needs and approaches are presented. These approaches focus largely on wetlands and sensitive communities, and pollutants. Next, the landscape-level needs and approaches are discussed. These needs contain information on the following: (1) the connectivity of terrestrial areas for wildlife, in part to better help prevent a-v-c; (2) the aquatic connectivity of streams and wetlands in large part for fish passage; and (3) an innovative developing method of bringing together plans, maps, and data from local and regional scales. This subsection is organized as follows:

Ecosystems and Landscapes

- Ecosystems—Wetlands and Sensitive Communities
- Ecosystems—Noise and Pollution
- Landscape Connectivity—Wildlife Crossings and Animal–Vehicle Collisions
- Landscape Connectivity—Streams and Fish Connectivity
- Overall Planning for Local and Regional Scales

Ecosystems—Wetlands and Sensitive Communities At least 11 respondents expressed concerns about wetland ecosystem survey needs. These comments included the need for better mapping, better understanding of the entire ecosystem function of a stream or lake, better methods for restoring wetlands, the need to assess chemical alterations to aquatic systems from roads, and surveys for streams and wetlands that are somewhat unusual compared with the typical definition. Respondents mentioned that surveys are needed to find high-quality waters as well as the degraded streams and wetlands in need of restoration. Respondents spoke of the need to maintain or restore functions of streams, and the need to better convey information about the three-dimensional nature of stream flow and culverts, and habitat loss by means of filling channels to improve the site for transportation. Although there was some digression from this survey's intent of environmental surveys, respondents had creative ideas regarding the need for stream and wetland information. A respondent in the Midwest spoke of the need for a classification system that contains functions, values, and overall qualities of streams as part of the database. As a planning tool, this could be used to assess transportation corridors following a logical low-impact approach. During construction and maintenance, this information could be used to monitor potential impacts and ensure that maintenance operations are not decreasing overall water quality.

Mapping of wetlands and sensitive natural communities was also identified as a survey need. The scale of mapping typically does not address the whole ecological "patch" as well as planners would like. The issue of appropriate scale was mentioned several times. Another concern expressed about ecosystem-level maps is the need to map at-risk communities. A Midwest respondent explained, "Surveys should be conducted to better determine the distribution of high quality examples of at risk natural community types such as those that are ranked G1–G3 by NatureServe and the network of Natural Heritage programs." Other respondents conveyed the need to survey unique biological assemblages. This may include rare plant communities, intermittent streams, scenic rivers, and farmland important to wildlife species. Special communities that are defined differently among respondents typically are not found in agency databases.

Oceanic and estuary systems were mentioned as areas in need of better survey data by several agencies in states that border the ocean. These states need data sets concerning sea grass beds and their damage, artificial reefs and true coral reefs, sea turtle activity, sea level, and trend analyses—particularly for land use, water quality, change in floodplain, species number, and habitat acreage. Scant information is available on new approaches to address these needs.

Following are a variety of new approaches for wetlands and sensitive ecosystems.

In Ohio, the state agencies are in the process of incorporating GPS and GIS technologies into their biological evaluation process. Their goal is to have all habitats delineated in the field with GPS and data directly downloaded into the GIS for analyses. Wetland delineation will be completed with the aid of field GPS data collectors. Habitat delineations will then be overlaid with species distribution and occurrence data to assist with the determination of potential impacts to species from transportation projects.

Ecological assessments, which represent another approach used during the transportation planning process, also require environmental surveys. The National Park Service (NPS) developed the Ecological Assessment Methods Database to address the challenges resource managers face when they need to identify ecological assessment methods that are appropriate to their resource setting and particular information needs. This database was created to help users identify suitable methods and quickly ascertain their utility for a specific application (see "Ecological Assessment Method Database").

Scientists are developing methods to use aerial photos and remote-sensed imagery to evaluate ecosystems, including wetlands, for specific attributes. The new methods involve existing and new software programs that analyze every pixel of information in a photo or map. For example, Booth and colleagues (2007) presented a Riparian Proper Functioning Condition (PFC) assessment through analyses of aerial imagery and compared the accuracy and time for assessments between the new imagery analyses and on-the-ground surveys. They tested the utility of low-altitude, high-resolution, intermittent aerial digital imagery for relatively inexpensive, high-intensity sampling in a watershed, versus similar on-the-ground assessments made during the preceding year. PFC assessments from aerial photography were made using an average 4 staff hours per stream compared with an estimated 36 staff hours per stream for ground PFC assessments. The two assessment methods yielded roughly comparable results. The authors recommend further testing of this aerial survey assessment and predict that its use could reduce riparian assessment time by more than half, while maintaining comparable results.

Booth and colleagues also analyzed a new method of using digital photographs of range land to assess groundcover (Booth et al. 2006b). They compared aerial photographic images of areas of sagebrush against artificially created images of this community. Pictures were evaluated for color cover under laboratory conditions using the conventional techniques of steel-point frame, laser-point frame, line-point intercept, ocular estimation, and line intercept. Photographs were measured for color cover using standard and custom-created algorithms within the VegMeasure (a software program) image analysis framework, and using the Digital Grid Overlay method (a conventional method). Results indicate that conventional techniques had significantly greater correlation (>92% agreement of measured to known) than measurements from the algorithms used in the VegMeasure analysis (70%). These findings provide an important measure of relative accuracy among methods for land managers and for researchers seeking to improve rangeland-monitoring methods.

Ecosystems—Noise and Pollution In the survey, respondents representing 14 agencies discussed the need to better evaluate the effects of noise and salt on species, and to evaluate waterborne pollutants in aquatic systems, all stemming from the transportation system, its construction, traffic, and maintenance. Because of the organization of this report, those pollution effects and new approaches are divided among the phases of transportation planning. The ecosystem-level ecological survey needs at the project level include the following:

- The need to consider the impacts of noise, light pollution, runoff, and road fragmentation on amphibian and reptile communities.
- The toxic effects of storm-water runoff including thermal increases resulting from canopy loss, sedimentation from runoff, and nutrient loading, on streams, fish, and fish connectivity.
- The effects of salt runoff on terrestrial and aquatic species (mentioned by eight agencies), especially amphibians and aquatic species and systems.

All but two of the new approaches to dealing with pollution in ecosystems are presented in the section Systems Long-Range Planning, *Ecosystems Long-Term and Cumulative Impacts* under cumulative impacts , as well as in the sections Construction, and Maintenance and Operations, *Ecosystems and Landscapes*. The following references are compilations of noise effects on wildlife.

In 2006, Kaseloo and Tyson published *Synthesis of Noise Effects on Wildlife Populations*. The report was sponsored by FHWA. It evaluates all studies the authors could find that analyze noise effects on wildlife in some manner.

Noise effects on birds have been reviewed by Dooling and Popper (2007) from the University of Maryland in a synthesis of existing literature. For a description of how researchers developed guidelines, see Dooling and Popper in the References.

Landscape Connectivity—Wildlife Crossings and Animal–Vehicle Collisions The need for more research, installation, and determining the effectiveness of wildlife crossings was mentioned by 27 agencies. This was the most often quoted need of the entire survey. The majority of respondents understood that the crossings were necessary not only as a safety consideration, but also for all kinds of animals, large and small. Respondents identified a lack of information to determine the placement and spacing of crossings for different species, the designs necessary for getting amphibians and reptiles under larger highways, general design requirements, and crossing effectiveness. Six respondents mentioned the need to research crossings to determine their effectiveness. Florida respondents specifically asked that the need for crossing criteria assessments be addressed. A respondent from the Northeast stated the need for understanding where wildlife is likely to cross the road,

> There is a need for development of a computer model that uses GIS data, observation data, and the literature (for species habitat use) to predict where animal crossings are most likely to occur in high numbers. This model should be inclusive for all species affected by the roads, with special consideration for rare species.

At least a half dozen respondents expressed a need for more data on areas where wildlife are most prone to crossing the road. These comments were also given relative to the need for survey information on wildlife-vehicle collisions.

Animal–vehicle collisions (a-v-c) or wildlife–vehicle collisions were mentioned by 21 agencies. The comment most often given was the need to improve the collection of data concerning wildlife involved in vehicle collisions, including a standardized data collection method and a standardized way of exporting those data. Several respondents expressed a need to identify areas where smaller animals, including small mammals, reptiles, and amphibians, are getting killed. Respondents from a wildlife agency in the Northeast gave a well-thought-out response:

> There is a need for a standardized statewide survey of road kills contained in a centralized database. The database should contain information on the location, date, and species of vertebrates and invertebrates killed on roadways. Particular attention must be given to those species of greatest conservation need and to species located in areas with high concentrations of roadways and relatively small patches of existing habitat. The data acquired from such a survey should assist in identifying the distribution and significant habitat areas for terrestrial and semi-terrestrial wildlife species and potential hotspots for significant losses related to transportation corridors.

The following are new approaches taken in wildlife crossings and a-v-c:

A continent-wide study funded by NCHRP was completed in 2008. The objective of this study, titled *Evaluation of the Use and Effectiveness of Wildlife Crossings* (Bissonette and Cramer 2008), was to develop guidelines for the selection (type), configuration, location, monitoring, evaluation, and maintenance of wildlife crossings. Other studies were published by this team of nine ecologists and engineers who researched this project.

An ongoing study is developing the software and hardware standards for a-v-c data. For more information on the Use of PDA Devices, see chapter three, Case Study 5.

The website of the Deer Vehicle Crash Information and Research Clearinghouse has been a central location to access information about the effectiveness of deer–vehicle collision prevention methods. So much data have been collected that a visit to this site may cancel the need for another study ("Deer Vehicle Crash Information Clearinghouse").

In Maryland, the SHA developed a Large Animal Removal Reporting System Database, which has proven useful in identifying information about a-v-c hot spots. This site was one of the success stories highlighted in the NCHRP study *Animal–Vehicle Collision Data Collection* (Huijser 2007).

A respondent from the Northeast worked with students from Framingham State College to develop a model that identifies turtle road-crossing hot spots. The modeled habitat was overlaid with Massachusetts roads to determine hot spots that may be of concern for turtles whose habitat is in proximity to roads. This information will be useful in determining whether special structures will need to be erected to protect turtles on existing roadways, as well as in the future when new construction or road improvements are made.

Although it was not identified as an environmental survey method, to prevent a-v-c, ADOT is currently evaluating several different types of fencing, escape ramps, and jump-out ramp options to keep wildlife off roads. ADOT is also experimenting with a driver warning system (for contact information, see Arizona GPS technology).

During 2006 and 2007, the Virginia DOT (VA Transportation Research Council) and Virginia Game and Inland Fisheries investigated the use of GPS-enabled PDAs to document a-v-c in a pilot study. Results indicated that maintenance personnel found greater than nine times more deer (*Odocoileus virginianus*) carcasses on the roads than were reported in a-v-c reports for the same areas (Donaldson and Lafon 2008). For more information, see chapter three, Case Study 4.

A 2007 study documents the different data collection methods for a-v-c and suggests the need for national standards. *NCHRP Synthesis of Highway Practice 370: Animal–Vehicle Collision Data Collection* reports on all the methods used by states and Canadian provinces to collect, store, and use a-v-c data. The study includes successful examples of states and provinces where the a-v-c data collection and use appears to be working well (Huijser et al. 2007).

Landscape Connectivity—Streams and Fish Connectivity Eleven agencies identified the need to map fish connectivity and install fish passages. Much landscape-scale analyses of fish and aquatic systems connectivity are covered earlier in Systems Long-Range Planning, *Landcover Maps and Wildlife and Aquatic Linkages* sections on GIS Analyses, Maps and Connectivity Plans, and Local and Regional Planning. The specifics of new approaches are presented that explain where and how to install fish passages at a project-oriented level. Respondents identified other needs as follows: to inventory culverts and determine which ones impede fish passage, and to develop rapid field assessment protocols to assess road-stream crossings and other barriers to aquatic organisms. One respondent in the Northeast mentioned that this need to survey culverts can help prioritize actions and secure funding. The respondent mentioned that the state interagency committee on wildlife crossings was asked to identify the specific unmet infrastructure needs in terms of highways and habitat to best prioritize where future policy and funding could be directed. The committee did not have an answer. The respondents noted that a culvert assessment and prioritization list would have enabled them to respond to policy and funding initiatives. To get a complete sense of new approaches for this survey need, readers should find aquatic and fish connectivity at each step of the planning process.

Following are new approaches for fish connectivity.

Passive Integrated Transponder (PIT) tags are being used inside fish to help determine aquatic connectivity. A monitoring device is mounted at a culvert or other aquatic structure and as fish pass through, it records which animals have passed through. Montana DOT sponsored a fish passage research project using this method. One of the researchers explains the technology:

> This report describes the use of PIT (passive integrated transponder) tags for assessing road crossings as barriers to fish movement. This technology holds great promise for accurately characterizing the barrier status of a crossing or any other type of in-stream hydraulic structure that might be a barrier to fish or other aquatic organism mobility. The technology is best used in combination with a gauging station. The gauging station's function is to record the hydrograph (flow vs. time) in the stream system. The PIT tags will identify the timing of fish movement. The last step is to overlay the hydrograph data onto the PIT tag information, and the passage thresholds are clearly shown. The downside to this technology is that it takes some time, effort, and expense to evaluate a crossing structure compared to more simple methods (Cahoon et al. 2007).

Michigan DNR is entering new data that are georeferenced. These data give the characteristics of culverts, such as that collected at the USGS National Fish Passage Program (U.S. Fish and Wildlife Service, Fish Passage).

In Connecticut, the Department of Environmental Protection is working with the Connecticut DOT (CTDOT) to allow for the avoidance and minimization of impacts to fisheries' resources during the design and construction of transportation projects. The CTDOT strives to avoid aquatic habitat loss with new projects, and to restore riverine continuity in areas where projects previously have caused fragmentation. Required replacement of aging infrastructure provides the restoration opportunity. The major concerns typically addressed include direct habitat loss and prevention of fish passage problems associated with elevated or steep culverts. Other impacts, such as thermal increases from canopy loss and from runoff over impervious surfaces, bituminous pavement in particular, and nutrient loading from storm water are more problematic.

A New Jersey respondent wrote:

> In recent years, there has been a significant advance in the types of tagging/marking approaches which could be employed to track the short- and long-term movements of fish and wildlife. Radio tags can and are being used to determine the movements of fish and wildlife through stream corridors, particularly in the vicinity of road crossings, dams and other types of barriers.

A Northeast agency responded:

> Through the use of radio tags and tracking devices, it would be possible to determine what the performance standards should be for designing/modifying road crossing structures to ensure that the upstream movement of invertebrates, non-game fish, amphibians, reptiles, and small mammals are not impeded. When conducted on a seasonal basis, radio-tagging studies would provide valuable information on the home ranges and migratory behavior of aquatic organisms within stream corridors and terrestrial organisms, e.g. amphibians and reptiles.

Such work is exemplified by the Montana PIT tags of fish, discussed earlier.

Visual elastomers are being used in Kansas. Researchers in Kansas are using a visual elastomer material injected under the epidermis layer of endangered fishes to determine how small cyprinid fishes pass through stream barriers including culverts. The information helped researchers determine what the fish habitat requirements are to increase movements across these barriers. Biologists then used ArcMap GIS software with mapping of landscape features to disseminate this information. General information about Visual Elastomers can be found in the References.

The Oregon Department of Fish and Wildlife provides guidelines and criteria for stream-road crossings (Oregon Stream Crossings).

Maine DOT has fish passage policy and design guides available online (Maine Fish Passage Policy and Design Guides).

University of Massachusetts–Amherst has sponsored a River and Stream Continuity Project that examines ways to inventory blocked culverts and gives instructions on assessing structures and crossing designs (Massachusetts Stream Guide).

The U.S. Forest Service maintains a site that provides software intended to assist engineers, hydrologists, and fish biologists in the evaluation and design of culverts for fish passage. The software is free and available for download (U.S. Forest Service Fish Xing).

Overall Planning for Local and Regional Scales Generally, survey respondent needs for environmental surveys that address overall planning, including local and regional plans, were presented in the section Systems Long-Range Planning, *Landcover Maps and Wildlife and Aquatic Linkages Overall Local and Regional Planning.* A plethora of different maps and plans from state to local agencies and organizations provides environmental resource and conservation data useful to project planning. Uniting them in one place represents a major need for transportation planning.

Following are the new approaches for planning at local and regional scales.

A transportation planning research project was under way in 2008 sponsored by the U.S.DOT Research and Innovative Technology Administration. The objective of this research is to develop new and innovative approaches to streamlining environmental and planning processes for transportation corridors that will use commercial remote-sensed data and spatial information technologies. Each activity typical of the transportation planning process will consider how remote-sensing and spatial information technologies may add efficiencies, reduce costs, and improve the quality and outcomes of the task or activity. The lead institution for this project is Mississippi State University. Mississippi State is working in collaboration with partners at Oak Ridge National Laboratory and Michigan Tech Research Institute, along with partner DOT agencies. The research will compare and quantify benefits of new and innovative approaches versus traditional methods for completing tasks in the EIS process. A completed EIS for a planned segment of I-69 that traverses Memphis, Tennessee, and northwest Mississippi serves as the research test bed to quantify benefits delivered by the technology deployment project. In addition, the project also addresses Hurricane Katrina lessons learned to derive nationally significant motivations toward enhanced geospatial preparedness for application to transportation planning practices (National Consortium for Remote Sensing in Transportation Streamlining Environmental and Planning Processes).

Construction

At the construction phase of transportation planning, the need for environmental data is at a fine scale, measured in just a few meters. Transportation and natural resource professionals need to examine how equipment and grading of the road will affect the immediate natural world. Of particular importance is judging ecological impacts to species and ecosystems during different times of year, and avoiding impacts during the period of time when they are most sensitive. The same construction activity can have different levels of impacts at different times of year. As a result, certain species and ecological processes present in an area (such as animals that need to nest or spring runoff) can affect construction timing. The survey needs for species usually are specific enough that they are for particular structures and patches of vegetation along the road project. Wetlands that may receive runoff or flow diversions are also analyzed at the local level, near the road. Some of the survey needs for species and wetlands have been addressed in previous sections and some are discussed in chapter three. The organization of this section is again provided in the species, and ecosystems and landscapes format.

Species Presence

Ecosystems and Landscapes

- Ecosystem Wetlands and Water Quality
- Changes to Water Features.

Species Presence

During construction, an understanding of species presence is typically needed for wildlife with nests or movement near the area to ensure that species have not entered the area since construction began, and for sensitive and invasive species of plants. The needs to track wildlife movement or detect their presence in the area are the same (as are the new approaches) as those for species detections at the project level. Better monitoring techniques that are specific to the construction phase are needed. The vegetation and sensitive species locations can be tracked with mapping methods, as described in the project-level approaches, as well as through the use of GPS devices. Innovative ways to use GPS devices on equipment are covered in chapter three, Case Study 5.

The most appropriate publication to address environmental survey needs during the construction phase is a study sponsored by NCHRP. This compendium is titled, "Environmental Stewardship Practices, Policies, and Procedures for Road Construction and Maintenance" (Venner Consulting and Parsons Brinckerhoff 2005). This project developed a compendium of environmental stewardship practices, policies, and procedures in the areas of construction and maintenance from 2003–2005.

Ecosystems and Landscapes

The majority of ecosystem and landscape-scale needs for environmental information at the construction phase called for information pertaining to proximate wetlands. Respondents mentioned three ecosystem-level ecological survey needs that could be applied to the construction phase. These needs related to streams and their inhabitants affected by noise and pile driving, and the effects of in-water work; jurisdictional wetlands and their documentation; and water quality related to in-stream flows and pollutants. The majority of landscape-scale needs for environmental information at the construction phase requested information pertaining to proximate wetlands. No responses from the survey directly addressed this need during the construction phase.

Ecosystem Wetlands and Water Quality Survey needs related to streams and their inhabitants during the construction phase included the need to better assess the effects of noise and pile driving on species, especially pallid sturgeon (*Scaphirhychus albus*). Additionally, respondents identified the need to learn more about impacts of in-water work and the effectiveness of current abatement measures versus an in-water work moratorium to reduce impacts.

Jurisdictional wetlands were mentioned by at least three state agencies from across the United States. One respondent mentioned that the determination of wetlands under this context was the most pressing ecosystem consideration for their agency. The general opinion was that jurisdictional wetland determinations are taking significantly more time to complete and require detailed mapping, which increases the cost of permits. Of note, no agencies provided innovative examples of how they are handling these needs.

Water quality was another process-associated need respondents believed warranted further survey evaluation. This survey need could be addressed at any level of the transportation planning process, but is significant at this stage because the flow of pollutants potentially could enter a wetland area during construction. Survey respondents stated that aquatic species could benefit from the determinations of in-stream or ecological flows, which could be maintained to support aquatic communities. Respondents also noted that knowledge of the chemical composition of pollutants in stormwater runoff is a critical piece of data necessary to assess aquatic system impacts.

Hydroacoustic monitoring of aquatic ecosystems for species while construction activities take place is a new research development that addresses aquatic survey needs. When piles are driven into substrate to support transportation infrastructures, underwater sound pressure can affect aquatic life, especially fish. Fish have been killed by these activities. Hydroacoustic monitoring is the measurement of sound transmitting through the water to evaluate the effects of these activities on fish and other aquatic organisms. The FHWA, in coordination with DOTs in California, Oregon, and Washington State, established a Fisheries Hydroacoustic Working Group to improve and coordinate information on fishery impacts resulting from the underwater sound pressure caused by in-water pile driving. Additional working member agencies, researchers, and methods to resolve the uncertainties regarding hydroacoustic impacts can be found online (see Hydroacoustic Monitoring in the References).

The NYSDOT is a co-sponsor in a water quality–related study that could be helpful for construction phase environmental survey needs. The project Regionalized Channel Geomorphic Characteristics for New York Streams is conducted by the New York State Department of Environmental Conservation (NYDEC) and USGS. The objective is to develop the NYSDEC–NYSDOT–USGS partnership to create regional hydrologic curves and regional channel-geomorphic characteristics at bankfull discharge. The work would be conducted for streams of New York State by physiographic region and by Rosgen stream type to define stable reach characteristics.

These characteristics would be used for DOT highway and bridge construction and maintenance projects, and for stream channel restoration and mitigation projects (see New York Study Water Quality in the References).

Buffering wetlands and construction zones may help runoff problems. Minnesota DOT (MnDOT) is sponsoring a study titled "Wetlands: Role of Buffers in Upland Infiltration, Nutrient Absorption, and Wildlife Habitat (2007–2010)." The objectives of the proposed research are as follows: (1) quantify the reduction in surface runoff entering a wetland through a buffer; (2) quantify the reduction in transported sediment and chemicals from the surface runoff; and (3) characterize the biodiversity of wildlife that uses the buffers and the wetlands (see Minnesota DOT Study—Wetlands in References).

GISHydro is a computer program used to assemble and evaluate hydrologic models for watershed analysis. The program combines a database of terrain, land-use, and soil data with specialized GIS tools for assembling data and extracting model parameters. The primary purpose of the GISHydro program is to assist engineers in performing watershed analyses, especially to support transportation design projects, in the state of Maryland (GISHydro computer program).

NCHRP Report 443 is helpful for assessing the impacts of construction on ground water. *Environmental Impact of Construction and Repair Materials on Surface and Ground Waters* (Eldin et al. 2000) developed a methodology to assess the environmental impact of highway construction and repair materials on surface water and groundwater, and to apply the methodology to a spectrum of materials in representative environments. Accomplishment of this objective involved several phases. In the final phase, the proposed methodology was developed and validated.

NCHRP sponsored a study titled "An Autonomous and Self-Sustained Sensing System to Monitor Water Quality Near Highways" (2007–2008). This project developed and demonstrated the application of a sensor system based on microbial fuel cells (MFCs) to monitor water quality near highways (see An Autonomous in References).

Changes to Water Features The majority of landscape-scale needs for environmental information at the construction phase are for information pertaining to wetlands nearby. No responses from the survey directly addressed this need during the construction phase. Some of the needs considerations are discussed in the section Maintenance and Operations. The following new approaches address water connectivity (flow), construction and engineering for fluvial geomorphology characteristics, a thermal imaging approach, and tracking the ability of projects to comply with commitments.

Water flow is monitored by Michigan's DNR, which enters data on changes caused by road construction to water flow at the USGS National Hydrography Dataset (NHD). The NHD is a comprehensive set of digital spatial data that contains information about surface-water features such as lakes, ponds, streams, rivers, springs, and wells (National Hydrography Dataset).

Fluvial geomorphology is a part of construction concerns in wetland areas. In Kansas, rivers and streams are some of their largest challenges. The standard approaches are culvert construction, channel relocations, habitat loss by means of filling the channels to improve side slopes for safety, and use of large non-native materials in sand bed streams. Recently, more natural stream engineering has been promoted through fluvial geomorphology training as taught by Dave Rosgen. There has been limited success in disseminating this information, but proponents have been working diligently on a stream mitigation guideline in which the state DOT was a cooperative sponsor.

Commitment and compliance is documented in Maryland. Much of the state's current survey activity is focused on developing tracking system databases to document the successful completion of Maryland SHA commitments. These databases include (1) Environmental Monitors (EM) Toolkit, (2) SHA Environmental Programs Division Toolkit, and (3) the Wetland Mitigation Monitoring System.

Maintenance and Operations

Although there are fewer regulatory requirements for daily operations than for new development, there are voluminous needs for information on the location of species that may nest, move, or grow near roads, their right-of-way, and infrastructures. Maintenance crews are often the personnel who need this information as they tend to structures, mow right-of-way lawns, maintain bridge and culvert integrity through annual maintenance, and keep wildlife and fish crossings open and useable for the intended species. Mitigation measures such as bat roosting sites on bridges, fish passages, and wildlife crossings need to be monitored to ascertain their effectiveness. The effects of pollution that come with road runoff from vehicles and de-icing agents also need to be monitored for changes to populations of aquatic and terrestrial species and ecosystem effects. Vegetation management is a large part of these maintenance activities. DOTs need to ascertain the extent of invasive species, manage for them, and determine the presence of rare species as well as manage for them. Although transportation departments struggle to predict and build for changes in ecosystems as a result of climate change, maintenance and daily operations have begun to make necessary changes to take into account higher water levels, changes in water flow and timing, and species compositions in communities. This section deals with these areas, in the following format:

Species

- Species Animal Use of Structures: Mitigation and Bridges
- Species Plants and Vegetation: Management, and Invasive and Rare Plants.

Ecosystems and Landscapes

- Ecosystems Pollution
- Ecosystems Climate Change
- Landscape Mitigation Monitoring.

Species

Species Animal Use of Structures: Mitigation and Bridges The majority of responses to the survey identified needs to survey for species at the project level. Other needs were identified to learn more about wildlife use near the road and of infrastructure such as bridges, and about wildlife and fish passages. Birds, bats, and fish were the three types of taxa mentioned for survey needs related to the operations and maintenance of existing structures typically in place solely for transportation. Respondents stated needs to determine wildlife use of wildlife passages to gauge their effectiveness. These needs for surveys were covered comprehensively in wildlife connectivity needs and approaches to projects. Although areas along roads need to be evaluated for wildlife permeability to move across the landscape, once the wildlife crossings are placed, they need to be monitored for effectiveness.

Respondents asked for more updates and data on bird species that are affected by roads, road lighting, and bridges, with special attention to waterfowl, migratory birds, and Hawaiian and Florida birds (agencies in those states identified specific needs).

Bats were the most often mentioned taxa type, with the Indiana bat (*Myotis sodalist*) the most mentioned animal. Four agencies referenced needs to learn more about this species' habitat needs on bridges for roosting and maternity sites, and movement data.

Fish and aquatic organisms' needs to move through culverts and under bridges are addressed at the long-range, project, and operations and maintenance phases of planning. Evaluation of culverts for blocked passage can be conducted as a regular routine survey over the course of maintenance of these culverts. The following new approaches are presented for blocked culverts, and even though daily operations can address some of the culvert inventory needs, this information is important at the long-range and project levels.

Knowledge of wildlife use of existing transportation structures is needed during daily operations. The majority of these survey needs are for bats and birds near bridges. Although bird detection approaches were presented in the project phase of new approaches for species, several are presented in this section. Bats roosting on bridges are another survey need for wildlife use of existing structures, and following is a common survey approach.

Several newly developing technologies can be used to detect birds near road infrastructures. VERTRAD equipment, Thermal Imaging (TI), and TI-VERTRAD target detection may be sufficiently developed to detect birds (see Thermal Imaging and VERTRAD—Vertical Beam Radar in the References). A respondent described the need for the use of automated photographic and auditory recordings to better understand how these techniques are being developed to obtain evidence of vertebrate use of existing bridges and culverts and to gather information on avian presence in forested landscapes. These techniques also have value in collecting data along new or proposed road alignments to develop the species lists. Videography also is being used in areas of nest sites to monitor birds and to determine when the young birds fledge and leave the area.

Bat surveys were mentioned by five respondents as new innovative technologies. The U.S. Fish and Wildlife Service, Kentucky Field Office, has provided protocols for acoustic surveys for bats to complement mist netting. The number one device mentioned to survey bats was Anabat, which is a passive monitoring device to detect and record bat echolocation calls and visually display the sonogram of the calls on a computer. The sonogram can be analyzed by Anabat and Analook software to determine the genus or species of bat. Detectors can be left at the site (Anabat).

Remote cameras have been placed in dozens of studies to evaluate whether wildlife use crossings structures. A few examples include the following.

An evaluation of the effectiveness of wildlife passage structure on the Bennington Bypass is available online (Vermont Bennington Bypass).

An overview of the methods and approaches for evaluating the effectiveness of wildlife crossing structures was presented at the 2003 ICOET conference (Hardy et al. 2003).

A study to determine placement of wildlife crossings was presented by van Manen and colleagues (2001) at the 2001 ICOET conference.

In Florida, Smith (2003) monitored wildlife use of passages and determined culvert design standards.

During 2005, the Virginia Transportation Research Council used remote cameras to monitor various underpass structures in Virginia to determine the structural and locational attributes that make a crossing successful in terms of its use by large mammals ("Virginia Transportation Research Council Report on Wildlife Use of Underpasses").

A new technology to monitor wildlife passages using DNA analysis was further developed in a pilot study conducted in Banff National Park, Alberta: "DNA Profiling to Identify Individuals Using Wildlife Crossings" (Clevenger 2007). The objective of this research was to develop a simple, noninvasive, cost-effective method to identify and quantify animals using wildlife crossing structures.

Wildlife use of wildlife crossings and the general road and road right-of-way area can be monitored by citizens who are willing to spend time inputting the data on sightings. In Washington State, citizens are helping to work with remote cameras placed before construction begins along I-90. Future crossings will be placed to determine wildlife use of the area. In Colorado, citizens are helping to do the same kind of work along I-70. In Idaho, citizens have helped input data on wildlife on the road in an area where mitigation is needed. In Crow's Nest Pass in Alberta, citizens are helping to input GIS-based data on areas where wildlife are seen alive and dead along the road.

Species Plants and Vegetation: Management, and Invasive and Rare Plants Eighteen agencies mentioned survey needs for plants. The majority of these comments related to the need to learn more about invasive species of plants that are spread along the road right-of-way, but needs also were identified to inventory for rare species of plants. Plant survey needs included the following: (1) statewide surveys of invasive species locations and their spread; (2) methods to inform maintenance workers about sites with invasive and rare species of plants so mowing and spraying impacts could be minimized; and (3) surveys of historical occurrence areas of rare species to better document their existence.

Following are a variety of new approaches to the survey and data management of plant species locations, with particular reference to the management of invasive species.

A Florida study, "Mapping of Invasive Exotic Plants and Rare Native Plants on Florida DOT District 6 Right-of-Way in Miami–Dade and Monroe Counties, Florida," was completed in 2008. The purpose of this project was to survey and map exotic and rare native plants along FDOT right-of-way within Miami–Dade and Monroe counties and to create a database that can be updated to reflect future activities and conditions. A second, similar study is under way as of this publication, slated for completion in the fall of 2009. FDOT funded this study, "Techniques for Management of Invasive Species on Florida Rights-of-Way."

In 2008, an NCHRP study was completed to assist with guidelines for vegetation management along roadways. The objective of the study was to develop proposed AASHTO Guidelines for management of roadside vegetation (Guidelines for Vegetation Management 2006–2008).

An NYSDOT-sponsored study evaluated recommendations on the Integrated Vegetation Management (IVM) program for control of right-of-way vegetation and on the Alternatives to Herbicide program. The study developed recommendations for the IVM program using an IVM/Environmental Management System (EMS) and developed a systematic framework and research protocol for identifying, evaluating, and implementing environmentally sensitive, lower maintenance, and cost-effective vegetation management techniques that can be integrated into an IVM program ("Herbicides—New York State DOT's Alternatives to Herbicides, Integrated Vegetation Management, and Related Research Programs" 2003–2004).

Blumenthal and colleagues (2007) documented a new technology that uses aerial photographs to analyze the size and distribution of invasive plant patches. Typically, sparse vegetative patches cannot be analyzed in aerial photos and have to be ground-truthed to best document their presence, size, and changes over time. The authors tested a novel approach that used a lightweight airplane to rapidly collect high-resolution images over relatively large areas. Through the analyses of older images of mixed-grass prairie, the authors were able to reliably measure small patches and even individual plants of an invasive forb, Dalmatian toadflax (*Linaria dalmatica*). These results suggest that such high-resolution aerial imagery could be used to obtain detailed measurements of many invasive weed populations. The data may be most useful for identifying incipient weed infestations and expanding the scale at which population-level attributes of weed populations can be measured effectively. Although transportation corridors typically do not allow for a plane to fly as low as 100 meters above the roadway, perhaps parallel flights could convey the same information. This methodology has the potential to allow for quick, cost-effective analyses of invasive species of plants along road corridors.

Ecosystems and Landscapes

Daily maintenance and operations need to consider two ecosystem-level issues: pollution and climate change.

Ecosystems Pollution Throughout the survey, responses touched on the issue of pollution at the species, ecosystem, and process levels. Noise and light pollution, chemical runoff (such as salt), sedimentation, and the invasion of non-native species (a form of pollution) were all mentioned in trying to determine the effects on species and ecosystems. Pollution is also addressed at all other phases of transportation planning, as discussed earlier.

The following new approaches to pollution are research study reports. Other methods are discussed in previous sections of this chapter.

NYSDOT sponsored a study to look at pollution impacts on water quality and aquatic life ("Impacts of Snow and Ice Control Practices in the Cascade Lakes Region of the Adirondacks" 2003–2006). The objective of this study was to determine the cause-and-effect relationship of past and present winter highway maintenance activities on water quality and aquatic life in the Upper and Lower Cascade Lakes; the study also evaluated survival of birch trees (*Betula* species) adjacent to this section of Route 73.

NCHRP Report 479: Short-Term Monitoring for Compliance with Air Quality Standards developed monitoring procedures (Caniparoli 2002). The project objective was to develop a short-term monitoring procedure that can produce more accurate input data for air quality dispersion models in a manner that requires less data collection and less time to complete than current monitoring requirements. It should result in the development of procedures that can accurately assess the validity of peak carbon monoxide or particulate matter predictions emanating from air quality models based on observed present conditions as opposed to modeled values. The study could provide an assessment of the differences between predicted and monitored concentrations appropriate for improving the reliability of model impact predictions.

An NYSDOT study (to be completed in 2009) looked at the amount of pollution generated from mowing and herbiciding ("Modeling Air Quality and Energy of NYSDOT Highway Right-of-Way Practice"). The study used mowing and herbicide data to develop a model that estimated the amount of air pollution and energy expenditure associated with mowing and herbicide application in the road right-of-way. The types of air pollutants evaluated were hydrocarbons, nitrogen oxides, carbon monoxide, carbon dioxide, sulfur oxides, and particulate matter. The types of soil and water pollutants evaluated included both the active and the inert ingredients of herbicides. The model also incorporated the frequency of each right-of-way practice.

Ecosystems Climate Change The causes and effects of global climate change are so broad in space and time scales that the traditional regulatory framework and transportation phases have not addressed them. Increasingly, however, states are taking the lead in finding ways to address these issues within the transportation planning, development, and operations process. Twelve participants described survey needs related to climate change. Responses indicated concern about the effects of climate change on existing species distributions and terrestrial and aquatic connectivity, the flow of water, loss of habitat and its degradation, and the timing of biological functions. Climate change is something that already is being dealt with in daily operations and maintenance, especially with respect to water flow and timing.

New approaches to climate change were addressed under *Systems Long-Range Planning, Ecosystems Climate Change Causes and Effects*. See that section for further discussion that relates climate change effects directly to maintenance and operations as well as long-term planning.

At the landscape level, monitoring of mitigation sites for performance is conducted to assist with everyday operations. Five agency responses mentioned the need to assess restoration mitigation. The two general comments referred to the need to determine the effectiveness of wetlands that were created for mitigation, and their ability to function and perform like nearby unimpacted wetlands.

Landscape Mitigation Monitoring Several studies have helped states track progress in mitigation areas.

Protocols were developed in an NCHRP Study, *Developing Performance Data Collection Protocol for Stream Restoration* (2004–2006). The objective of this study was to develop protocols for the collection and analysis of performance data that would show the effectiveness of stream restoration in removing pollutant loads and improving ecological benefits.

Wisconsin funded the study "Tracking Environmental Mitigation Projects: A Survey of Methods Used by State DOTs" (2008). The objectives of this study were to learn how DOTs track environmental mitigation projects through forms and databases to ensure that departments communicate with each other and that their commitments stay attached to projects throughout their life.

In California, Caltrans is exploring the concept of developing or facilitating the development of a joint "sensor" network in which all properly equipped field equipment (e.g., cameras, flow meters, and acoustic detectors) can transmit data to a collaborative centralized backend system. This could optimize field time, leverage investment between agencies and parties by allowing real-time data sharing on a local or regional level, and create a web-based environment in which reporting could transition to data queries that utilize both site-specific and regional data. An added benefit would be access for academic research or community group involvement. It is not known how far along this system is.

WSDOT maintains and publishes the *Gray Notebook*, which provides quarterly performance measure reports on how well the state is meeting performance standards objectives (see chapter three, Case Study 7).

Matrix of Needs and New Approaches to Address Those Needs

Table 1 presents a matrix of the newly emerging technologies and methods that are in use or are starting to be accepted for use by state DOTs and wildlife agencies in environmental surveys. The table is organized in several ways. First, under a section header in the first column, a specific type of emerging technology or method is presented. This technology or method is listed according to the stage in which it can be used: systems long-range planning, project development, construction, or maintenance and operations. If the technology or method is applicable to more than one stage, it is presented in the other stages as well. Second, in columns two and three, the applicability of the technology or method is examined for its potential use in the determination of species or groups of species (taxa), and general ecosystems (such as wetlands), landscapes, and processes, such as climate change, vegetation changes, and hydrology.

This table is a handy reference guide for use during different stages of transportation and operations and ecological survey needs. The entries are further organized under the different transportation stages, with technologies that pertain to individual species locations presented first, and those technologies that enable a broader landscape level, typically a GIS approach, in the second tier. Each entry is presented in the report under the transportation sections and specific websites for each entry, if available, can be referenced in the Literature and Website Review.

TABLE 1
MATRIX OF STAGE OF TRANSPORTATION PLANNING, OPERATIONS, AND MAINTENANCE AND THE TYPES OF TECHNOLOGIES, METHODS AND COOPERATION THAT COULD ASSIST WITH ECOLOGICAL SURVEYS AT THAT STAGE

Type of Technology/Methods/Cooperation	Species/ Taxa	Ecosystems, Landscapes, and Processes
Long-Range Planning		
Cyber Tracker	x	x
Florida Efficient Transportation Decision Making Tool for GIS Data Sharing (under GIS and Case Studies)	x	x
NatureServe (under GIS)	x	x
Satellite Imagery (under GIS)	x	x
Predictive Modeling (under Species)	x	x
Google Earth (under GIS)	x	x
FHWA Website on Planning and Environment Linkages (under GIS)	x	x
Trust for Public Land GreenPrinting Web Service (under GIS)		x
National Geospatial Program (under GIS)		x
The National Map (under GIS)		x
USGS Landover maps (under GIS)		x
Wetlands Geodatabase (under GIS)		x
CAPS—Conservation and Prioritization System (under Ecosystems and GIS)	x	x
USDA Natural Resources Conservation Service (NRCS) Soil Mapping (under GIS)	x	x
ESRI (under GIS)	x	x
National Spatial Data Infrastructure (under GIS)	x	x
Dr. Paul Beier's Corridor Design for Identifying Wildlife Linkages (under GIS)	x	x
Maryland's Green Infrastructure (under GIS)	x	x
Washington Fish Passages (under Maps and Connectivity Plans)	x	x
California Fish Passages (under Maps and Connectivity Plans)	x	x

Type of Technology/Methods/Cooperation	Species/ Taxa	Ecosystems, Landscapes, and Processes
Massachusetts Fish Passages (under Maps and Connectivity Plans)	x	x
USFWS iPac Decision Support System Tool (under Local and Regional Planning)		x
Climate Change book: *Potential Impacts of Climate Change on U.S. Transportation*	x	x
Goddard Space Flight Center Global Change Master Directory Website (under Climate Change)		x
LIDAR Technology to Measure Topographic Change Data Along Shorelines (under Climate Change)		x
Landscope America (under Local and Regional Plans)	x	x
CRAFT (under Local and Regional Planning)	x	x
Community Viz (under Local and Regional Planning)	x	x
"Eco-Logical" (under Local and Regional Planning and Case Study 6)	x	x
NCHRP SHRP 2 (under Local and Regional Planning)	x	x
Natural Capital Project (under Local and Regional Planning)		x
Ecosystem-Based Management (EBM) (under Local and Regional Planning)		x
NatureServe Vista (under Local and Regional Planning)	x	x
Metro Quest (under Local and Regional Planning)		x
Trust for Public Lands GreenPrinting (under Local and Regional Planning)		x
Project-Level Planning		
Trail Cameras (See Maintenance and Operations—Species)	x	
Anabat (See Maintenance and Operations—Species)	x	
VERTRAD (See Maintenance and Operations—Species)	x	
Cyber Tracker	x	x
GPS—PDA Handheld Devices w/Data (under Species and Case Studies)	x	x
Visual Elastomers for Fish (under Species)	x	x
Hydrophones for Fish and Streams (see Construction—Ecosystems)	x	x
Sonic Tag Detectors (under Species)	x	x
DNA Analyses (under Species)		
eBird (under Species)	x	x
Amphibian and Reptile Monitoring Handbook (under Species)	x	x
Occupancy Estimation Modeling Book (under Species)	x	
Thermal Imaging (under All Types of Biological Organization)	x	x
VERTRAD—Vertical Beam Radar (under Species)	x	x
Florida's Efficient Transportation Decision Making Tool for GIS Data Sharing (under GIS and Case Studies)	x	x
Google Earth (under Species)	x	x
Northwest Habitat Institute (under Species)	x	x
Utah's Geographic Transportation Environmental Assessment—GTEAS (under Species)	x	x
NatureServe and Natural Heritage Programs (under Species)	x	x
GPS Data on Wildlife Movement in Arizona (under Species)	x	x
USGS National Fish Passage Program	x	x
USFWS Service Fish Passage Support System	x	
USFWS Fish Crossings	x	x
Website www.wildlifeandroads.org, for Wildlife Crossings and Other Mitigation (under Landscape Connectivity)	x	x

Type of Technology/Methods/Cooperation	Species/ Taxa	Ecosystems, Landscapes, and Processes
PDA Device for Animal–Vehicle Collisions to Help Identify Placement of Wildlife Crossings (under Landscape Connectivity)	x	x
Deer–Vehicle Collisions Clearinghouse, www.deercrash.com (under Landscape Connectivity)	x	
Digital Photograph Analyses [see Booth (under Ecosystems)]		x
Noise Effects Syntheses (under Ecosystems)	x	
NCHRP Report 615 on Wildlife Crossings (under Landscape Connectivity)	x	x
Passive Integrated Transponder (PIT) Tags (under Landscape Connectivity)	x	x
Oregon Guidelines for Stream Crossings	x	x
Maine Fish Passages Policy and Guidelines	x	x
Massachusetts River and Stream Continuity Project	x	x
U.S. Forest Service Fish Xing	x	x
National Consortium for Remote Sensing in Transportation Streamlining (under Planning—Local and Regional)		x
Construction		
Cyber Tracker	x	x
GPS—PDA Handheld Devices w/Data (Case Studies)	x	x
GIS Hydro—Hydrologic Models (under Ecosystems)		x
Hydro-acoustic Monitoring (under Ecosystems)	x	
Report—Environmental Impact of Construction and Repair (under Ecosystems)		x
Dave Rosgen's fluvial geomorphology (under Ecosystems)		x
Environmental Stewardship, Practices, Policies, and Procedures for Road Construction and Maintenance (under Species)	x	
Maintenance and Operations		
Trail Cameras	x	
Cyber Tracker	x	x
GPS—PDA Handheld Devices w/Data (under Case Studies)	x	x
Google Earth (under GIS) for Changes in Vegetation, Hydrology, and Boundaries over Time	x	x
Goddard Space Flight Center's Global Change Master Directory		x
VERTRAD to Detect Birds (under Species)	x	
Anabat for Bat Surveys (under Species)	x	
DNA Analyses for Wildlife Crossings (under Species)	x	
Citizen Scientists (under Species)	x	
Studies on Mapping Invasive Species in Roadway (under Species)	x	
Guidelines for Vegetation Management (under Species)	x	x
Study on Alternatives to Herbicides (under Species)	x	x
Aerial Photo Analyses Blumenthal (under Species)		x
Study on Monitoring for Air Quality Standards (under Ecosystems and Landscapes)		x
Report on Protocols for Stream Restoration (under Ecosystems and Landscapes)		x
Wisconsin Tracking Environmental Mitigation Projects (under Ecosystems and Landscapes)		x
Washington's *Gray Notebook for Performance Measures* (under Ecosystems and Landscapes and Case Study 7)		x

Note: See References for literature and website review.

CHAPTER THREE

CASE STUDIES

The subject matter covered by this synthesis spans ecological levels, the geography of the entire nation, and multiple partnership challenges and initiatives. The case studies presented in this chapter span these many levels of organization and challenges, with an emphasis on innovations and technologies that address the most often mentioned subjects of the survey. These case studies present (1) initiatives in one state to develop partnerships in data sharing, (2) two approaches to mapping wildlife and ecological resources, (3) national level efforts to standardize GIS data dealing with natural resources, (4) a regional effort by governors to identify wildlife corridors and to standardize data collection, (5) the use of GPS devices, (6) expanding the scale of ecological considerations for transportation projects, (7) assessment of performance measures, and (8) invasive species and the use of technology for rapid response.

This survey was different from other surveys in that it gave open-ended questions to respondents. As a result, all respondents gave details that were best suited to their understanding, their situation, and their thoughts on ideas much larger than could be captured in a multiple-answer survey instrument. These rich responses from more than 100 people allowed for a variety of topics, ideas, and potential solutions that could not have been predicted in the survey development. Some of these responses led to the detailed case studies in this chapter.

CASE STUDY 1. FLORIDA'S DATA DEVELOPMENT PARTNERSHIPS

A consistent trend among responses to the survey was the need to develop better partnerships among agencies so that data are communicated in ways that help the transportation planning process in a timely manner. This case study concerns the communication and use of data after this information has been acquired by different agencies. Florida's ETDM web-based tool is known across the country and is featured in other NCHRP Syntheses, as well as *NCHRP Research Results Digest 304* (Schwartz and CH2M Hill 2006). Florida's ETDM may be the most highly developed GIS state data source enabling multiple users to access multiple data layers all in one place. Since the development of Florida's ETDM, Florida agency and university professionals have further developed partnerships to develop additional databases to assist with development and the protection of natural resources. This case study not only demonstrates the ETDM tool, but also provides examples of other major data development partnerships and efforts taking place in Florida to enhance accessibility to environmental data, improve data-sharing capabilities, and promote interactive and effective interagency coordination. Taken together, these multiple working groups, databases, and dedication to improvement make Florida the continued leader in state initiatives to produce useable databases.

FDOT has developed an Internet-accessible GIS application called the Environmental Screening Tool (EST) to support the ETDM Process. The EST integrates environmental resource and transportation project data from multiple sources into an easy-to-use, standard format to facilitate environmental reviews and analyze the effects of proposed transportation projects on natural, physical, cultural, and community resources. This integration combines Internet mapping technology, relational database management systems, and GIS, and is implemented using industry-standard platform-independent development tools such as Hyper Text Markup Language (HTML), Hibernate, Velocity, Javascript, and Extensible Markup Language (XML). The application is deployed at the GeoPlan Center of the University of Florida in conjunction with the Florida Geographic Data Library, which has been developing a comprehensive environmental resource database for many years.

The EST provides tools to input and update information about transportation projects, perform standardized analyses, gather and report comments about potential project effects, and provide information to the public. It brings together information about a project and provides analytical and visualization tools that help synthesize and communicate that information. Agency representatives review project details, resource maps of the project location, and the results of the GIS analyses. Environmental resource agencies have agreed to use the system to provide their comments on the scope and magnitude of likely environmental impacts that will be found in particular areas, or are related to specific projects. This screening tool is used to flag potential critical environmental and cultural considerations early, involve resource agencies and the public in the transportation planning process, supply the necessary data for informed decision making, and decrease the time and costs associated with project development and permitting.

Each resource agency provides copies of the environmental GIS data they currently use in-house for transportation project review. Data have different update cycles, which are coordinated through the database. The EST database sends automated requests to agencies requesting any data updates based on the established and agreed-upon update schedules. Agencies update data through an online form, placing data on a secured FTP (file transfer protocol) site for download and quality assurance and quality control. Protocols and responsibilities for the GIS data are established through formal ETDM Agency Agreements with the 23 state and federal resource agencies participating in the ETDM Process. Detailed instructions for data collection, processing, and management protocols are also provided in the Environmental Screening Tool Handbook available on FDOT's ETDM Public Access site. Currently, 525 data sets are incorporated into the EST, including more than 70 data sets pertaining to the state's wildlife and habitat resources. These data sets currently are available online and for download [see "Florida's Efficient Transportation Decision Making (ETDM) Process" in the References].

At the state level, the Florida Department of Environmental Protection serves as the principal source of information on protecting the state's environment and has developed online collections of spatial data that can be useful in transportation planning. Three of the more recently available databases include the GeoData Directory, the Geospatial Resource Index, and MapDirect. The GeoData Directory is an online database of GIS layers, including land use and landcover, habitat, wetlands, watersheds, floodplains, topography, geology, and a myriad of other resources. The Geospatial Resource Index is the agency's central database for searchable maps and spatial data. The MapDirect application was launched in the summer of 2008 and replaces a number of existing single-purpose web-mapping applications into a single integrated application with extensive capabilities. Mapdirect provides access to a large number of environmental resource data layers and imagery layers, buffer analysis capabilities, drill-down reporting capabilities, and general data browsing (see Florida Department of Environmental Protection's GIS for more details).

The Florida Fish and Wildlife Conservation Commission uses a statewide grid for wildlife that has been incorporated into FDOT's EST, which is an integrated grid of resources in one GIS layer rather than 10 separate layers of data. IWHRS is a GIS-based, rapid assessment tool that allows landscape-scale identification of ecologically significant lands in Florida and assessment of potential impacts of proposed development projects. The IWHRS assists with reviews of FDOT projects, including new highway construction or expansions and dredge-and-fill activities associated with bridge construction. The Florida Fish and Wildlife Conservation Commission uses the IWHRS to evaluate and compare multiple alignments, and to assess direct, indirect, and cumulative impacts to important habitat systems and wildlife resources (Florida's Integrated Wildlife Habitat Ranking System).

FDOT is an interagency partner with the Florida Fish and Wildlife Conservation Commission on the implementation of the "Florida Comprehensive Wildlife Conservation Plan" and development of a "Cooperative Conservation Blueprint." The blueprint is a new GIS tool that unifies existing tools and identifies Florida's most critical lands and waters needing conservation. This tool also fills information gaps on the life history, status, trend, population, and management needs for the Species of Greatest Conservation Need that are identified in the plan [see Florida Cooperative Conservation Blueprint (CCB) for more details].

The Critical Lands and Waters Identification Project (CLIP) is the flagship project of Florida's Century Commission. The project is led by the GeoPlan Center at the University of Florida and the Florida Natural Areas Inventory of Florida State University. The Century Commission is a volunteer commission tasked with envisioning Florida's future by forecasting what Florida will look like in 25 and 50 years. The Commission makes recommendations to the governor and legislature regarding how they could address the impacts of population growth. CLIP uses science and the best available statewide spatial data to show Florida's critical environmental resources in a database that can be used as a decision-support tool. Use of this tool for collaborative statewide and regional conservation and land use planning allows the state to envision and ensure the sustainability of Florida's green infrastructure and vital ecosystem services [see Florida CLIP for more details].

Florida's Wildlife Conservation Planning Tool was created by the Florida Fish and Wildlife Conservation Commission to provide information that assists with planning and conservation on a regional scale. The electronic manual provides guidelines for habitat mapping, initial site assessments, survey protocols for listed species, multiple-species habitat management, population monitoring, and wildlife conservation planning and management. This web-based tool was developed to help the collaborative process prioritize wildlife conservation. It is the starting point for users to begin the process of planning for wildlife. The tool is an electronic manual and does not require an Internet connection, but it does have hyperlinks to online resources. This tool uses a systems approach, which incorporates a holistic approach to the study of ecosystems. This method embraces the complexity of ecosystems by focusing on the interactions between biotic and abiotic functions and human influences.

This technique is similar to the needs several survey respondents expressed, which were related to more large-scale approaches to ecological systems, and a one-stop place to collect information. This manual-tool provides regional information such as GIS maps, databases, and literature related to vegetation communities and wildlife habitat, and explains how to manage the habitat, survey and monitor for wildlife, implement best management practices and conservation actions, and pursue landowner opportunities (Rousso and Hoehn 2009).

CASE STUDY 2. VERMONT WILDLIFE LINKAGES AND MARYLAND'S GREENPRINT PROGRAM: TWO ALTERNATIVES TO LOOKING AT IMPORTANT LANDSCAPE LINKAGES

Twenty-two respondents from across the United States identified the need to identify, map, and prioritize wildlife connectivity in states and across regions. The majority of efforts in mapping wildlife corridors and areas of connectivity have occurred in western states (e.g., Arizona). The following two examples demonstrate how two east coast states have tackled wildlife connectivity using different approaches. In states with more intact ecosystems that support a large component of original wildlife species, connectivity can be based on wildlife movements and preferred habitat modeling. In states with little of the original species' assemblages, wildlife connectivity mapping is carried out by linking (through protection or restoration) the remaining ecologically intact lands.

In 2006, the Vermont Agency of Transportation (VTrans) and the Vermont Fish and Wildlife Agency released "Vermont Wildlife Linkage Habitat Analysis: A GIS-Based, Landscape Level Identification of Potentially Significant Wildlife Linkage Habitats Associated with State of Vermont Roadways." This mapping research is presented as a case study because it was part of an effort that involved work among personnel of the two agencies to better understand and address the issues associated with wildlife and roads. The linkages report and database were developed from a GIS-based landscape-level model designed to predict locations of potentially significant wildlife linkage habitats associated with state highways. The limitations of this report and data are that they are specific to only highways: the core areas and connectivity zones appear to be defined solely near these roads and are not broad-based zones across the landscape and for other roadways. The findings assist in mitigation directly related to those specific highways, but do little to help with large-scale long-term planning in areas away from the road, or areas where new road projects may go. Future efforts may address the broader landscape.

In 2001, the Maryland state legislature created the GreenPrint Program. It was designed to protect lands critical to long-term ecological health of the state. The lands identified in this project became known as Maryland's Green Infrastructure [see Maryland Green Infrastructure Assessment in References]. The objective of this program is to protect the most valuable remaining ecological lands in the entire state, not only those along highway corridors. The Green Infrastructure assessment was developed to provide an "objective, independent and equitable quantitative system for identifying natural resource improvement opportunities." Maryland's SHA responded to the survey associated with this research that the Green Infrastructure Assessment has been useful during the highway design process to locate potential forest, wetland, and stream mitigation sites. The database has the capacity for "layering in" a variety of natural and cultural resource information into a GIS format. It also has the potential to provide useful information to planners early in the highway planning process. A Smart Map technology was developed to build on the Green Infrastructure data to integrate local land uses and other socioeconomic and environmental resources. This approach has formed the basis for a collaborative watershed approach to environmental mitigation for highway projects. This system of GIS data on natural resources is much broader than a wildlife linkages system. It is presented in this case study because it provides an example of how a state with little of its original wildlife communities remaining can prioritize lands and mitigation based on other ecological attributes, such as wetlands and natural communities.

CASE STUDY 3. NATIONAL LEVEL EFFORTS TO STANDARDIZE GEOGRAPHIC INFORMATION SYSTEM DATA DEALING WITH NATURAL RESOURCES

A recurring theme in survey responses was the need to standardize data available in a GIS format, and to have all data layers in the same place. If professionals can go to a single source, or at least have the GIS resources provided in similar formats, then they can more efficiently and timely consider environmental resources during ecological survey efforts. Needs for standards have begun to be addressed for transportation engineers with TERRA, the Transportation Engineering and Road Research Alliance, which is a partnership of government, industry, and academia that continuously advances innovations in road design. Perhaps a similar central standards organization can be brought together to assist transportation biologists working at the crossroads of the natural environment and transportation. The natural world is managed and regulated by multiple agencies and it is dynamic. Methods of data gathering and access are quite varied as well. It may not be possible to standardize data methodologies for things as varied as the coastline in an estuary, the parts per million of a particular pollutant, acoustic surveys of bats, or satellite imagery of a prairie. A central standards organization, nonetheless, can begin to refer users to standards created by national entities, such as NatureServe's Natural Heritage program.

Although the bioregions of United States are quite variable, efforts to establish several GIS data standards are under way. The National Geospatial Program, for example, was developed by the USGS. It provides leadership for USGS geospatial coordination, production, and service activities. The program engages partners to develop standards and produce consistent and accurate data through its Geospatial Liaison Network (see "U.S. Geological Survey Geospatial Liaison Network").

NatureServe and its network of Natural Heritage programs in every state use a standardized GIS. This network is the main source of information on rare, endangered, and threatened species and ecosystems. More recently, NatureServe has been developing information products, data management tools, and conservation services to help meet local, national, and global conservation needs. Two such products are Vista and Landscope.

NatureServe Vista is a Decision Support System software for conservation planning that integrates conservation information with land-use patterns and policies. It provides planners, resource managers, and communities with tools to manage their natural resources. This conservation planning software enables users to create, evaluate, implement, and monitor land-use and resource management plans that operate within the existing economic, social, and political context to achieve conservation goals.

NatureServe's Landscope is a new technology designed to promote conservation by changing how users view natural places locally and across the nation. Released in late 2008, this interactive website brings together maps, data from many sources, and stories about natural places and presents them in dynamic and accessible formats. The map viewer allows users to zoom from a national to state and local perspectives. Users can switch among different views of the landscape, including available aerial photography and detailed satellite imagery. Through the viewer's interface, one can access critical data on the character and condition of the places one is exploring, highlight a state's natural areas, and examine the threats they face [refer to NatureServe Vista and NatureServe Landscope for more details].

CASE STUDY 4. REGIONAL EFFORT BY GOVERNORS TO IDENTIFY WILDLIFE CORRIDORS AND TO STANDARDIZE DATA COLLECTION

On June 29, 2008, the Western Governors' Association (which represents the 19 governors of the western states and territories of the United States) adopted the Wildlife Corridors Initiative (see "Western Governors' Association, Wildlife Corridors Initiative"). This policy established the Western Wildlife Habitat Council. The mission of the council is to identify key wildlife corridors and crucial wildlife habitats in the U.S. West and coordinate implementation of needed policy options and tools for preserving those landscapes. Using the policies in the Wildlife Corridors Initiative Report, the governors will take actions to coordinate interagency and interstate science and management of data to help introduce wildlife concerns into the early stages of transportation planning, land use, energy development, oil and gas activities, and global warming issues. This represents the first time governors have taken action to identify wildlife corridors within and among states. Within the report are many recommendations on needed science, data collection, data storage, and data-sharing abilities to use the GIS information across agency and state boundaries.

This effort was conducted through the work of approximately 150 advisors across the U.S. West who served on six Wildlife Linkages working groups and committees: the Science Committee, and the Energy, Land Use, Oil and Gas, Climate Change, and Transportation working groups. Using the knowledge and energy of leaders in these areas, the WGA was able to develop working policy recommendations on how to collect standardized data, make it available to all levels of government, encourage or mandate state agencies to work together in early planning, and discuss many other specific actions that are intended to identify and avoid or mitigate for crucial wildlife habitats and corridors.

This case study is an outstanding example of how state leaders can proactively come together to create and then mandate standards for data collection, storage, and retrieval, and to encourage working relations among agencies. A recurrent theme in this survey was the need to identify ecological resources before they are gone, and before developers, including transportation agencies, make plans to build in areas of high ecological value. If this Wildlife Corridors Initiative is successful, it will provide a blueprint for the nation for connectivity analyses for wildlife, and for the use of GIS information at all levels of government.

CASE STUDY 5. USE OF GLOBAL POSITIONING SYSTEM DEVICES

A common need across the nation was the collection of field data in a device that was accurately georeferenced, meaning locations with quantitative values that can be brought into a GIS program for mapping. This need called for surveys related to wildlife-vehicle collisions, rare and invasive plant locations in the road right-of-way, bird and bat locations near bridges, the extent of changes in vegetation and landcover, areas where maintenance workers should not spray or cut vegetation, and many other location-specific pieces of information. Examples of how GPS units are being used with other equipment to identify specific locations of ecological concern include GPS units available in handheld portable devices, and GPS units mounted on equipment, which convey a vehicle's location by means of the Internet to a central location in real time and into databases.

GPS units used in handheld devices assist in the georeferencing of plants, a-v-c, pollutants, and habitat locations, and many other kinds of environment-related location data. For example, FDOT uses portable GPS applications to collect easily transferable data related to species occurrences, nest locations, wildlife mortality sites, areas where habitat and water quality information is collected, and areas of pollution, such as sediments. This is not a recent advance, but such wide applicability of these devices still is not common. The collection of GPS data can be managed so that the information is standardized, and using wireless technology, users can upload the information directly to a database.

Standard methods for using these GPS devices are developing within states and across the nation. In Florida, the FDOT provides customized handheld ARCPAD applications to their consultant community to assist with field collection for project development data to support the delivered environmental documents. The handheld unit is synchronized with existing databases, uploaded data are verified by FDOT staff, and data are brought into databases available for use in the Florida ETDM planning process. For more information, see chapter three, Case Study 1.

There is a national effort to standardize locational data pinpointing areas where a-v-c's occur. The researchers at the Western Transportation Institute at Montana State University have been developing a prototype PDA with a GPS unit, and corresponding software for use in collecting spatially accurate animal road roadkill. As part of this nationwide study on use of standard PDA/GPS units, the Virginia Transportation Research Council investigated how they worked for Virginia's needs. Details on these and other studies can be found in the References under the entries under Global Positioning Systems.

GPS units are being used on machinery to help track areas where equipment is positioned in relation to wetlands, sensitive plant species' locations, and other areas of interest. In Missouri, the Missouri DOT uses GPS units on vehicles that automatically upload location data by means of the Internet and transmit the data to office computers so that office personnel can assist the vehicle users in determining areas to go to and areas to avoid. For instance, technology experts are developing ways that GPS units can be used to map areas of sensitive species of plants' location and create a "geo-fence," which is a series of GPS points in computers that indicate exactly where these areas are located. When herbicide sprayers are applying their chemicals, the GPS units on the vehicles can upload exact GPS locations to office computers, enabling a manager to direct the driver away from the geofenced areas. Conversely, areas of invasive plants and noxious weeds can similarly be delineated and their locations uploaded so office personnel can accurately direct drivers to those locations. These types of applications are being used to direct snow plows, salting trucks, and mowers. Similar efforts are being developed in other states such as Florida. GPS has been used to develop Oregon's Restricted Activity Zone Mapping (RAZ). Through the use of computer software and field data-gathering equipment such as GPS units, maps are created to help maintenance staff identify sensitive areas along roadways or areas of specific maintenance needs, such as patches of invasive plant species. RAZ was originally created to help in maintenance activities near *salmonid* species (salmon) habitat [see Schwartz and CH2M Hill (2006) for a more detailed description of this program].

CASE STUDY 6. EXPANDING SCALE OF ECOLOGICAL CONSIDERATIONS FOR TRANSPORTATION PROJECTS

Transportation construction, infrastructures, maintenance, and traffic can affect ecosystems directly, indirectly, and cumulatively over the long term. Effects extend well beyond the road right-of-way, with up to 20% of the land in the United States being affected (Forman et al. 2007). When transportation programs are considered piecemeal on a project-by-project basis, mitigation is also conducted in fragments, sometimes with repetitious lengthy environmental compliance procedures. A recent federal guide to ecosystem approaches has been developed. It is called *Eco-Logical*. This guide helps make transportation infrastructure more sensitive to wildlife and ecosystems. This is conducted through greater interagency cooperative conservation that streamlines the environmental approval process while comprehensively helping to manage water, land, and the biotic and abiotic resources possibly affected by transportation. Key components of the approach include integrated planning, the exploration of a variety of mitigation options, and performance measures (*Eco-Logical*).

The *Eco-Logical* approach was applied by an interagency group in Montana to create the Integrated Transportation and Ecosystem Enhancements for Montana (ITEEM) process, the pilot effort to apply the *Eco-Logical* approach. Hardy (2007) details how the ITEEM process was developed and offers insights for other interagency efforts to increase the efficiency of transportation project delivery, while at the same time applying mitigation where the greatest conservation efforts are needed. The state has taken lessons learned along this highway and has begun the next set of steps in projects along MT 83 to the east of US-93. One lesson learned from MT 83 is that the process works best if a project is at the stage between its nomination from the long-range plan to a project on the STIP. If the plans for the project are too far off in the future, the integrated planning efforts may be difficult because of too many unknown factors. Yet, it is imperative that these efforts occur before the project is set to the point at which there is little room for alternatives and additions.

Transportation and natural resource agencies may be able to follow a standardized national program of large-scale analyses and mitigation once the results of a National Academies' pair of projects are published. National Academies' TRB, NCHRP SHRP 2 sponsored two research projects beginning in 2008. The projects looked at ways to enact these landscape-scale long-term ways of doing business among transportation agencies and the natural resource agencies. Project C06(A) is titled "Integration of Conservation, Highway Planning and Environmental Permitting Using an Outcome-Based Ecosystem Approach." The objectives are as follows: (1) to create an ecological framework for making decisions about transportation capacity enhancements and the surface environment across key decision points and geographic scales of the collaborative transportation decision-making process; (2) to solve the problem of assurances—for example, how can agencies that invest in ecological-level action to minimize or mitigate impacts or restore resources to the ecosystem be assured that agencies that mitigate or avoid get credit for their actions with regulatory agencies and the public? and (3) to link implementation mechanisms and the business model developed in C06(A) to the Ecological Assessment Process developed in C06(B). Study C06(B) is titled "Integration of Conservation, Highway Planning, and Environmental Permitting Through Development of an Outcome Based Ecosystem Approach and Corresponding Credits System." The objective of this project is to create an ecological assessment method(s) for highway capacity enhancements that supports the ecological framework and business model being developed in SHRP 2 Project C06(A). The method(s) may be a credits system, an index system, or some other scientifically justifiable method. (Refer to "Integration of Conservation, Highway Planning and Environmental Permitting Using an Outcome-Based Ecosystem Approach" in References.)

CASE STUDY 7. ASSESSMENT OF PERFORMANCE MEASURES

Transportation agencies are accountable for their actions. Performance measures can provide a quantitative basis for evaluating how well actions are meeting stated objectives. When transportation projects affect the natural environment, when restoration projects are created, when pollution is abated, or when vegetation is managed, the impacts and results of actions to mitigate those impacts must be quantified.

WSDOT maintains and publishes the *Gray Notebook*, which provides quarterly performance reports supporting WSDOT's commitment to accountability, and which is the basis of external performance reporting. Also known as "Measures, Markers, and Mileposts," the notebook is published in three cycles (quarterly, biquarterly, and annually). Environmentally related topics include before and after analyses of projects, environmental management systems, air and noise quality, erosion control, water quality, fish passage barriers, stormwater treatment, wetland replacements, environmental compliance, NEPA documentation, and integrated vegetation management. The electronic format of the reports, available on the Internet, allows readers access to current and archived performance information, along with specific project information. Through the use of "Performance Journalism" the reports contain quantitative writing supported by the use of charts, tables, and measurements, and also tell stories in the form of special features, text, and pictures. The goal of the *Gray Notebook* is to share the performance of even the more complex and diverse programs and projects in a clear and concise format that is easily understood.

Performance measures have been created nationally. For example, the *Eco-Logical* approach to developing infrastructure projects has applied the logic model to the process linking objectives with performance measures. An overview is provided on the Eco-Logical—Federal Highway Administration website (see Eco-Logical Performance Measures).

Haufler et al. (2002) is a commonly used reference for performance measures and ecosystem management.

CASE STUDY 8. NEW YORK INVASIVE SPECIES CONTROL IN ADIRONDACK PARK, USE OF TECHNOLOGY FOR RAPID RESPONSE

Invasive species of plants and some animals are commonly spread by means of roadways. Respondents in the survey stated the need to identify and manage such species. A northeast respondent mentioned the invasive species monitoring program in New York State as an example of what other states could be doing to track and manage these types of mainly plants along roadways. The current NCHRP research project was fortunate in that a member of the Topic Panel was from NYSDOT and was able to convey information on how this invasive species-monitoring program is standardized and has become part of the standard operating procedures for all stages of transportation planning and operations. This example is given to help other states learn how a data inventory method can become standardized and institutionalized, and how these data can become available on the Internet for all interested parties.

Some regional initiatives, such as the Adirondack Park Invasive Plant Program (see References), have incorporated a systematic regimen to set management priorities, and to identify, inventory, and control priority invasive plant species. The Adirondack Park Invasive Plant Program has been used as a test case in carrying out Executive Order No. 13112, which requires NYSDOT to consider and address, to the extent practicable, the impacts of invasive species in all aspects of transportation.

During the NYSDOT project development phase in NYSDOT transportation planning for the Adirondack region of northern New York, locations of invasive species of plants and animals are inventoried. Practitioners can first survey an electronic database of all priority invasive plant locations identified in association with capital projects to see whether the area has already been inventoried. For prioritization purposes, regional inventories have begun with interstates, expressways, and parkways. There is a standard inventory method that includes an inventory data collection form and a GPS method to georeference plant and patch locations. For instance, specific instructions tell users how to use the GPS unit to implement the "Mapping Mode" to collect point data in the center of a patch of invasive plants, use the "Line Mode" to map linear patches, and use the "Area or Polygon Mode" to map regular patches, as well as how to collect marker locations and information, and enter these data into the Regional Invasive Species Inventory database (a GIS project). This database is then searchable for the Adirondack region through a web-based interactive map of the counties or USGS quad maps of the region. (More information is available from the Adirondack Park Invasive Plant Program.) NYSDOT has published an environmental procedure manual (*Invasive Species Manual and Data Collection*) for dealing with invasive species during all phases of transportation planning and maintenance and operations (see New York State DOT, *Invasive Species Manual* 2004).

CHAPTER FOUR

CONCLUSIONS

As the world becomes more developed and intact natural resources become more scarce, it will take greater and greater commitments to protect ecological resources. Respondents to this synthesis' survey gave thoughtful responses to how state departments of transportation (DOTs) and natural resource agencies are coping with the challenges of protecting the natural world. The rich diversity of responses from more than 100 survey participants gave a wide spectrum of biological and ecological survey needs, and developing approaches to those needs. The major themes of this synthesis, as developed from those responses and concurrent literature and new initiatives searches are as follows:

1. Transportation planners and their colleagues are moving beyond the traditional framework in the consideration of ecological resources; the 2005 Transportation Act (SAFTEA-LU) encourages and expects this. Long-range transportation planning will consider ecological resources to a greater degree than in past actions.

2. The innovations that assist with the developing broad-scale approach to transportation planning involve new ways of thinking; a paradigm is developing that encompasses broad biological and landscape scales of viewing the natural world and years' long time frames to detect potential impacts and to create solutions.

3. These large spatial scale and long-term plans and potential solutions require increasingly higher resolution data. These data increasingly need to be in similar formats and easily accessible.

Overall, the survey revealed a wide range of needs and new approaches that involve cooperative coordination among organizations that collect and store data and those who need the data, such as DOTs. This is further addressed in Appendix B.

In summary, the future holds many promising new ways to gather data, bring them into common GIS formats, and improved working relations among agencies. The expanded responsibility for transportation agencies to broaden their approach to areas outside the road right-of-way and to consider ecological resources early in planning is the model for change in transportation. This paradigm change began happening in the past decade as state and federal transportation departments became more responsible for the world outside of the road right-of-way. New ways of doing business, such as Context Sensitive Solutions and the provisions of the 2005 Transportation Act (SAFETEA-LU) Sections 6001 and 6002, are becoming more standard. The dozens of responses to this synthesis' survey are reflective of how those within and outside departments of transportation expect these organizations to operate. An approach to view transportation and the environment in a more holistic manner than traditionally considered will be more common in transportation planning. This expanded vision of responsibility will necessitate more interactions between DOTs and state fish and wildlife agencies. Agencies increasingly will need to be more proactive about identifying areas that state, regional, and local organizations have targeted for development and those areas that need to be avoided, minimized, or mitigated because they are conservation areas. The current initiatives such as *Eco-Logical*, and the Western Governors' Association Wildlife Corridors are examples of how states and regions of the country are coming together to develop an interagency approach to transportation planning, development, and maintenance. These new ways of doing business will be supported by more standardized Geographic Information Systems data that will be synchronized among data layers and across agencies. Technological advances in survey methods will become better developed and disseminated. A promising sign of how ecological survey data will be used proactively to help avoid, minimize, or mitigate environmental impacts is the wealth of responses from the survey respondents. The DOT and fish and wildlife agency professionals who replied to the survey are doing an admirable job at protecting the natural world and finding ways to work together. The general consensus is that it is essential for these professionals to understand what the ecological resources are before they are gone. Judging from the wealth of knowledge and commitment from the survey respondents concerning the natural world, the United States is well on its way to defining how it will protect and restore its ecological legacies.

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GLOSSARY

AASHTO—The American Association of State Highway Transportation Officials is a nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico. Its primary goal is to foster development, operation, and maintenance of an integrated national transportation system. Much of AASHTO's work is done by committees composed of member department of transportation personnel who serve voluntarily. AASHTO's standing committee on research (SCOR) makes reports and recommendations on the National Cooperative Highway Research Program (NCHRP) and other activities to the AASHTO Board of Directors.

a-v-c—Animal–vehicle collisions are the reported vehicular accidents that involve an animal (usually a large ungulate such as a deer, elk, or moose) large enough to cause vehicle damage or injury or worse that evoke an accident report with local or state law enforcement. These reports are taken by sheriff's deputies, highway patrol, or other authorities, and are reported to the traffic safety division of state departments of transportation. These reports rarely involve animals smaller than a deer, and typically have to cause a minimum of $1,000 in damage and occur with a driver who is willing to report the accident. Reporting these accidents is rare among those driving tractor trailer trucks, or with vehicles that have no comprehensive collision insurance coverage. As such, the record of a-v-c is considered a portion of actual collisions.

Context sensitive solutions—The context sensitive solutions approach instructs transportation agencies to consider the ecological, historical, and human community values and attributes of an area under transportation development consideration.

DNR—Department of Natural Resources, a state agency.

DOT—The state department of transportation is the agency responsible for road building and maintenance of state and federal roads in each state. Some states have slightly different names, such as state transportation department, but all states are referenced in this manner. County and local roads are not under the purview of these agencies, but do work with them.

ESRI—Environmental Systems Research Institute is the company that helped create the original and today's most commonly used geographic information systems software (see GIS).

FHWA—U.S. Department of Transportation, Federal Highway Administration, is the federal agency responsible for working with state and local transportation agencies in the delivery of funding for road projects, research, and general guidance in up-to-date techniques for road planning, construction, maintenance, and monitoring. Tax dollars that come from a state's fuel tax are returned to the states through FHWA with specific instructions on the projects they are to be spent on, usually with matching state money.

GIS—Geographic information systems are basically maps in computers. GIS software allows data about the earth, natural resources, and human attributes on the landscape to be combined into maps from fine (local) to broad-scale (regional or the world) levels. ArcGIS is an updated version of the GIS software ArcView.

GPS—Global Positioning Systems are a system of satellites, software, and computers that allow users of a GPS device to detect exactly where they are on the earth within a few meters, in a georeference data set. Georeferenced means that the location has exact coordinates that can be uploaded to a computer and mapped.

National Environmental Policy Act (NEPA)—As of 1970, NEPA established procedural policies requiring federal land management agencies to create environmental reviews of potential projects that have ecological impacts. An Environmental Assessment (EA) is required for development projects that may have some impacts on ecological resources, and a full Environmental Impact Statement (EIS) is required in situations in which the environmental consequences of land use or changes have to be identified and considered in decisions affecting the public domain. Often in transportation planning, NEPA requirements begin once a project is defined.

NCHRP—The National Cooperative Highway Research Program is a program of the Transportation Research Board, which is a division of The National Academies. See initial pages of this final report for further descriptions.

PDA—A personal data assistant is typically a handheld computer that allows users to input data that can be downloaded into a computer; the device also can be read and worked with using the data it contains.

Permeability—A principle that wildlife, plant propagules, and natural processes can move across the terrestrial and aquatic landscapes freely in both daily and long-term dispersal movements. When applied to the transportation setting, it implies that mitigation and avoidance measures have sufficiently been constructed to allow different types of animals of different ages and genders, plant seeds, and natural processes such as the flow of water to move to natural areas on either side of a road corridor on a daily basis.

SAFETEA-LU—The U.S. 2005 Transportation Act, which is the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users. Sections 6001 and 6002 relate directly to environmental considerations in transportation planning.

State Transportation Improvement Plan—STIP is a statewide transportation plan that projects what transportation projects will be selected to become active construction projects in the next 5 years. These have been selected from the Long-Range Transportation Plans that scope potential projects 20 years into the future. Those long-range plans in turn are reflective of what local communities would like to see developed, based on Metropolitan Planning Organizations (MPOs) plans, for communities of 50,000 or more, and from Rural Transportation Planning organizations' plans.

Taxa—A group of taxon, which is a group of organisms of any taxanomic rank. These ranks are organized by class, order, family, genus, and species. Taxa would be a general category to group a number of species that have a common characteristic. In this document, it is the species that often have a similar quality related to roads.

APPENDIX A
SURVEY INSTRUMENT

Dear :

I am conducting a survey for the National Cooperative Highway Research Program (NCHRP) to learn more about biological survey needs and innovations. Please forward this e-mail to the member of your staff in the best position to respond to this survey. **Survey responses should be sent to patricia.cramer@usu.edu by March 26, 2008**. Responses will be kept in strictest confidence; only aggregated data will be reported.

Introduction

State transportation agencies need to collect biological resource data to assist in transportation planning, design, construction, and maintenance that may be difficult to obtain and process in a timely and cost effective manner. The goal of this survey is to learn about biological survey needs that are not being met, and identify technologies and techniques **recently** available to fulfill those needs, including data collection, data analysis, and information delivery. The information you provide will become part of a synthesis report that will assist both transportation and natural resource officials responsible for planning, designing, constructing, operating, and maintaining projects in an environmentally sensitive and fiscally responsible manner.

Contact Information

State: ____

Name: ____

Mailing Address: ______________________________________

E-mail Address: _______________________________________

Phone Number: _______________________________________

Survey Questions

1. What are the most-pressing **unmet needs for environmental surveys** that are necessary to assist in transportation planning, design, construction, and maintenance? These include data collection needs, analyses, and the ability to transfer the information to professionals. Please provide needs concerning:

Habitats, plants, fish, and wildlife, either specific species or in general:

Ecosystems such as wetlands, landscapes, and other unique biological assemblages:

Ecological processes such as water, disturbance forces, global warming:

2. This research will also bring together information on **recent advances in environmental survey methods** such as new uses of GIS data and technologies such as using genetic markers in scat to identify presence of sensitive species. Could you please tell me about recent advances and innovations that show promise in helping transportation planning and other arenas to better consider ecological resources? These methods may be in use or under exploration. Please provide a description and perhaps related websites and other resources.

Thank you for your participation. You will be sent a copy of this research's final report when it is published next year, using your return email address.

APPENDIX B

IDEAS FOR CHANGE

OVERALL IDEAS ON NEEDS FOR CHANGES

This survey was a bit unique in that it gave open-ended questions to respondents. As a result most respondents gave details that were best suited to their understanding and situation, and their thoughts on ideas much larger than could be captured in a multiple answer survey instrument. These rich responses from over one hundred people allowed for a variety of topics, ideas, and potential solutions that could not have been predicted in the survey development. The most pressing needs for environmental surveys were also given with specific ideas about what needed to change about current systems approaches to looking at the ecological world from a transportation development perspective. Over 30 respondents in every region of the country and in departments of transportation (DOTs) and Fish and Wildlife agencies addressed needs for change in the current systems that require environmental surveys. These concerned: coordination and cooperation; the need to study long-term, cumulative, and post-construction effects; how roads are placed in remaining undeveloped natural areas; how mitigation does not solve problems; and a need to increase concerns beyond the road right of way. These are presented here.

THREE NECESSARY FUNDAMENTAL CHANGES TO THE TRANSPORTATION DEVELOPMENT PROCESS

The responses that went beyond the specific needs questions in the survey to speak of the fundamental flaws (as respondents saw them) to the transportation–development process can be summarized by three statements:

1. There is a need to be proactive and to understand what species and ecological resources are out there across a state long before any development or road project is considered.
2. There is an unfortunate belief that a road can be built without deleterious effects because the mitigation will “take care of it.”
3. Road impacts occur at spatial and temporal scales far beyond what current environmental surveys methods consider, and there is a need to think beyond the road right of way in a holistic manner.

The need to be proactive and survey all species in a state comprehensively prior to any development plans was a need conveyed in a variety of ways. A northeast wildlife agency respondent wrote, “We have a need for basic information on the statewide distribution and abundance of wildlife of all taxa.” In the southeast, a respondent stated, “Oftentimes it is not the type of data that is missing, but that the surveys may only cover a limited geographical area and not provide statewide coverage and/or its application.” A Midwest response helps to see where respondents would like to see the results of this survey research headed; “We are continually pushing for a proactive measure in comparison to a reactive one, which appears is what this survey may help provide.” The following list of ideas on how this can be accomplished is a summary of how respondents thought this could come about.

1. There are needs to address species at risk, and what they are at risk from: construction; the road itself; traffic and predicted increases in traffic volume; additional development in the areas; pollutants in soil, water, and air (runoff, noise, light pollution); vegetation changes including invasive species, and right-of-way management; mowing and chemical management.
2. Streams and wetlands have species and processes we are unaware of. What species are there and in the different layers of the resource, what do they need, and where are the culverts that block those needs?
3. Go beyond the threatened and endangered species requirements.
4. Wildlife agencies and other natural resource agencies need to establish presence or absence of species.
5. The same natural resource agencies need to help determine habitat requirements of animal and plant species.
6. Natural resource researchers need to help determine the connectivity and movement requirements of all species that may be impacted by transportation corridors and ancillary impacts.

Response from a group within a northeast wildlife agency can help to summarize the problem that mitigation is seen as a cure to road impacts; "As fish and wildlife biologists, we are unanimous in our opinions that roads are largely deleterious to natural resources and mitigation measures fall far short of offsetting the larger issue. Numerous research studies have already been conducted on the various aspects of the effects of roads to include collisions, fragmentation of habitat, degradation of habitat, population effects, etc. While implementation of some of this work may alleviate some issues, especially regarding culverts, it is unlikely that newer surveys will do more than restate the obvious. I do acknowledge that it is often necessary to demonstrate on a local scale in order to prove a point, but this does not amount to innovative research or survey methodology." While this type of reply only occurred in approximately 10 responses, the author believes this quote accurately reflects the theme of those who chose to address this quandary. One of the respondent's simple suggestions may help to address what we have already done; after construction, evaluate the mitigation and the impacts that actually do happen.

A thoughtful federal employee respondent provided a list of questions that should be considered when framing survey needs for transportation projects. These concerned increasing the time and space scales when we look at potential transportation impacts, and addressing ecological phenomena beyond the typical regulatory aspects of species and wetlands, such as evaluating impacts at a landscape scale of disturbance regimes, wildlife movement, plant dispersal among ecosystems, and changes in vegetation. A Midwest DOT respondent wrote of the need to change the "vision" of state DOTs to include more of a landscape scale way of examining the road effect, especially for those at higher level positions within DOTs. Other respondents mentioned similar concerns with expanding the scope of concern to larger scales and multiple impacts. These ideas are directly related to the overall paradigm change that is occurring among DOT's; expanding the scope of concern beyond the road right-of-way.

TIMING AND PLANNING OF SURVEYS

Nine respondents mentioned the need to better plan surveys with respect to time. The two major themes of these responses were that planning needs to occur at longer time scales ahead of projects to better plan for surveys, which ties into the second theme, which was the timing of surveys are important for research–survey planning years ahead of the actual survey and the time of year surveys occur. One western DOT respondent gave a succinct statement: "Knowing about projects with enough advance notice to get the needed surveys done, and getting the information to the planners in enough time for them to plan the project to avoid or minimize impacts" is crucial. Whether responses mentioned plants or animals, it was often conveyed that there is a need to survey for the intended species at the correct time of year. Another respondent, from the Mid-Atlantic region is also quoted: "Guidelines need to be established that prompt the DOT to confer with natural resource agencies early enough in the process such that there are an adequate number of seasons to gather data on the potential presence of species."

COOPERATION AND COORDINATION

A lack of cooperation in certain places, the need for better coordination, and overall cultivation of working relations among agencies was mentioned by at least 18 respondents when discussing survey needs for species. A Midwest DOT professional eloquently wrote of how important working relations were to the successes of their agency; "I believe that in order to truly accomplish the goal of building or retrofitting transportation facilities to accommodate both the human and natural environment, it is necessary to cultivate relationships with local, state, and federal resource/permitting agencies." Others wrote of the need to establish full-time dedicated wildlife and DOT agency employees that could take wildlife–ecological data and bring it to the long-term and project planning processes within DOTs. The need for increased cooperation often was in response to specific complaints. At least one-half dozen respondents mentioned the need to gain better access to on-line databases.

While there were specific needs for greater cooperation and coordination, there were also concrete examples given on how some states have benefited from improved interagency cooperation. For example, Programmatic Agreements have become standard operating procedure in most states. Examples of how these agreements have bolstered cooperative relations were given by several respondents. Examples include the Ohio and Minnesota experiences here.

Ohio DOT in cooperation with the U.S. Fish and Wildlife Service has developed a Programmatic Agreement on the Indiana Bat (federally listed). The programmatic developed standard definitions and a two-tiered process for consultation that has reduce consultation time and efforts. See Ohio DOT Indiana Bat in the References.

A Minnesota respondent replied, “I’ve included some of the agreements/arrangements that we have recently established. I am optimistic that these endeavors will go a long way in building relationships, establishing a sense of ownership by all parties, and assisting in building long-term partnerships. These agreements include: (1) Designation of the FHWA as the Lead Federal Agency for Endangered Species Act Consultations; (2) Designation of Minnesota DOT Office of Environmental Services as the Non-Federal Representative for the FHWA for Informal Consultations under Section 7 of the Endangered Species Act; (3) Minnesota DOT/Minnesota Department of Natural Resources (DNR)—Rare Species Surveys—Pre-qualification Agreement; and (4) Streamlining the Section 7 Consultation Process—Counties in Minnesota without Federally Listed Species or Designated Critical Habitat.

An exemplar situation of coordinated cooperation appears to occur in Wisconsin. There were several innovative solutions in that state that appear throughout chapter two. A Wisconsin respondent explained working relations in their state:

> Our success is really based on the strong relationship that our agencies share. We share a level of trust. DOT trusts that DNR is serving the public by protecting natural resources. Likewise, DNR trusts that DOT is serving the public by providing safe and efficient transportation facilities. So DOT trusts DNR if they say that there is certain habitat that should be avoided. So instead of spending time and money on surveys to prove or disprove it, the DOT simply accepts it and does what it can to avoid an area. If it is a species that has a level of legal protection, then the DOT works with the DNR on reasonable mitigation measures. Sometimes the DNR doesn’t ‘know’ but the DNR has a hunch something could be there. In that case, the DNR asks DOT to conduct an appropriate level of study to answer the question of present or not present. The flip side is that DNR doesn’t usually make a big deal about purpose and need. Not to say the DNR doesn’t push the DOT on need, but the DNR rarely says at the end of the day that a project isn’t needed. It goes back to trusting that DOT is the transportation expert in the state. The basis for our relationship is our DNR/DOT Cooperative Agreement [see Wisconsin Cooperative Agreement in References]. This agreement works because there is a state law exempting DOT from state water permits as long as they follow the ‘liaison process’ in the agreement. This may seem like it gives a lot of environmental protection away, but in reality it gives the DNR an awful lot of flexibility. For instance, unprotected lands like oak savannahs and prairies could not ordinarily be protected from impact by a private housing development. However, through the liaison process, the DNR can withhold their ‘concurrence’ to DOT for the project if they fail to avoid impacts to the prairie.

While this appendix presents information beyond the scope of the original objectives of this research, the number of respondents with these ideas and the striking similarities of these responses truly require that these issues be addressed in this report. They are not meant to offend or to lay blame with any single group of professionals. They are meant to stimulate thought on changes that many see as necessary to help continue doing business, but not as usual.

Abbreviations used without definition in TRB Publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETY-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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