Central Texas is among the nation’s fastest growing regions and experiencing significant levels of roadway construction in environmentally sensitive locations. Current roadway design, construction, and maintenance specifications within this region are based on Texas Department of Transportation (TxDOT) standards developed for state-wide applicability. However, dramatic swings in climatic conditions across the region’s three ecosystems have contributed to significant systematic roadside failures and follow-on environmental degradation. These increasingly common negative results have demonstrated that the status quo of a singular state-wide roadside development approach is problematic and not attuned to the complexity of the local ecological, cultural, topographical, and financial conditions. In response, the Protocols for Sustainable Roadsides (Protocols) were developed under the guidance of the authors for Williamson County, Texas, as an effort to expand the long term success rate of Central Texas roadsides, and thereby reduce or avoid financial and environmental costs. This paper documents the research and public policy efforts to create the Protocols with emphasis on the life cycle cost aspects to balance ecosystem and road development needs and requirements. The Protocols draw from current leading research and practices in highway design and construction from around the nation and abroad, and overlay general and specific planning, design, and construction specifications. Because the benefits and avoided costs that might accrue from the use of sustainable techniques are rarely monetized, extensive fieldwork along a 12 mile section of roadway was undertaken. This validation effort demonstrated the life cycle benefits and costs associated with an ecosystem based framework for roadside development. The results were also used to document and validate the ecology-related practices established in the Protocol for policy makers as well as the engineers, contractors, and maintenance staff involved with roadside planning, design, construction and maintenance. As such, the Protocols are a significant contribution to the body of knowledge on a comprehensive process to establish ecosystem-based roadside development given that this effort includes a benefit and cost evaluation combined with detailed guidance and specifications on planning, design, construction, and maintenance.

In the course of implementing this effort local policy makers and engineering staff have become acutely aware of the lifecycle financial and environmental costs associated with construction, operations and maintenance, and initiated a comprehensive program to address both immediate and long-term issues associated with roadway development. The Protocols are now seen as a deliberate and effective response by implementing environmentally responsive and low-impact solutions that are well documented as cost-effective and tested sustainable practices. The anticipated results will reduce long-term maintenance costs, enhance ecosystem performance, maintain roadway safety, and install a greater sense of regional character. Equally significant to this effort has been the collaboration among the disciplines of landscape architecture, environmental science and policy, and civil engineering. These lessons can be adapted by others and this paper will conclude with a discussion on what are the critical components that bring about such success.

1. INTRODUCTION

The 2010 U.S. Census documents Texas as the state with the fastest population growth between 2000 and 2010. A significant portion of this growth has been in the ecologically sensitive and transportation network deficient region of Central Texas. In response to the increasing demands on developing a roadway network, a number of counties in the region have responded to these needs with the expansion of a county-level roadway network using nontraditional funding mechanisms such as bond programs. When local governments pursue roadway development in such a manner, lifecycle costs and frugality are among the parameters that must be considered.
Because roadway budget decisions are based primarily on design requirements, capital costs of construction, and ease of operation and safety to the roadway user, most roadway construction and maintenance specifications in Texas follow Texas Department of Transportation (TxDOT) standard specifications. Whereas TxDOT specifications are designed to work well in most situations, they do not necessarily address the multitude of situations that exist throughout the state. Moreover, current design guidance, and construction and maintenance specifications do not always account for or attempt to optimize the roadside environment and ecological performance. Conversely, an increasing body of evidence documents that giving consideration to the roadside environment, not only can enhance ecological performance, it can also serve a role to reduce long-term maintenance costs.

Implementing well-chosen sustainable practices can save money for communities and property owners while protecting and enhancing water quality through both cost reductions and cost savings (Roy, et al. 2008). It is also the case that communities can experience benefits from sustainable roadides that go beyond financial cost savings. These include improved aesthetic qualities, improved habitat and potentially enhanced property values. So, a broader and longer-term view of economic and environmental considerations of roadides is needed for the region.

In the course of implementing these sustainable programs, the Williamson County Commissioners Court initiated a comprehensive program to address both immediate and long-term issues associated with roadway development. The Protocol for Sustainable Roadides is a result of this program (TGB Partners et al. 2010).

By implementing these environmentally responsive and sustainable practices, Williamson County sought to reduce long-term maintenance costs, enhance ecological performance, and maintain roadway safety and greater sense of regional character. Accomplishing these goals required combining current experience with new methods and technologies. In developing this protocol, current leading research and practices in highway design and construction from around the nation and abroad were consulted.

Difficulty in monetizing the environmental benefits of sustainable practices has been one of the major reasons in preventing sustainable practices from receiving equal consideration with other methods (Gudmundsson 2004). Without adequate data and relative certainty that these alternatives will work and not increase risk or cost, current standards of practice are difficult to change. In this research, extensive fieldwork along a 12-mile section of Ronald Reagan Boulevard in Williamson County informed and supported the practices established in the Protocols.

In the following sections, TxDOT specifications for roadway construction and maintenance will be described briefly along with the specific condition and climate of the central Texas and Williamson country. The protocol for sustainable roadides and its benefits will then be explained and overall conclusions will be presented. A detailed discussion regarding the validation of the protocol by testing a 12-mile section of Ronald Reagan Boulevard will be presented at the 2011 ICOET Conference in Seattle, Washington.

2. PROTOCOL FOR SUSTAINABLE ROADIDES

2.1. Current Roadside Landscape Practices in Central Texas

Current Central Texas roadway construction and maintenance specifications are based primarily on Texas Department of Transportation’s standard specifications. While the TxDOT’s standards has been designed to work in most cases, this singular approach will not succeed at every location and every situation, given the complex nature of the ecological, topographical and financial conditions found within the 254 counties within Texas. The Protocol is an effort to reduce the limitations associated with current TxDOT standards, widen the “success rate” of roadides, and design the roadides based on unique specifications of central Texas. Limitations of the current practice in Central Texas, which is based on TxDOT specifications, have some financial and environmental consequences.

The financial consequences of current roadway practices include:

- Conventional practice of conveying and managing storm water in large, end-of-pipe facilities results in significant construction costs and impacts.
- Closer scrutiny within an ever-increasing regulatory environment results in added construction costs and an increase in non-compliance issues, resulting in delays in public use of the roadway and added taxpayer dollars.
- A policy of removal of existing tree and vegetative cover throughout the right-of-way contributes to unnecessary erosion, soil instability, poor water quality and added financial costs.
- Mowing right-of-ways more extensively and frequently than is necessary for roadway safety and operations leads to higher maintenance costs, additional erosion problems and the dispersal of noxious weeds.
Timing of vegetative installation is often not seasonally appropriate and results in added repairs to address the ensuing erosion and sedimentation caused by poor plant establishment.

The environmental consequences of current roadside practices include:

- Conventional practices fail to adequately address the hydrologic modifications that increase stormwater volumes and runoff rates and cause excessive erosion and stream channel degradation. Stormwater drainage design often relies on macro solutions and promotes “end-of-pipe” solutions, contributing to erosion, soil instability, and poor water quality.
- Widespread disruption of soils contributes to siltation of drainage structures and receiving waters and eroded cross slopes.
- Plant installation specifications that do not respond to local environmental conditions.
- A policy of shunning reforestation of woody plant material, i.e., trees and shrubs, in favor of a monoculture of turf grass landscape areas.
- Roadway corridors exhibiting a poor aesthetic value as a result of a policy of removal of existing tree and vegetative cover.

Some of these practices have both financial and environmental consequences: For example, preparation of right of way construction by removal of existing trees and vegetation followed by the process of adding new vegetation. Such practices directly contributes to widespread erosion and sedimentation, and new vegetation not only has a difficult time growing on the eroded soils but it also adds to the cost of the project. While the new vegetation becomes established, the ability of the existing vegetation to buffer the storm water is gone. Moreover, mowing the new vegetation, which is mostly grass, increases the required maintenance of the road while often times decreases the aesthetic value of the road.

2.2. Roadside Design Considerations in Central Texas

The ecological characteristics of Central Texas and the four ecoregions present in the region were of critical concern in developing the Protocols. Benefits that can be achieved by designing to the local environmental conditions include:

- Integration of the roadway corridor into the surrounding landscape
- Creation of ecosystem services such as filtering runoff
- Providing educational opportunities and partnerships
- Minimizing the negative effect on biotic communities and reducing the driver fatigue.

Of the 52 level II ecoregions in the continental United States, four are represented in Central Texas. Ecoregions are distinct zones categorized based on characteristics such as geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology (Omernik 1987). Awareness of the difference between existing ecosystems in the region is essential for integrated roadway design and construction success.

2.2.1. Edwards Plateau Landscape Region

This ecoregion is largely dissected limestone plateau that is hillier to the south and east. Because of Karst topography and its underground drainage, the region possesses a network of clear, cool perennial streams. The shallow, rocky soils enable both grasses and tree species to become established, forming a region dominated by juniper oak savanna and mesquite oak savanna. The region was developed through ranching, due to the difficulty of plowing the land, and is predominantly used for grazing cattle, sheep, goats, exotic game animals and native wildlife. (Griffith et al. 2007). By 1900 and after European settlers introduced fences, cows, sheep, goats and a strict control of fire, the land use changed from grassland to brush land. Today, poor quality forbs and grasses dominate much of the Edwards Plateau with juniper woodland being the dominant plant habitat of the region.

2.2.2. Texas Blackland Prairie Landscape Region

The Northern Blackland Prairie subdivision of the Texas Blackland Prairie ecoregion comprises a wide band along the eastern edge of the Edwards Plateau. The gently rolling plains of this sub-region possess soils that are mostly fine-textured, dark, calcareous and productive clays. While the dominant vegetation used to be tallgrass species such as little bluestem, yellow Indiangrass and tall dropseed with trees, most of the prairie has been converted to cropland, non-native pasture, and increasingly urban and industrial uses around Waco, Austin and San Antonio. Less than one percent of the original vegetation still exists in the region.
2.2.3. East Central Texas Plains Landscape Region

A relatively wide band closer to the Gulf Coast is the East Central Texas Plains ecoregion, also referred to as the Post Oak Savanna or the Claypan Area. Soils vary among the parallel ridges and valleys, but tend to be acidic, with sands and sandy loams on the uplands and clay to clay loams in low-lying areas. In many areas, the dominant vegetation is determined by underlying clay pans affecting water movement and moisture available for plant growth. The bulk of this region is now used for pasture and range (Griffith et al. 2007).

The East Central Texas Plains ecoregion has more woods and forest than the adjacent Blackland Prairie ecoregion and consists of mostly hardwoods. Historically, a post oak savanna land cover is a mix of post oak woods, improved pasture and rangeland, with some invasive mesquite to the south. A thick understory of yaupon and eastern red cedar occurs in some parts. Sand exposures within these tertiary deposits have a distinctive flora, and in a few areas of this region unique bogs occur (Griffith et al. 2007).

2.2.3. Cross Timbers Landscape Region

The northernmost portion of Central Texas is the Limestone Cut Plain sub-region of the Cross Timbers ecoregion, a transitional area between what was at one time prairie to the west (now winter wheat growing regions), and the forested hills of eastern Texas. It is a mosaic of forest, woodland, savanna, and prairie. The transitional natural vegetation of grassland with scattered oaks is used mostly for rangeland and pasturceland, with some areas of woody plant invasion and forest (Griffith et al. 2007).

Soils are typically clay based, and underlain with limestone, sometimes with alternating layers of limestone, chert, and marl that erode differentially. The Limestone Cut Plain has flatter topography, lower drainage density, and a more open woodland character than the Edwards Plateau. The vegetation is similar to that of the Edwards Plateau, but less diverse. Although the grasslands of the Limestone Cut Plain are a mix of tall, mid, and short grasses, some consider it a westernmost extension of the tallgrass prairie (Griffith et al. 2007).

The analysis of the region can help inform sustainable roadside design decisions. Consideration of different landscape characteristics assists in better designs of the roadways and reduces the long-term maintenance cost of roadways. Also, it is the base for designing the long-term maintenance techniques. For example, road placement in the Edwards Plateau would require careful placement in locations near karst topography and riparian river crossings due to limited soil layers and steep slopes that increase erosion possibilities and pose a threat to water quality.

In areas that have more significant soil profiles and gradual slopes such as the Blackland Prairie, roadside design and development should protect and maintain these characteristics. Additionally, due to past development practices many native grasses that historically existed in this region have been replaced by invasive species, requiring a more rigorous invasive species management plan.

In the East Central Texas Plains regions, the existing soils tend to be much sandier than the other regions and require the use of a specific sandy soil seed mix. Steep cross slopes have greater erosive tendencies and require aggressive erosion control methods.

Considering the ecoregions throughout design, construction and maintenance processes will ensure that the roadway will be long lasting, safe and cost effective.

2.3. Key Strategies

The objective of the Protocol for Sustainable Roadsides approach is to develop criteria for the design, construction and maintenance practices targeting the unique conditions found in Central Texas. The standards developed in this Protocol build upon TxDOT standards, the Williamson County Design Criteria Manual and the Texas Commission on Environmental Quality's Complying with the Edwards Aquifer Rules. A summary of the key strategies in the Protocol for Sustainable Roadsides is provided below.

2.3.1. Schematic design phase

An in depth site assessment is required to reduce the costs and environmental impacts of the project. Clear understanding of the impacts of specific environmental conditions creates more appropriate roadway design responding to those conditions.
2.3.2. Design Phase

- Development of Best Management Practices (BMPs) to address critical roadside design factors, including low-impact grading and low-impact drainage design.
- Detailed storm water runoff design and velocity controls
- Applying effective water quality controls
- Selection of appropriate native vegetation.
- Materials specifications, including new technologies, new techniques and introducing the use of recycled materials.

2.3.3. Construction Phase

- Development of a menu of BMPs to address specific environmental conditions typically found on roadway projects conditions such as high-velocity channels, steep cut and fill slopes, and riparian restoration conditions.
- Limiting construction disturbance to the area minimally necessary to construct the project.
- Protection and restoration of healthy soils for re-vegetation.

2.3.4. Maintenance Phase

- Modified mowing specifications.
- Fostering restoration of woody species.
- Invasive species control.

Some of the principles that enable the protocol to be effective include the following:

Maintaining Existing Vegetation: It helps retain soil conditions, thereby reducing the amount of erosion on a given site, and also helps other environmental and user conditions such as runoff infiltration, nighttime headlight buffering and reduced County maintenance. While existing vegetation will be disturbed in the process of roadway construction, a shift in policy from blanket clearing to site-specific clearing (based on a comprehensive site assessment) can help ameliorate the negative consequences associated with the loss of vegetation.

Low Impact Development (LID): LID policies incorporate sustainable practices into the design of roadside landscapes, thereby mitigating erosion, sedimentation and water quality issues. Many of the best management practice techniques associated with LID are shown to be more cost effective than conventional, large-scale approaches. The goal of this approach is to mimic the watershed’s natural ability to transfer as well as absorb storm water.

Use of Native Plants: There are three important reasons to use the native plants. First, Native plants are best suited to withstand the harsh ecological conditions of Central Texas. Native plants better achieve the goal of maximizing the roadside’s tolerance for the range of environmental conditions found in the region. They are accustomed to withstanding long periods of drought as well as periodic heavy rain events. Native plants can also help speed vegetative establishment and, once established, and provide robust erosion control.

Second, a native roadside environment can contribute to the preservation of existing native plants, which provide habitat for regional species of plants and animals.

Lastly, native plants add to the natural aesthetic of the region, giving the area its unique identity. This is especially true in rural areas where the use of native plants can help roadways visually and environmentally connect with ranchland and fields along the roadside.

Considering long-term maintenance: The long-term maintenance needs of the roadway corridor are a critical consideration in the protocol. The maintenance requirements are addressed with the recognition of the Central Texas regional characteristics and capabilities.

Planning for future development: For the purpose of this protocol, Central Texas roadways are organized into corridor types based on the context of their location and usage. The corridor types are rural, suburban and urban corridors. As currently written, the protocol is oriented to rural arterial corridors while it can change over time as these corridors may change.
2.4. Description of the Protocol for Sustainable Roadsides

The protocol for sustainable roadsides integrates ecological considerations into each phase of roadway development. The following is a summary of best management practices for the design, construction and maintenance phase of development.

2.4.1. Roadway Corridor Planning and Schematic Design Protocol BMPs

*Environmental Inventory:* An Environmental Inventory helps ensure environmental features and areas of ecological significance are identified so they will be integrated into the design process and protected to the greatest extent possible. The benefits of an Environmental Inventory include the reduction of financial and environmental costs by identifying and evaluating the roadway corridor's ecological systems.

*Low-Impact Grading Design:* Conventional grading techniques create large-scale solutions that include conveying, managing and treating stormwater in large facilities located at the bottom of the macro-drainage areas. A key goal of this BMP is allowing the constructed condition to better mimic the infiltration rate of pre-development conditions. Low-impact grading design incorporates small-scaled controls along the drainage shed to infiltrate, store and slow stormwater runoff and minimizes disturbance and impacts by identifying and preserving sensitive areas that affect the hydrology, including streams and their buffers, wetlands, steep slopes, high-permeability soils and woodlands.

*Low-Impact Drainage Design:* It includes an analysis for evaluating the hydraulic design of roadside ditch and conveyance channels, including channel flow capacity and channel velocity. Velocities above five feet per second cause significant erosion. The benefits of low-impact drainage design include early identification of problem areas likely to experience severe erosion problems and the ability to design corrective measures to address erosion and sedimentation problems during the design phase.

*Soils Management and Limits of Disturbance:* Conventional grading techniques often result in the wholesale removal of vegetative cover within the ROW, often compacting and laying bare soils at the beginning of a roadway project and exposing the site to an extended period of erosion and sedimentation. The benefits of soils management and limits of disturbance include reducing the potential for erosion and sedimentation and their associated costs, reducing maintenance requirements and enhancing roadway corridor appearance.

*Dynamic Erosion Control:* It is an erosion and sedimentation control plan that corresponds directly to construction sequencing on the site. The plan provides a methodology for controlling erosion and sedimentation for sequential activities during the construction phase. The benefits of dynamic erosion control include increasing the effectiveness of controls used by optimizing capture of runoff as drainage patterns and construction sequencing are modified and ensuring appropriate protection of environmental features during construction.

2.4.2. Roadside Construction Protocol BMPs

The construction phase BMPs are divided into three categories: materials, temporary erosion and sedimentation controls, and permanent erosion and sedimentation controls.

2.4.2.1. Materials

*Low-Nutrient Compost:* It is an organic material used as a soil amendment or as a medium to grow plants. It is created by combining proper ratios of organic wastes such as yard trimmings, food wastes and manures. Wood chips are added as bulking agents to accelerate

2.4.2.2. Temporary Erosion and Sedimentation Controls

*Surface Ripping and Roughening:* It is a temporary erosion control measure that involves establishing a rough soil surface through the creation of horizontal grooves, furrows or small depressions running perpendicular to the slope. The purpose is to prevent erosion in sheet flow conditions. When used in conjunction with practices such as erosion control compost, these rips allow for organic matter to move deeper into the soil, serving to anchor surface compost treatments and rapidly establish healthy soil conditions. Increasing soil surface roughness and providing areas for sediment to be captured reduce runoff volume and erosion.

*Mulch Topdressing:* Mulch topdressing is the application of organic mulch material to an exposed soil surface to protect it from compaction, to conserve soil moisture and control soil temperature. Mulch topdressing is used to increase
infiltration, decrease runoff and protect soil surface from rain. Woody vegetation that is proposed to be removed due to construction is the preferred source for mulch.

Erosion Control Compost: It is a uniform surface application consisting of a mixture of compost and wood mulch applied on top of exposed soil for the purpose of erosion control and to provide a medium for vegetation growth. It also helps filter and assimilate pollutants from runoff, which improves water quality.

Fiber Roll: Fiber rolls are tubular-shaped erosion and sedimentation control devices that are filled with natural material and wrapped with a containment mesh. Fiber rolls are used, often on slopes, to intercept runoff, reduce the velocity of flows, remove sediment and release runoff as sheet flow. Fiber rolls biodegrade as the soil stabilizes with vegetation and can be left in place.

2.4.2.3. Permanent Erosion and Sedimentation Controls

Maintaining Existing Vegetation: It involves the protection of existing trees, shrubs, grasses and other flora for the purpose of erosion and sedimentation control. Maintaining existing vegetation is a particularly effective means of erosion and sedimentation control for sites that contain or are adjacent to sites with floodplains, wetlands, stream banks, steep slopes or critical environmental features.

Riparian Bioengineering: It involves the planting of a native, vegetated zone within riparian areas adjacent to receiving bodies of water for the purpose of erosion control, filtration of sediment and pollutants carried in storm water, and flood control. Riparian bioengineering may also increase water quality, natural habitat and the health of aquatic ecosystems.

Native Grass Seeding: Native grass seeding is the reestablishment of native plants in a disturbed area to improve soil stabilization and prevent erosion and the subsequent movement of sediment and pollutants into water systems. Native plants require less maintenance, water and fertilizer than non-native plants due to adaptation to the regional climate and soils. Native seed mixes exhibit denser growth compared to non-native seed mixtures and have deep fibrous roots. Therefore, they are more effective for controlling erosion on roadside landscapes.

Wildflower Seeding: Wildflower seeding is the establishment of seasonal wildflower displays as part of maintaining permanent vegetative cover for the purpose of protecting soil and water resources and aesthetic display. Wildflower species do not need fertilizers, pesticides or herbicides, and watering is minimal, thus reducing establishment and maintenance costs, particularly when compared to turf maintenance (EPA, 2008).

Biofiltration: Biofiltration, also known as bio-retention, areas are depressed landscape zones that provide water quality control by removing stormwater sediments and pollutants through the chemical, biological and physical properties of plants, microbes and soil. Additionally, these areas reduce stormwater velocity, promote infiltration directly into the soil and promote sheet flow (City of Austin Environmental Criteria Manual 2009).

2.4.3. Roadside Maintenance Protocol- Best Management Practices

Mowing: Appropriate mowing techniques maintain roadside safety requirements of good visibility and clear zones while retaining the purpose of the native vegetation for erosion control, biodiversity, improvement of water quality and beauty (adapted from Idaho DOT). Mowing limitations allow native vegetation to establish, flourish and maintain a vigorous stand of vegetation on the roadsides to prevent weed invasion and control soil movement (Ehley 1990).

Invasive Species Control: Invasive species control is the prevention, management and removal of invasive species, which are non-native species that cause environmental damage. Invasive species often overtake native plants, reduce species diversity, and harm native habitat and ecosystem functions. In addition, invasive species may harm the regional or historic character of the landscape, threaten endangered species, reduce water quality, increase soil erosion, alter fire frequency and spread pathogens (National Invasive Species Council 2005). Disturbed sites are especially vulnerable to the proliferation of invasive species if the normally resistant, existing native species are reduced during the construction process. It is therefore vital to control invasive species. The techniques used to eradicate invasive species are physical, chemical or prescribed burn.

Reforestation: Reforestation is the natural regeneration of vegetation in an area previously disturbed or damaged by construction. Utilizing passive or natural techniques such as elimination of mowing and installation of bird perches along existing roadways encourages growth of native woody plant material.
Photographic Monitoring: Photographic point monitoring is a quick and effective means of documenting changes in soil and vegetation over time. Evidence taken from these photographs provides investigators with spatial data that may be used in the assessment of a project’s health and development. Photographic monitoring should occur in areas where documentation of change is needed, such as areas of potential erosion, vegetation establishment, etc. It also provides a mechanism for evaluating the benefits and limitations of the roadside construction and management practices over time.

2.5. Benefits of the Protocol

2.5.1. Financial Benefits

Identifying and evaluating the roadway ecological systems can reduce financial and environmental costs. Cost reductions will come from a comprehensive understanding of the ecology and integrating the most appropriate construction, maintenance, and design techniques to address those conditions.

More research is needed to monetize the cost reductions that can be achieved through environmental performance, reductions in long-term operation and maintenance costs, and/or reductions in the life cycle costs of infrastructure.

Additional financial benefits include:

- Reduced costs for site grading and preparation, stormwater infrastructure and landscaping.
- Maintaining existing vegetation reduces capital costs associated with land clearing, re-vegetation and erosion and sedimentation controls.
- Reduces costs associated with roadside maintenance and operations.
- Reduces construction and maintenance costs by preemptively addressing erosive drainage channel conditions in the design phase.
- The use of native plants reduces costs for water, pesticides, herbicides and mowing requirements compared to non-native plants.
- Use of recycled, on-site mulch reduces material and transportation costs and is readily available.
- Several BMPs do not have to be removed upon project completion since they degrade naturally, saving labor and disposal costs.
- Several BMPs have a low labor component; they are easily installed and shaped to the contours of a site.
- Over time, the material cost for certain BMPs will be reduced as their use becomes more prevalent (e.g., native grass seed and low-nutrient compost).

2.5.2. Environmental Benefits

There are three integrated environmental benefits:

2.5.2.1. Low Impact Development (LID) - Promotes the reduction of the volume and rate of storm water runoff through the restoration of the hydrologic cycle:

- Runoff conveyance practices that promotes slow flow velocities, lengthens the runoff time of concentration, and delays peak flows that are discharged off-site.
- Reduces erosion and sedimentation.
- Improves water quality and infiltration – a benefit especially important over the Edwards Aquifer where maintaining drinking water supplies and stream baseflow is of special concern.
- Improves the establishment of healthy vegetation that requires less maintenance.
- Ensures maximum protection of ecological integrity of the receiving waters and absorbs pollutants (grease, oil and other hydrocarbon pollutants, pesticides, nutrients) and reduces the amount transported into water systems.
- Maintains better health of preserved trees and other vegetation and reduces soil compaction and erosion from construction activities.
- Suppresses weed growth and plant diseases.
2.5.2.2. **Context Sensitive Solutions** - roadside design responds to the physical setting and enhances the environmental resources:

- Integrating the roadway corridor into the surrounding regional landscape keeps roadway corridors in context with the adjacent property and promotes good stewardship of a sustainable landscape - good for adjacent landowners as well as enhancing public perception.
- Provides habitat for flora and fauna.
- Reestablishes native wildlife habitat and biological diversity.

2.5.2.3. **Renewable Resources** - applies recycled materials and techniques for roadside construction practices:

- Several BMPs can be created from on-site woody vegetation scheduled for removal (e.g., mulch topdressing, mulch fiber roll, erosion control compost).
- Incorporates recycled waste by-products. Reintroduces native grasses. Provides locally obtained organic nutrients to plants.

2.5.3. **Social Benefits**

- Creates interesting and diverse roadway corridors, offering added motorist safety by enhancing the driver’s perception of vehicle speed and distance along the roadway and increasing motorist awareness of their surroundings.
- Displays native vegetation and introduces motorists to the regional landscape.
- Reduced chemical control use for vegetative management and enhances worker and public safety as well as public perception.
- Reduces driver fatigue by providing visual interest.
- Provides a buffer against noise.

### 3. CONCLUSION

The Williamson County Protocols for Sustainable Roadsides (Protocols) does a very good job of taking a host of science, engineering, construction, and cost estimating information and boils it down for policy makers, consultants, engineers, contractors, and the general public. The Protocol address the issues of additional erosion and sedimentation controls, water quality management, protection of environmental features, and preservation of existing vegetation and existing soils that are not included in the TxDOT design criteria manual or technical specifications. The Protocols provide Williamson County environmentally responsive solutions to county roadsides that are cost effective and tested to reduce long term maintenance and improve the safety and ecological performance, as well as restoring a natural vernacular to the landscape. The research team believes that the Protocols will help guide the development of Williamson County roadsides to a system of roads that make the manmade and natural environments compatible and sustainable.

### BIOGRAPHICAL SKETCH

**John A. Walewski, Ph.D.,** is an assistant professor with the Zachry Department of Civil Engineering at Texas A&M University with research interests in sustainable design and construction techniques, risk management and insurance, pre-project planning, and the use of alternative project delivery and procurement methods. Dr. Walewski obtained a Civil Engineering Ph.D. (Construction Engineering and Project Management focus) at The University of Texas at Austin (UT) in May 2005, and became a research associate with UT’s Center for Transportation Research. Before moving to Texas, John was a program officer with the Board on Infrastructure and the Constructed Environment at the National Research Council, National Academy of Sciences, in Washington, DC. He has over fifteen years of experience in industry and research associated with the planning, design, and construction professions. Dr. Walewski obtained a graduate degree in urban planning from the University of Michigan, and a BS in construction management as well as a BLA in landscape architecture from Michigan State University. His research interests include Risk management, International construction risk assessment, Public private partnerships, Alternative project delivery methods, Sustainable design and construction techniques, Building information modeling for sustainability, and Ecological ramifications of resource use.
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ABSTRACT

Incorporating regional planning principals into mitigation processes is recognized as a best practices objective for action agencies such as transportation departments. Some state transportation agencies have already begun taking advantage of the efficiencies and ecological and economic benefits that a regional advance mitigation approach permits, but no state has fully implemented the practice, because significant technical, cultural, regulatory, and financial roadblocks remain. Here we examine the challenges and possible solutions to full implementation of this approach, using ongoing projects from California as the point of departure.

Three of the main challenges to implementation of regional mitigation plans are: 1) creation of equitable and transparent data development, assimilation, and mitigation estimation procedures; 2) development of trust and coordination between action and regulatory agencies; and 3) finding a funding mechanism to allow mitigation actions to occur in an advanced timeframe.

The Caltrans Statewide Advance Mitigation Initiative and a multi-agency working group, the Regional Advanced Mitigation Project (RAMP), have been discussing these issues over a three-year period. To address transparent data development and analysis, we developed a two-track system that compiles natural resource and biological maps, and coordinates their use with maps of programmed transportation projects. The two sets of data are combined through the use of a conservation portfolio program, MARXAN, to assess the suitability of parcels or regions for mitigation actions, thereby enabling advance implementation of mitigation efforts.

To facilitate communication between the infrastructure and regulatory agencies, an effective means of reaching consensus on their common objectives and acceptable business practices is needed. California agencies have developed a series of memorandums of understanding (MOUs), one signed by the State Department-head leadership, and another by agency staff. These agreements signal a desire from both the top- and field-levels of both types of agencies to improve the overall practice of mitigation and the ‘rules of the road’ to advance regional mitigation. In addition, RAMP stakeholders drafted state legislation to establish a statewide regional advance mitigation program, and agency staff are developing a policy framework identifying attributes and policies for a statewide program.

Funding for advance mitigation remains a challenge in California. Because mitigation funding is directly tied to projects, it is typically not available for mitigation actions in advance of project construction. Advance mitigation requires access to a funding stream in the project planning stage. This necessitates the creation of a revolving fund that can be reimbursed as project construction begins. Some areas of the state have initiated their own funding initiatives, such as a sales tax in San Diego and Orange Counties. However, generally the state has not found a single mechanism by which funds can be appropriated and used. If funds can be brought to bear, there is the potential for those to become a revolving fund that can permit proactive mitigation actions such as acquiring high value conservation properties.

We conclude that while significant obstacles to advance mitigation remain, recognition of its advantages can be used to develop the analyses, business practices, and funding needed for implementation.

INTRODUCTION

Construction of transportation and other infrastructure projects impacts the natural world (Forman et al. 2003). In the United States, The National Environmental Policy Act (US Congress 1970) requires that agencies first seek to avoid significant impacts and if they cannot avoid them, agencies must mitigate such impacts. In California, this principle is further refined and enforced under the California Environmental Quality Act (California State Government 1970). Typically, mitigation is prescribed and implemented on a project-by-project basis, which can lead to piecemeal
In recent years, law makers and agency personnel have demanded that transportation impacts be considered collectively and regionally. Enacted by the U.S. Congress in 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (23 USC 507) (SAFETEA-LU), mandates early consultation on transportation projects. Section 6001 of the law requires transportation agencies to identify future mitigation needs (agency obligations incurred through road construction projects) and future mitigation sites (to offset those impacts) in long-range transportation plans. These plans are to be developed through coordination with state and federal agencies early in the planning process and are required to consider available conservation plans, land-use plans, maps or resource inventories. In 2006, a team of agencies expanded SAFETEA-LU's section 6001 and published Eco-logical: An Ecosystem Approach to Developing Infrastructure Projects (Brown 2006). This document encourages Federal, State, tribal and local partners involved in infrastructure planning, design, review, and construction to use flexibility in regulatory processes. Specifically, Eco-Logical puts forth the conceptual groundwork for integrating plans across agency jurisdictions, and endorses ecosystem-based mitigation - an innovative method of mitigating infrastructure impacts that cannot be avoided.

Development of a regional planning approach to transportation mitigation is underway in many states, including California. Ideas from these efforts are presented at the ongoing International Conference on Environment and Transportation (ICOET), a conference series organized with the support of the Federal Highways Administration (FHWA), and the American Association of State Highways and Transportation Officials (ASHTO). Individual states have contributed to programmatic development including Florida, through its Environmental screening tool (http://www.dot.state.fl.us/emo/EST-Overview.shtm) and efficient transportation decision model (ETDM-http://etdmpub.fla-etat.org/est/#); North Carolina, which has integrated a wetland mapping effort with transportation environmental planning with its ecosystem enhancement program (http://www.nceep.net/); Washington State, which is incorporating habitat connectivity objectives along Highway 90 in the Cascade Mountains (Singleton et al. 2002); the Arizona Department of Transportation, which has created a state-wide assessment of wildlife linkages for consideration in infrastructure planning (Arizona Wildlife Linkages Workgroup 2006); and Colorado’s award winning Shortgrass Prairie Initiative, an effort to use proactive mitigation planning to help conserve endangered shortgrass prairies, as well as a state-level MOU titled the ‘Planning and Environmental Linkages Partnering Agreement’ (June 2009), signed by multiple agencies.

The California Department of Transportation (Caltrans) has led the way in regional environmental planning with a number of initiatives. These include the signing of three MOUs, two at the state level and another at the implementation level, which all recognize the desired objective of using regional planning to improve efficiencies of environmental protection, project review and land acquisition. There have been several proof-of-concept projects, including an effort to inventory projected impacts for statewide highway projects (Thorne et al 2009a); a watershed-level planning effort in the Elkhorn Slough watershed (Thorne et al. 2009b) that led to the implementation level MOU and received national recognition with Federal Highway Administration’s Exemplary Ecosystem Initiative award for ‘Exceptional Environmental Stewardship’, 2009; a conceptual effort in the Sacramento Valley (Thorne et al. 2009b); and a project in San Diego County that links regional urban and transportation planning to land acquisition.

Some of these projects have been incorporated into an ongoing working group on Regional Advance Mitigation Planning (RAMP). RAMP as a policy is strongly supported by resource agencies and infrastructure agencies because it provides benefits to both. Infrastructure agencies find that RAMP can potentially allow for faster and more cost effective project delivery; and for resource agencies, it is hoped that RAMP will provide a more strategic and landscape scale approach to mitigation and conservation, leading to more effective conservation. RAMP can allow a better, more strategic use of mitigation dollars. It can also stretch project dollars further and contribute to implementing a larger conservation vision. Despite the broad support for RAMP, challenges remain that need to be addressed in order to implement it at meaningful scales.

This paper presents three classes of challenges to implementing RAMP in a seamless and timely manner, discusses how some efforts have approached these challenges, and recommends solutions for their resolution from the experiences in California. The challenges are: 1) analytical; 2) cultural and leadership, the development of support, trust and coordination for advance mitigation between action and resource agencies and among staff at all levels of the agencies; and 3) funding challenges (finding a funding mechanism).
Why is California Different?

The practice of advance mitigation has been evolving over the past decade as acceptance of the concept has grown in the infrastructure and resource sectors. Programs have been established throughout the country in varying jurisdictions and scale, covering varying projects and laws. The effort to establish a program in California is ambitious and complex on a number of levels: The size and scale of infrastructure investment is large with over 690 state highway construction projects currently programmed or under implementation (Caltrans, unpublished). California is a globally-ranked biodiversity hotspot – with unusual richness and diversity of species, many of which are threatened by infrastructure investment (Meyers et al. 2000). California is attempting to address a number of laws under RAMP if applicable, such as the federal Endangered Species Act (ESA; US Congress 1973), the California Endangered Species Act (CESA; California State Government 1984), Section 404 of the federal Clean Water Act (US Congress 1972) and California Environmental Quality Act (CEQA; California State Government 1970). Other programs cover fewer species, fewer laws and with a smaller scope of infrastructure investment.

CHALLENGES

1. Analytical Challenges (Data and Analysis process)

Infrastructure and regulatory agencies work in the project environmental review stage to determine the impacts of a project on threatened and endangered species, and natural ecosystems, and the actions needed to mitigate for those impacts. Typically, a project is designed and then goes through NEPA/CEQA review, during which specific impacts are determined. If there are impacts, mitigation measures are identified, such as changes to project design to avoid or minimize the impacts, and if the impacts would still occur, to address them through compensatory mitigation actions. Often the negotiations on mitigation between action agencies and regulatory agencies occur years after project development begins and frequently are the last stage before project construction begins. These discussions and negotiations take time, and if compensatory mitigation is required, action agencies must find land that meets the requirements and negotiate with willing sellers to acquire and/or restore. These negotiations can be long and difficult. They can lead to project delay and increased expense, especially if land that can satisfy mitigation needs is scarce, there are competing needs for that land, or there are no willing sellers. Mitigation must be satisfied before the project can continue to construction.

Advance mitigation can help avoid that problem by having already mitigated for the impacts. However, fundamental to the process is the importance of maintaining the integrity of the environmental review. Environmental review is typically done on-site, with the argument that only site-level assessment will capture all the impact elements potentially embedded in a project. A major analytical challenge is therefore to recognize what types of impacts can be identified in pro-active manners that do not require extensive field surveys.

Three further technical steps are needed to provide the RAMP process with decision-support level analyses: the estimated mitigation need for each impacted element must be identified; the acceptable service area for mitigation considered by each regulatory agency must be included; and, a portfolio of potentially suitable mitigation sites must be identified for consideration.

The RAMP group has adopted a GIS-based approach to these problems (Thorne et al. 2009a; Huber et al. 2009) in which the footprint of programmed projects is overlaid on assembled biological inventories and mapping and, at least for major vegetation types and previously recorded sightings of listed species, an estimate of project impacts can be developed. Experience from previous projects and interviews with regulatory agency personnel can identify a range of estimated mitigation needs for each species and habitat. For regional planning, impacts from multiple projects within a county, region, or ecoregion can then be summed to get a broader view of the mitigation needs of the infrastructure agencies. Potential mitigation portfolios can be developed through a GIS integration of known species and habitat locations with state, local, and other regional conservation plans. These assembled data can then be integrated with the projected mitigation needs through the use of a reserve selection algorithm such as Marxan (http://www.uq.edu.au/marxan/) to identify a portfolio of sites that could meet the mitigation needs.

2. Cultural & Leadership Challenges

Central to the notion of regional advance mitigation is the ability to implement mitigation analyses and actions in advance of project delivery, including in advance of environmental review, such as NEPA, CEQA, ESA, and CESA. In order for advance mitigation to be successful, two challenges must be addressed: cultural challenges – or the development of trust and coordination between infrastructure and resource agencies and among staff at all levels of
the MOU but they provided a joint letter expressing support for the goals of regional advance mitigation planning and agencies, the U.S. Army Corps of Engineers (USACE) and the U.S. Environmental Protection Agency (EPA), did not sign Board (WCB), U.S. Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS). Two federal

Signatories of the MOU include the California Business, Transportation and Housing Agency (BTH), California Department of Transportation (Caltrans), California Natural Resources Agency (Resources Agency), California Department of Water Resources (DWR), California Department of Fish and Game (DFG), California Wildlife Conservation Board (WCB), U.S. Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS). Two federal agencies, the U.S. Army Corps of Engineers (USACE) and the U.S. Environmental Protection Agency (EPA), did not sign the MOU but they provided a joint letter expressing support for the goals of regional advance mitigation planning and
the process set forth in the MOU. Both agencies have continued to participate in the RAMP Work Group, lending their expertise and guidance on the policy concepts and pilot project.

While the agency staff have changed during the process, the MOU has provided a common framework, strategy and approach for instituting regional advance mitigation, and a commitment by the agencies to work together toward that end.

However, while the MOU has been effective in allocating staff and resources to the effort, challenges remain to ensuring that all staff have the buy-in needed to implement a pilot project. Given budget cuts, some agencies are struggling with vacancies that result in a cycling through of staff who are assigned to work on the RAMP work group. This inconsistency of staff has been challenging, as new staff need to be briefed on the issue and the commitment to participating in meetings and solving problems is less than adequate. RAMP work group members have tried to counter this by conducting consistent and regular outreach to new staff and tapping into agency leadership to reinforce the support for RAMP and the need to apply adequate resources to the effort. Communications materials (such as hand-outs, presentations and copies of letters of support) have been effective in communicating support at all levels of the agencies as well.

Two other MOUs associated with RAMP have also been signed. The first is a result of a mitigation planning roundtable at Elkhorn Slough; the second an effort initiated by the California Department of Transportation (Caltrans). The Elkhorn Slough MOU, Early Mitigation Planning for Transportation Improvements in the Elkhorn Slough Watershed, July 9, 2009, is notable because it represents an effort at the region/district level to identify the common elements of agreement for early collaboration among the transportation and resource/regulatory agencies in the transportation planning and environmental mitigation process. Mitigation for one Caltrans project was facilitated through this MOU, with an offsite mitigation parcel acquisition completed following a watershed scale analysis. In addition, the site will be set up as a Mitigation Bank for future projects proposed within the watershed.

The Caltrans Statewide Advance Mitigation Initiative (SAMI) MOU executed on February 17, 2011 describes a multi-agency level of effort to establish a mutual framework for coordinated review for advance mitigation and conservation planning for planned transportation projects at a landscape scale. SAMI is Caltrans’ effort to establish a statewide advance mitigation program using federal highway funds to initiate the program. Caltrans has modeled the program after the work that the RAMP has developed, and is designing the program to allow other agencies (such as regional transportation agencies and other state agencies with responsibility for infrastructure development) to opt in to the program. SAMI may include establishment of or participation in mitigation banks, conservation banks, in-lieu fee programs, or other appropriate mitigation or conservation measures.

The RAMP Work Group began the effort with monthly meetings to talk about common goals, motivations and strategies to achieve those goals. While the Work Group considered and drafted the MOU in the first year, the more important outcome was the identification of the appropriate participating staff with the experience and appropriate level of decision making authority, and the establishment of a comfortable working relationship among the agency staff that continues to this day. Simply spending time with each other discussing the common issues, barriers, and goals for regional advance mitigation allowed staff members to understand each other’s respective obligations and motivations, develop common and transparent analysis approaches, share their agencies’ policies and points of view, identify areas of common ground and points of conflict, and develop strategies to address the conflict. The result has been a trusted working relationship, with a regular forum to air ideas, raise issues and brainstorm on solutions. Furthermore, we found that the regular Working Group members are effective liaisons to their agency leadership and to other agency staff. They help navigate through the agencies’ networks to get the answers needed or cooperation of other agency staff. Finally, an ancillary benefit to the interaction of the Work Group has been Work Group members sharing information and working together on issues and projects not directly related to the RAMP effort but helpful to their work, which has resulted in efficiencies in work load and innovative projects other than RAMP.

2) Development of a common analytical approach and conservation design incorporating conservation priorities of the resource agencies as well as other conservation stakeholders

RAMP requires a conservation greenprint, which is the overlay of regional conservation priorities and a regional summary of estimated impacts from current and pending projects, in order to direct the mitigation dollars to protect or restore off site mitigation acquisitions. This is a central benefit of RAMP – driving mitigation dollars to established conservation priorities on a larger scale, which allows mitigation dollars to contribute to larger landscape or ecosystem scale protection. The Work Group has developed a methodology to identify and map conservation priorities from agencies such as the California Department of Fish and Game, and the US Fish and Wildlife Service, as well as local county and conservation organization level habitat conservation plans. With technical assistance from UC Davis, the process has identified the range of mitigation options that meet participating agencies’ criteria. Through this process,
the Work Group also discussed concepts such as proximity to impacts and how to quantify mitigation needs. We found that different agencies require mitigation to fall within different distances of any given project, typically (but not always) defined as within the same watershed. We found that mitigation requirements for replacement or restoration of lost habitat important to impacted species can usually be projected in terms of a range of mitigation area needed, based on the projected impact footprint of each infrastructure project, rareness of the impacted species and other factors. In the experience of the infrastructure agencies, mitigation needs can be represented as some proportion of area of habitats impacted. These proportions can then be used in the GIS modeling to help identify the extent of possible mitigation need, which in turn can help in identification of a portfolio of potential mitigation sites. Developing these types of understandings, and the capacity to represent all the concerns within a GIS helped to build a common framework for implementation among the agencies, particularly between the infrastructure (or action) agencies and the resource agencies. It has also led to the Work Group as a whole understanding specific conservation needs of our pilot study area, and supporting a conservation vision for the region.

3) Take a programmatic approach to mitigation that strategically plans mitigation for multiple projects in a region.

Central to the success of advance mitigation is the need to consider multiple projects in a region and mitigate for some portion of the estimated impacts. This approach provides at least four benefits: 1) it reduces the infrastructure agency’s risk that it will take pre-decisional mitigation actions, 2) it reduces the infrastructure agency’s risk that it will over-mitigate for any one project in advance, 3) it allows for efficiencies of scale and 4) it ensures a more comprehensive conservation outcome. Through a program that assesses multiple projects that are expected to be delivered within a specified time frame, RAMP can identify a range of potential impacts for those multiple projects and designs for mitigation actions to satisfy the majority of potential impacts. This is useful in the first place because some projects may be redesigned or relocated through NEPA/CEQA review.

For example, Caltrans might identify a region in the state in which ten projects are planned or programmed over the next 20 years. Caltrans knows where the projects will be located, can use reference maps and data to project what the ecological impacts will be, and with resource agency involvement, generally what habitat and species mitigation may be required. A conservation greenprint is designed with resource agency staff input that identifies priority conservation areas to protect. Caltrans estimates the range of impacts – the low (100 acres) and high (1,000 acres) – and, with the support of the resource agencies, advance mitigates by protecting 500 acres of important habitat that relate to the habitats that may be impacted by the projects. Over time, as Caltrans’ projects come on line, each will go through NEPA/CEQA and the final design and specific mitigation needs will be identified, taking into account the avoid-minimize-compensate hierarchy. Each project will be able to redeem “credits” in the already protected 500 acres as necessary. Throughout the years, some of those projects may be redesigned to reduce the expected impacts and some may be canceled altogether. By planning for many projects and by mitigating at the average of the range, Caltrans both acquires higher quality mitigation sites (that might not be available if mitigation were done on a case by case basis over 20 years) and reduces its risk of over-mitigating and of taking pre-decisional actions. Caltrans also benefits from mitigating in advance as it saves time, money and provides certainty.

4) Regulatory statement of support

Mitigating in advance poses a fundamental challenge: how can one mitigate for a project before the environmental review occurs that includes the mitigation hierarchy and identifies with certainty the actual impacts and mitigation requirements? While regulatory agencies cannot give an assurance that the mitigation actions will satisfy each project in a Regional Assessment in advance, regulatory agencies have issued statements of support for the mitigation framework through instruments such as a Memorandum of Understanding, Memorandum of Agreement or a letter that describes the framework, the methodology to assess the estimated impacts, the description of the conservation priorities, the funding approach and the process by which infrastructure agencies will be credited with the mitigation actions in the future.

Reaching this milestone is one of the final steps in the planning phase, but the speed and ease of which this is achieved can be dependent on the work that has been done through the planning phase. The main reason that the regulatory agencies are able to support the approach is because they have been involved at all stages; the techniques used provide transparency for all participants into how the impacts, mitigation needs, and potential mitigation sites are identified. This is through a GIS framework that incorporates projects, mitigation requirement projections, and the identification of suitable mitigation sites that also meet the spatial criteria of each of the regulatory agencies that would be called into action for the given set of projects.
A good working relationship based on discussions and transparency, agreement on the goals of the program, the methodology employed to determine the estimated impacts, the conservation priorities and the mitigation approach establishes a solid foundation on which to secure the necessary agreements.

Other California examples exist of regulatory support or assurances. In 2006, SANDAG, DFG, USFWS and Caltrans signed a MOU that formalizes the process for implementing advance mitigation, which gave all parties the comfort needed to implement SANDAG’s Environmental Mitigation Program (http://www.sandag.org/index.asp?projectid=263&fuseaction=projects.detail). Similarly, to implement the Orange County Transportation Authority’s Freeway Mitigation and Resource Protection Program a master agreement was signed among the parties in early 2010 that stipulated the process for implementing advance mitigation and the assurances from the resource agencies (http://www.octa.net/pdf/freewaymit.pdf). These efforts are detailed in the examples section below.

3. Funding Challenges

Funding a RAMP planning effort and the capital for mitigation projects remains a challenge for three reasons: 1) Since RAMP requires a significant up-front planning effort in advance of project development when the benefits will be realized, agency leadership is required to invest scarce planning funds in a RAMP effort perhaps at the expense of existing planning programs; 2) As RAMP results in mitigation in advance of project implementation, political and agency leadership is needed and existing funding structures need to be amended to allow for capital funding to be available years in advance of project development; and 3) As the source of capital funding for mitigation is usually considered an integral cost of each specific project, RAMP’s framework of considering and planning mitigation for multiple projects in a regional advance mitigation plan blurs that tie and requires different funding structures for strategically mitigating for multiple projects in a region.

1) Planning funds

Because implementing RAMP requires an investment of time and resources in planning years in advance of project development, agency support is needed to invest in a planning effort when the benefits may not be realized for a number of years. This is particularly challenging in the start-up of a program when planning dollars are scarce and leadership is needed to divert planning dollars from existing planning programs to a new RAMP effort. In California, transportation planning funds are not tied to project funds. Those funds are used to prepare required documents such as State Transportation Improvement Programs and Regional Transportation Plans. Investing in the development of a RAMP requires a change of behavior and in the initial stage, the belief that the return on investment in terms of time, resource savings, and conservation outcome will be significant enough to justify the investment. In California, Caltrans and the Department of Water Resources have each allocated staff and resources to initiate a RAMP program for their projects which has resulted in sustained and focused effort on establishing a framework for RAMP as well as a pilot project in the Central Sacramento Valley to test the concept. Prior to dedicated staff and resources being made available, the RAMP effort was supported but progress was slow and not the main focus of the participating employees. Agency leadership is needed to dedicate staff to the effort.

In addition to existing agency planning or general funds, other sources of potential funding for RAMP planning and administrative activities include bond funds approved by the voters, contributions from agencies who would benefit from mitigation in a regional advance mitigation plan and a transaction fee for all transactions in a regional plan and federal or state grants.

- State bonds: In 2006, California voters approved $42 billion in infrastructure and natural resource bonds, including a $4.1 billion bond for flood infrastructure (Prop. 1E) and a $19.9 billion transportation bond (Prop. 1B). Those bonds can be used for planning activities in connection with infrastructure project delivery; California DWR is tapping into the Prop. 1E funds to fund its role in the statewide and pilot RAMP effort.

- Contributions from agencies: The lead entity managing a mitigation strategy in a regional advance mitigation plan can collect a small percentage of the projected cost of mitigation in a regional advance mitigation plan from all infrastructure agencies seeking mitigation in the region and are interested in forming a legal partnership to obtain the benefits of RAMP. The funds collected would be used to fund staffing and cover the direct expenses of the program. The specific percentage would need to be determined based on the costs of the program and the expected revenue stream.

- Transaction fee: The lead entity could create a permanent deposit that would generate enough interest, dividends, or appreciation to fund staffing and the administration and planning necessary for the RAMP
program. This approach might require charging a flat fee for all transactions in regional assessment areas and having those funds transferred to an agreed-upon third-party holder. Over several years, the collection of fees has the potential to generate funds sufficient to support ongoing program operations.

- Federal or state grants: states or the federal government may offer grants for innovative program development. For example, the federal State Highway Research Program provides grant awards for innovative program development that promote the use of regional planning for mitigation plan development.

2) Capital Funding for Mitigation Actions

As mentioned above, securing capital funding to implement mitigation actions (restoration or land protection) in advance of project development presents challenges related to source of the funds and the mechanisms for accessing the funding. In addition, RAMP’s framework of multiple projects adds complexity to the issue. Typically, mitigation actions are funded on a project-by-project basis at the time of need, making it difficult to fund mitigation in advance and for many projects.

In California, this is especially the case for transportation projects, given the established rules for allocating state transportation funds through the California Transportation Commission. Under the current construct, an advance mitigation project would face competition from road construction and other capacity-building projects for state funds. For federal funds, the Federal Highway Administration (FHWA) has authority through SAFETEA-LU to advance federal funds for mitigation; however, it can only be done on a single project, reimbursable basis. For both state and federal funds, therefore, changes in the way transportation funding is allocated are needed.

3) Funding structure possibilities

An important step toward obtaining a sustainable funding source for advance mitigation work would be to establish a RAMP revolving trust fund (revolving fund) that would receive and distribute capital funds for developing regional advance mitigation plans and advance mitigation projects. An initial infusion of funding is needed to capitalize the revolving fund to establish the program and begin the advance mitigation work. Whether a revolving fund is established or capital funds are advanced by another mechanism, the Work Group has identified a number of sources of capital funding. In the case of funding that is tied to infrastructure projects (such as the state infrastructure bond funds or the federal funds transfer), other sources of capital would need to be identified to ensure that the trust fund is truly revolving and that the program endures after the initial investment from the infrastructure agency(ies) is expended. The potential sources include:

- **State infrastructure bond funds for infrastructure projects**: An agency or agencies (e.g., Caltrans or DWR) could advance bond or other funds to capitalize the trust fund. Appropriate accounting mechanisms would need to be developed to ensure that the funding agency recoups its funds after mitigation actions are completed.

- **Federal funds transfer**: Federal funds, such as federal transportation funds, could be invested to capitalize a revolving fund. Recent federal-aid policy at the Federal Highway Administration (FHWA) allows federal transportation funds to be used for advance mitigation, and the “Eco-Logical” agreement between the U.S. Department of Transportation and the federal regulatory agencies creates an opportunity for a more proactive approach to biological mitigation under the federal Endangered Species Act and the Clean Water Act. Appropriate accounting mechanisms would need to be developed to ensure that the funding is allocated for the correct purposes. This is currently being developed under the SAMI program and with FHWA’s Every Day Counts initiative.

- **State infrastructure bond funds not tied to infrastructure projects**: The water bond currently on the Fall 2012 ballot, the “Safe, Clean, and Reliable Drinking Water Supply Act of 2012” includes $50 million for advance mitigation – intended to initiate a statewide program and provide early capital for advance mitigation activities. Since this funding is not tied to specific infrastructure projects, the funding would establish a truly revolving fund and have simpler accounting needs.

- **Local transportation funds**: Some counties in California have developed advance mitigation programs using sales tax funding approved by the voters for transportation projects. The San Diego County TransNet Measure approved by the voters in 2004 includes funding for an advance mitigation program using the revenue stream provided by the sales tax. SANDAG has approved a $650 million Environmental Mitigation Program that will
fund mitigation in advance and direct those funds to the priorities included in the county’s Natural Communities Conservation Plan (NCCP) (Greer & Som 2010), established under the California Natural Communities Conservation Act of 1991. SANDAG estimates $200 million in cost savings. Similarly, voters in Orange County approved a sales tax measure in 2008 which also included an advance mitigation program. Administered by the Orange County Transportation Authority, the Freeway Mitigation and Resource Protection Program allocates at least five percent of the transportation projects for advance mitigation, with funds directed to implement conservation priorities as provided in an NCCP/HCP (http://www.octa.net/pdf/freewaymit.pdf).

- **State appropriation funding:** The state legislature could appropriate funds from the General Fund. Even as RAMP would provide cost savings in the long run, in a time of declining budgets, this source is unlikely.

- **Federal grant funding:** Although no opportunity exists today, an incentive program could be developed that would give states funding to capitalize a RAMP program, possibly authorized by the next surface transportation reauthorization legislation. The program could issue grants to states that have established or intend to establish RAMP programs to accelerate infrastructure project development and ensure conservation outcomes.

- **Private financing:** Private companies who finance mitigation or nonprofit organizations who are involved in mitigation may be interested in providing initial capital funding for an appropriate return on investment. Several organizations and firms are available for this purpose, and the agency or agencies involved in RAMP could make a competitive selection based on a request for qualifications and include consideration such as what types of transactions would be allowed and how much profit could be made by the account holder.

**CASE STUDIES**

**OCTA’s Mitigation and Resource Protection Program (2007)** — In November 2006, Orange County voters passed by a two-thirds majority vote the Orange County Transportation Authority’s (OCTA) Renewed Measure M (M2)—a ½ cent sales tax continuation for transportation improvements. Negotiated into and supported by more than 30 conservation and community groups, the 30 year measure includes $243.5 million for comprehensive mitigation (in 2005 dollars). By August 2007, OCTA Board of Directors approved the Measure M2 Early Action Plan, which included early funding for this innovative mitigation program. Called the Environmental Mitigation Program, this new program designates a minimum of 5% of the M2 freeway budget for comprehensive advanced mitigation of the environmental impacts of freeway expansions and improvements. The Measure’s Ordinance called for the creation of the Environmental Oversight Committee (EOC) with members from OCTA, USACE, California Wildlife Conservation Board, conservation organizations, US Fish and Wildlife Service (USFWS), Caltrans, California Department of Fish and Game, and others to make recommendations on the allocation of mitigation funds and to monitor the execution of a Master Agreement between OCTA and state and federal agencies. The Master Agreement allows OCTA to receive advance mitigation assurances by proactively acquiring, restoring, and managing lands recommended by the EOC through a Natural Community Conservation Plan/Habitat Conservation Plan (NCCP/HCP). Science-based evaluation criteria were established to guide property selection. These criteria considered ecological richness, species diversity, importance for countywide habitat connectivity, endangered/threatened species, threat of development, and more. Properties getting restored or acquired through this willing seller program must align with impacted habitats in order for OCTA to receive mitigation assurances by the permitting agencies. In return, OCTA’s approval process for new freeway improvements and expansions was streamlined. This effort both reduces permitting delays for new freeway projects and results in a net environmental benefit as compared to the traditional project-by-project mitigation approach. The shift from project-by-project mitigation to a larger countywide scope allowed OCTA to provide more meaningful and effective environmental mitigation. By May 2011, $5.5 million had been spent in the first round of funding for five restoration projects. Additional funds are expected to be allocated in the OCTA FY 11-12 budget totaling $5 million. Additionally four properties have been acquired thus far, totaling nearly 900 acres, with roughly $8-$9 million more available to spend in this first round of funding. Future funding is expected for the acquisition and management of lands will be released in FY 15-16.

**Similarity of OCTA’s approach to RAMP:** This California-based approach has funding strategies and mechanisms for approval of advance mitigation systems that are similar, and in some cases in advance of RAMP. The Master Agreement (another MOU) between OCTA and state and federal agencies sets up the advance mitigation. Also, OCTA’s success in mitigation with a regional planning scope is a strong indicator of the potential of the whole approach. It may be helpful to investigate OCTA’s ranking system for ecological value as it could inform the way RAMP selects habitat need to restore and conserve. The master planning agreement and ecological evaluation criteria are posted online: http://www.fhbp.org/projects/PDFs/MeasureM-PlanningAgreement.pdf; http://www.fhbp.org/projects/measure-m-funding.html.
SANDAG TransNet Environmental Mitigation Program (2004) — The San Diego Association of Governments (SANDAG) is a regional planning body governed by a Board of Directors including mayors, council members, and county supervisors from each of the region's 19 local governments. In November 2004, the Environmental Mitigation Program (EMP) was approved as part of the TransNet extension. EMP establishes a program to provide for proactive, regional-level acquisition and management of habitat lands for future mitigation in advance of individual regional transportation projects, thereby creating a reliable approach for funding mitigation for future transportation improvements while reducing overall costs and accelerating project delivery. EMP goes beyond traditional mitigation for transportation projects by including a funding allocation from the TransNet sales tax revenue stream for habitat acquisition, management, and monitoring activities as needed to help implement the Multiple Species Conservation Program (MSCP; http://www.sdcounty.ca.gov/dplu/mscp/) and the Multiple Habitat Conservation Program (MHCP; http://www.sandag.org/?projectid=97&fuseaction=projects.detail). In March of 2008, SANDAG entered into a MOA with USFWS, California DFG, and Caltrans to formalize a process for implementing early land mitigation. The MOA is a 10-year processing agreement that will allow all the agencies to evaluate how EMP implements the provisions of the TransNet ordinance for early land mitigation.

Similarity of TransNet EMP to RAMP: This California-based approach incorporates some key concepts of RAMP in that it provides funding, planning, and approval mechanisms for advanced mitigation of multiple years of environmental impacts associated with planned regional transportation projects. Lessons learned in development of the associated MOA are needed for review of the general MOU and MOA process relating to RAMP agreements. Since the Transnet program is within California, it would be useful to review this MOA language and to understand the commitment made by the state and federal agencies signatories. The program also highlights the benefits of a fee-based system for funding early land mitigation, which is a necessary component for successful implementation.

Elkhorn Slough Early Mitigation Partnership (2009) — The Elkhorn Slough Early Mitigation Partnership (ESEMP) is a Caltrans-sponsored interagency effort comprised of ten government agencies and a non-governmental organization intended to provide early mitigation for a series of future transportation improvement projects within the Elkhorn Slough Watershed. ESEMP seeks to address regional scale conservation and expedite project delivery by developing a process for identifying funding strategies and implementing conservation agreements early on in the process. The Information Center for the Environment at the University of California, Davis (UC Davis) assisted Caltrans in supporting ESEMP by helping to coordinate and facilitate an Interagency Steering Committee, assisting with compiling and editing Committee documents, and providing strategic GIS data layers to the Committee in part based on a conservation network software analysis (Marxan) of the ecological and biodiversity features of the watershed. ESEMP invests in collaborative planning and negotiations with appropriate resource, regulatory, and planning organizations, relying on the best available science to develop mitigation agreements that meet the needs for transportation mitigation and promotes resource conservation. On January 28, 2009, the Transportation Agency for Monterey County awarded ESEMP the 2008 Transportation Excellence Award as recognition for collaborative efforts that promote environmental stewardship among participants while promoting efficiency in developing transportation projects. Many of the methods developed in this project are being applied to the RAMP program in California at this time.

DISCUSSION

Implementation of regional advance mitigation planning is an ongoing effort in California. A series of elements has emerged from the combined experiences in California that may be useful in launching or advancing a regional approach to mitigation in other areas. First, the development of an approach that permits infrastructure agencies to interact with regulatory agencies in a pro-active framework is needed. This can be achieved through the use of GIS, and requires the development of an estimate of future impacts, understanding of what the likely mitigation to be required is, and a map of biological resources that can be used to identify potential mitigation sites. Second, leadership at both the agency head and field officer levels is needed to implement a new and unfamiliar, if more beneficial approach. Finally, a funding mechanism is needed that can permit the implementation of the project. When these are able to be combined, the benefits can be considerable- faster environmental review, less costly acquisition of land, lower risk exposure to infrastructure agencies, and better environmental results of mitigation conducted. The approach, predicated on developing the ability to bring regional planning principals into the transportation mitigation arena, holds much promise for the future.

BIOGRAPHICAL SKETCHES

Dr. James H. Thorne is a landscape ecologist working at the Information Center for the Environment at the University of California, Davis. He has about $1,000,000 in current contracts and grants focused on two areas of research: climate change and its impacts to natural ecosystems; and, bringing regional planning to the off-setting of government-funded
infrastructure. He has over 25 years of experience working on conservation and restoration projects in California, has over 30 peer-reviewed journal publications, and dozens of technical reports and conference presentations.

Elizabeth (Liz) O’Donoghue is Director of Infrastructure and Land Use for The Nature Conservancy of California in San Francisco. Liz oversees The Nature Conservancy’s California Chapter’s policy agenda on infrastructure development and land use, innovative mitigation approaches, strategic growth and integration with natural resource protection and is The Nature Conservancy’s lead on transportation policy. Liz currently serves on the California Public Infrastructure Advisory Commission. From 2006 – 2009, Liz served as the Director of External Affairs, where she oversaw the California program’s engagements with government and stakeholders at the federal, state, county, and local levels. She helped develop and direct the Conservancy’s strategies on public policy, public funding, legislation, bonds, and constituency building. From 1999 – 2006, Liz worked at the western regional headquarters of Amtrak, first as Director of Communications, Government, and Public Affairs, then as Director of Strategic Planning, where she was responsible for developing and implementing Amtrak’s strategy on developing passenger rail corridors in the West. Previously, she served for seven years as legislative assistant for U.S. Senator Frank Lautenberg, specializing in transportation and natural resource policy. Before that, she worked in a public policy firm in Princeton, New Jersey, consulting with major corporate clients on environmental, health care, and transportation issues. She holds a B.A. in government from Oberlin College.

REFERENCES


DOES WILDLIFE TRANSPORTATION MITIGATION MAKE CENTS:
A CASE STUDY OF HIGHWAY 3 IN THE CROWSNEST PASS IN THE SOUTHERN CANADIAN ROCKIES

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ABSTRACT
The Highway 3 transportation corridor, including land use and development adjacent to the highway, has been identified as a major challenge to maintaining wildlife connectivity in the southern Canadian Rockies. Highway 3 is a two-lane, east–west highway supporting 6,000 to 9,000 vehicles per day traveling over the Continental Divide at Crowsnest Pass. Wildlife – Vehicle Collisions (WVC’s) involving large mammals along Highway 3 predominantly involve deer; collisions also occur with less common species such as elk, moose, bighorn sheep, grizzly bear, wolf, lynx and cougar.

A cost–benefit analysis was conducted using annual rates of WVCs for 31 mitigation emphasis sites identified along Highway 3 in British Columbia and Alberta. Mitigation emphasis sites (MES) were identified based on a synthesis of carnivore and ungulate use of the landscape surrounding Highway 3, the site’s local and regional conservation value, development status of land adjacent to the MES, and the highway mitigation potential. At each MES an analysis of wildlife vehicle collision mortality data was conducted. The number of collisions per kilometer per year involving deer, elk, moose and bighorn sheep were summarized at each mitigation emphasis site and the total cost of the ungulate–vehicle collisions (UVCs) was compiled.

Using the UVC rates at each MES, the annual costs of the UVCs were then derived based on each ungulate species’ average cost per collision (i.e., human fatalities and injuries, vehicle damage): deer ($6,617), elk ($17,483), moose ($30,760) and bighorn sheep ($6,617). In British Columbia, total annual costs of UVCs at MES ranged from a low of $1,323 to $28,329 (includes 23 MES). In Alberta, total annual costs of UVCs varied from a low of $6,617 to a high of $31,405 (includes 14 MES)(all figures in 2007 Canadian dollars).

A recent cost–benefit analysis for a variety of highway mitigation measures across North America found the average cost of building and maintaining a wildlife underpass with fencing and jumpouts (escape ramps for wildlife) is $18,123 km/yr. Although underpasses are often considered an “expensive” infrastructure investment for wildlife, nearly one-third of the monetary costs for the sites in British Columbia were estimated in excess of $18,123 km/yr and half of the MES in Alberta had estimated annual costs in excess of this threshold number. These costs indicate many of the MES along Highway 3 in the study area are excellent candidates for underpasses or other infrastructure investments. Further, if the underreporting of WVCs were accounted for, then investment in mitigation at even more sites would have been considered cost effective for using infrastructure investments. Focusing highway mitigation efforts in these areas could improve motorist safety, reduce wildlife mortalities, improve habitat linkage and animal movements across Highway 3 and be cost effective.

INTRODUCTION
The southern Canadian Rocky Mountains connect the Crown of the Continent Ecosystem (centered about Glacier–Waterton International Peace Parks) with the Banff–Jasper–Kootenay–Yoho mountain parks complex to the north. Maintaining landscape connectivity is crucial for the well-being of the many native wildlife species that currently thrive...
in the region. One area that has been identified as a major challenge to maintaining wildlife connectivity is the Highway 3 transportation corridor and adjacent land use and development as they represent a potential fracture zone for wildlife movement at the northern edge of the Crown of the Continent ecosystem (Figure 1).

The Highway 3 transportation corridor runs east-west over the Continental Divide at Crowsnest Pass in the Canadian Rockies. Highway 3 is a two-lane highway supporting 6,000 to 9,000 vehicles per day, depending on the season and section of road. Local transportation use is compounded by transcontinental trucking and the increased recreational needs of Calgary residents. A railway runs parallel to the road for the entire length of the corridor. Both modes of transportation are experiencing an increase in traffic volume. The implications to wildlife include direct mortality from collisions with highway vehicles and trains, fragmentation of the landscape, and avoidance behavior by wildlife due to the increased activity and presence of humans.

![Crown of the Continent Ecosystem](image)

**Figure 1:** Highway 3 study area in the Crown of the Continent Ecosystem (courtesy Miistakis Institute).
Understanding wildlife use and movements, associated behavior, and habitats along this transportation corridor is essential for developing mitigation strategies to reduce transportation–wildlife conflicts and maintain connected populations. Fortunately, a number of research projects in the past decade allow us to better understand how a variety of different species use these landscapes (e.g., bighorn sheep, elk, grizzly bears). These include studies that have identified key linkages for several carnivores, including grizzly bears that cross Highway 3 and the Canadian Pacific railroad in the project area. The syntheses, field assessments and recommendations described in this study reflect the best available understanding and options for direct mitigation of highway impacts to local populations of large terrestrial wildlife.

REGIONAL AND ECOLOGICAL CONTEXT

The southern Canadian Rocky Mountains encompass the northern half of the Crown of the Continent Ecosystem and comprise a zone of utmost strategic importance in the securing of connected wild land ecosystems (Tabor and Soulé 1999, Apps et al. 2007). Most of this region is managed for multiple values, including resource extraction, agriculture, human settlement, and tourism that includes both motorized and non-motorized recreation. And it is on this economic basis that local human communities have grown and thrived. While much of the southern Canadian Rockies is relatively undeveloped and ecologically intact, such landscapes are bounded and interspersed with human settlements and activity. Despite the significance of this region in supporting some of the greatest ecosystem and large mammal diversity in North America (CORE 1994, Apps et al. 2007), few landscapes in the southern Canadian Rockies are managed primarily for ecological values.

For wide-ranging species, there is concern on the potential impacts of the Highway 3 transportation corridor that bisects the Crown of the Continent Ecosystem from west to east (Figure 1). From the Rocky Mountain Trench in the west to Alberta agricultural lands in the east, Highway 3 is associated with human settlement and development in and around the communities of Sparwood, Fernie and Elko, British Columbia, as well as the Municipality of Crownest Pass in Alberta. Given the existing communities, a large proportion of private land ownership and high human accessibility, much of the landscape through which Highway 3 passes is composed of, or is potentially subject to, permanent human development. Considering human demographic and socioeconomic trends, there is obvious potential for the highway corridor to fracture the north–south contiguity for populations of wide-ranging carnivores and some ungulates. As a source of high mortality and a constraint to the movements of resident and dispersing animals, the genetic and demographic implications of such a fracture zone can destabilize populations and increase the likelihood of localized extirpation. Moreover, human development and activity along the highway corridor undoubtedly results in extensive ancillary impacts, potentially reducing the effectiveness and security of core habitat areas within the larger region.

The Highway 3 conservation issue is essentially defined by potential impacts to wide-ranging species that persist at low densities and/or in limited distribution in the larger region. Since the Apps (1997) report, several other researchers have independently corroborated the importance of Highway 3 as an issue in carnivore conservation. In a broad scale assessment across the Y2Y ecoregion, Carroll et al. (2001) identified Highway 3 as an emerging gap for several large carnivores. In his assessment of habitat connectivity for large mammals in the transboundary Flathead drainage, Weaver (2001) also reiterated the threat of population fracture from Highway 3 and its associated land development. Theoretical predictions of population impacts were partially substantiated by Proctor (2003) in a study demonstrating that the Highway 3 transportation and settlement corridor has had a measurable impact in restricting gene flow among grizzly bears.

It is acknowledged that conservation measures at regional and landscape scales are critical in conserving and promoting connectivity of wildlife populations across Highway 3. However, the focus of this study is at the finest scale necessary to address Highway 3 impacts on terrestrial wildlife—that of site-specific mitigation of the highway itself. While the information and recommendations presented here are informed by studies and data across geographic scales, our focus is in best mitigating highway impacts in terms of wildlife movement and mortality specific to current and future transportation infrastructure scenarios.

WILDLIFE–TRANSPORTATION CONFLICT AREAS ASSESSMENT

To evaluate where wildlife-vehicle collisions (WVCs) are occurring and enable highway mitigation to address both human and wildlife safety we undertook an assessment of WVCs using mortality data collected along Highway 3.

Identifying Ungulate–Vehicle Collision Zones

Alberta and British Columbia collect Wildlife Vehicle Collision (WVC) data separately and use different methodologies. In British Columbia, point data were provided by British Columbia Ministry of Transportation. In Alberta, data were
acquired from three sources: (1) Highway Maintenance Contractors (Volker Stevin; 1997–2008), (2) Road Watch in the Pass (2005–2008) and (3) ENFOR data from Alberta SRD (1997–2007). Locations were provided to the nearest kilometer marker along Highway 3 in each province.

For each province, datasets were examined in a GIS software program to identify WVC hotspots for large mammals occurring along 1.0 kilometer (km) segments on Highway 3. Mortality data points were assigned to the nearest highway segment. To address the potential for spatial error and the possibility of observations occurring on the segment boundary, a smoothing function was implemented where the mortality observations per road segment were equated to the sum of the road segment and its two neighboring segments. The number of WVCs per segment was then categorized into 20, 40, 60 and 80 percentiles equating to “very low” (0–20%), “low” (20–40%), “medium” (40–60%), “high” (60–80%), and “very high” (80–100%) as modeled after Huisjer et al. (2008). Segments with no observations were excluded from the analysis. Zones meeting medium, high and very high standards were identified as WVC hotspots.

**Results**

Deer were the most common species involved in WVCs, although other ungulates and carnivore species were also recorded (Figure 2). On the 136 km section of Highway 3 in British Columbia, 1906 wildlife mortality observations were recorded from 1998–2007 between the Rocky Mountain Trench (Highway 3/93 junction to Fort Steele) and the British Columbia/Alberta provincial border. Local experts were asked to review the WVC maps for each large mammal species as provided by the British Columbia Ministry of Transportation (Figure 3). Based on local expert knowledge, the WVC hotspots were deemed spatially accurate but the wildlife mortality dataset underestimates the true rate of mortality occurring along Highway 3 (Lee 2009).

The stretch of Highway 3 from Rocky Mountain Trench to the provincial border at Crowsnest Pass contains 81 km of medium to very high WVC segments, representing 59 percent of the highway and 79 percent of total WVCs. On Highway 3 in Alberta, there were 1359 WVCs recorded from 1998–2008 along the 44 km section between the British Columbia/Alberta provincial border and Lundbreck. Deer were the most common species involved, representing 90 percent of the WVCs (Figure 3).

![Figure 2: Large mammal composition of wildlife–vehicle collisions in the Highway 3 study area.](image-url)
Figure 3: Ungulate vehicle collision zones where rate is greater than 3.2 UVC/km/year.

VALUATION OF WILDLIFE CORRIDOR AND WILDLIFE–TRANSPORTATION CONFLICT ZONES

Identifying Priority Areas for Highway Mitigation

Below, we describe specific sites along Highway 3 that have been identified as in need of mitigation due to current impacts on wildlife mortality and movement based on a synthesis of WVC data and carnivore modeling and GPS locations. The importance of specific locations varies by species, landscape and conservation concern. These “mitigation emphasis sites” are at the relatively fine scale necessary for highway planning and mitigation (Figure 4). The mitigation emphasis sites are identified through a synthesis of information provided by detailed wildlife movement data, habitat models, highway data, researcher opinion, available anecdotal reports, and opportunities and constraints with respect to adjacent land ownership and use.

The selected mitigation emphasis sites were visited in the field and evaluated for mitigation potential. To assist in ranking sites for mitigation priority, we assigned each site a subjective score from 1 (low) to 5 (high) on the basis of the following criteria:

- **Local Conservation Value** – the value of the highway mitigation to local wildlife conservation regardless of regional significance
- **Highway Mortality** – relative rate of wildlife–vehicle collisions as a proxy for motorist safety risk
- **Land-Use Security** – the degree to which lands adjacent to the site are secured de facto for conservation
- **Opportunities for Highway Mitigation** – the degree to which mitigation options are available and can be implemented with reasonable cost
- **Regional Conservation Significance** – the potential significance of highway mitigation to address wildlife conservation concerns of regional significance
Table 1 and Table 2 display the scores for each criteria and the average for all five criteria for each mitigation emphasis site, by province. These matrices may assist transportation planners in prioritizing sites for wildlife mitigation based on the five criteria.

### Table 1: Highway 3 wildlife mitigation emphasis sites prioritization matrix in British Columbia.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Species</th>
<th>Local Conservation Value</th>
<th>Highway Mortality</th>
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<th>Transportation Mitigation Options</th>
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### Table 2: Highway 3 wildlife mitigation emphasis sites prioritization matrix in Alberta.

<table>
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<th>Site Name</th>
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HIGHWAY 3 WILDLIFE MITIGATION OPTIONS

Introduction

In rural and suburban areas of North America, accidents with wildlife are quickly becoming a major safety concern for motorists. In Alberta, collisions with large ungulates (deer, elk, moose) comprise 50 percent of all accidents on rural roadways with an average of five human fatalities per year (Peter Mah, Alberta Transportation, personal communication). In 2006, these accidents cost Albertans more than $250 million (Clevenger et al. 2008).

Road mitigation measures are designed to facilitate the safe movement of wildlife across roads and increase motorist safety. Warning signs and reflectors have become standard measures used by transportation agencies for decades; however, research shows that they along with many other tools that agencies routinely use are not effective in preventing accidents and wildlife mortality (Huijser et al. 2007). Wildlife crossing structures are being designed and incorporated into road construction and expansion projects to help restore or maintain animal movements across roads. Engineered wildlife crossings are designed to meet the dual needs of allowing animals to cross roads with reduced hazard to motorists and wildlife. Typically crossing structures are combined with high fencing and jump-outs (escape ramps), and together are proven measures to reduce road-related mortality of wildlife and connect populations (Clevenger et al. 2001, Dodd et al. 2007).

There are many benefits provided by mitigation measures aimed at reducing WVCs, such as fewer motorist accidents that may include human injuries, deaths, and property damage. Benefits to wildlife include protecting individual wildlife from death or injury, keeping populations intact, allowing individuals free movement to access important habitats and resources, thus enhancing long-term survival and population viability. A review of 13 different mitigation measures used by transportation agencies to reduce WVCs (Huijser et al. 2009)—such as warning signs, vegetation removal, fencing, and wildlife crossing structures—indicated estimated effectiveness can vary from as low as a 26 percent reduction in WVCs (seasonal wildlife warning signs) to a 100 percent reduction in WVCs (elevated roadway).
As the rates of WVCs have increased over the past two decades (Huijser et al. 2008b), transportation and natural resource agencies are increasingly seeking to mitigate highways to increase motorist safety as well as provide for the conservation of wildlife. To support their efforts, recent advances in evaluating the monetary costs and benefits of mitigation measures are helping decision makers, managers and the public better understand the trade-offs of investing in a variety of mitigation measures to reduce WVCs. Unfortunately, estimations of the economic costs and benefits of maintaining local- and landscape-level connectivity for wildlife have not been developed at this time.

**Summary of Ungulate–Vehicle Collision Rates at Each Mitigation Site**

Total ungulate–vehicle collision (UVC) rates varied at the mitigation emphasis sites in British Columbia between a low of 0.6 WVCs/kilometer/year (UVCs/km/year) at the Carbon Creek bridge segment to a high of 3.1 UVCs/km/year at the Trench 3 site (Table 3). These relatively low numbers are most likely a result of underreporting based on British Columbia’s information collection system. As a result, it has been estimated that for every observed WVC in British Columbia there are three unreported collisions (Hesse 2006). Therefore, Table 3 totals could be multiplied by a factor of three to reach a more realistic estimate of ungulate–vehicle collision rates at these mitigation emphasis sites in the study area.

<table>
<thead>
<tr>
<th>Highway 3 - British Columbia: Mitigation Emphasis Site</th>
<th>Average Collision Rates: Species/Kilometer/Year</th>
<th>Total Annual Average Ungulate Collision Rate</th>
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<tr>
<td>Trench 1</td>
<td>Deer 0.8</td>
<td>Elk 0.4</td>
</tr>
<tr>
<td>Trench 2</td>
<td>Deer 1.4</td>
<td>Elk 0.1</td>
</tr>
<tr>
<td>Trench 3</td>
<td>Deer 2.9</td>
<td>Elk 0.1</td>
</tr>
<tr>
<td>Trench 4</td>
<td>Deer 2</td>
<td>Elk 0.7</td>
</tr>
<tr>
<td>Trench 5</td>
<td>Deer 1.1</td>
<td>Elk 0.8</td>
</tr>
<tr>
<td>Trench 6</td>
<td>Deer 2.2</td>
<td>Elk 0.2</td>
</tr>
<tr>
<td>Elko-Morrissey 1</td>
<td>Deer 0.9</td>
<td>Elk 0.1</td>
</tr>
<tr>
<td>Elko-Morrissey 2</td>
<td>Deer 1.2</td>
<td>Elk 0</td>
</tr>
<tr>
<td>Elko-Morrissey 3</td>
<td>Deer 0.6</td>
<td>Elk 0.1</td>
</tr>
<tr>
<td>Fernie-Morrissey 1</td>
<td>Deer 1.2</td>
<td>Elk 0.1</td>
</tr>
<tr>
<td>Fernie-Morrissey 2</td>
<td>Deer 1.05</td>
<td>Elk 0.2</td>
</tr>
<tr>
<td>Fernie-Morrissey 3</td>
<td>Deer 0.5</td>
<td>Elk 0.1</td>
</tr>
<tr>
<td>Fernie-Morrissey 4</td>
<td>Deer 0.9</td>
<td>Elk 0.4</td>
</tr>
<tr>
<td>Hartley Creek</td>
<td>Deer 0.9</td>
<td>Elk 1.1</td>
</tr>
<tr>
<td>Hosmer</td>
<td>Deer 0.4</td>
<td>Elk 0.1</td>
</tr>
<tr>
<td>Hosmer-Sparwood 1</td>
<td>Deer 0.8</td>
<td>Elk 0.2</td>
</tr>
<tr>
<td>Hosmer-Sparwood 2</td>
<td>Deer 0.4</td>
<td>Elk 1.1</td>
</tr>
<tr>
<td>Hosmer- Sparwood 3</td>
<td>Deer 0.8</td>
<td>Elk 0.6</td>
</tr>
<tr>
<td>Michel Creek</td>
<td>Deer 0.6</td>
<td>Elk 0.1</td>
</tr>
<tr>
<td>Carbon Creek Bridge</td>
<td>Deer 0.1</td>
<td>Elk 0</td>
</tr>
<tr>
<td>Alexander-Michel 1</td>
<td>Deer 0.8</td>
<td>Elk 0.9</td>
</tr>
<tr>
<td>Alexander-Michel 2</td>
<td>Deer 0.2</td>
<td>Elk 0</td>
</tr>
</tbody>
</table>

Total ungulate–vehicle collision rates were higher in Alberta than in British Columbia, most likely the result of the more concentrated effort to record UVCs in Alberta. Total ungulate–vehicle collision rates varied at mitigation sites in Alberta between a low of 1 UVC/km/year at the Rock Creek site to a high of 4.28 UVCs/km/year at the Leitch Collieries site (Table 4). The Rock Creek site has a large culvert and the highway is slightly elevated in this area, which may account for the relatively low collision rate; however, on the adjacent kilometer of highway on either side of this mitigation site, deer–vehicle collision (DVC) rates are very high, 8.45 DVCs/km/year to the east and 4.73 DVCs/km/year to the west of the Rock Creek site. Nearly half of the Alberta sites (n=4) had total ungulate–vehicle collision rates in excess of 3 UVCs/km/year (Table 4).
Table 4: Average annual number of ungulate–vehicle collisions for the Highway 3 road segment at each mitigation site in Alberta.

<table>
<thead>
<tr>
<th>Highway 3 - Alberta: Mitigation Emphasis Site</th>
<th>Average Collision Rates: Species/Kilometer/Year</th>
<th>Total Annual Average Ungulate Collision Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crowsnest Lakes</td>
<td>Deer: 0.36, Elk: 0.36, Moose: 0, Bighorn: 2.55</td>
<td>3.27</td>
</tr>
<tr>
<td>Crowsnest West</td>
<td>Deer: 0.82, Elk: 0.9, Moose: 0, Bighorn: 0</td>
<td>1.72</td>
</tr>
<tr>
<td>Iron Ridge</td>
<td>Deer: 1.36, Elk: 0.45, Moose: 0, Bighorn: 0</td>
<td>1.81</td>
</tr>
<tr>
<td>McGillivray Creek</td>
<td>Deer: 4.09, Elk: 0.09, Moose: 0.09, Bighorn: 0</td>
<td>4.27</td>
</tr>
<tr>
<td>Crowsnest Central</td>
<td>Deer: 1.73, Elk: 0.09, Moose: 0, Bighorn: 0</td>
<td>1.82</td>
</tr>
<tr>
<td>East Blairmore Bridge</td>
<td>Deer: 2, Elk: 0, Moose: 0, Bighorn: 0.18</td>
<td>2.18</td>
</tr>
<tr>
<td>Leitch Collieries</td>
<td>Deer: 4.28, Elk: 0, Moose: 0, Bighorn: 0</td>
<td>4.28</td>
</tr>
<tr>
<td>Rock Creek</td>
<td>Deer: 1, Elk: 0, Moose: 0, Bighorn: 0</td>
<td>1.00</td>
</tr>
<tr>
<td>Crowsnest East</td>
<td>Deer: 3.27, Elk: 0, Moose: 0, Bighorn: 0</td>
<td>3.27</td>
</tr>
</tbody>
</table>

Direct Monetary Costs of Ungulate–Vehicle Collisions

Huijser et al. (2009) summarized the costs of the most prevalent group of ungulates—deer, elk, moose—that are the source of over 90 percent of WVCs in North America (Table 5). All three species are present in the Highway 3 corridor and have been recorded in the mortality databases for Highway 3 in both Alberta and British Columbia. Although Huijser et al. (2009) developed monetary costs in U.S. dollars, for the purposes of this report it is reported in Canadian dollars at a par exchange rate.

Table 5: Summary of the monetary costs of the average wildlife–vehicle collision in North America for three common ungulates.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle repair costs per collision</td>
<td>$2,622</td>
<td>$4,550</td>
<td>$5,600</td>
</tr>
<tr>
<td>Human injuries per collision</td>
<td>$2,702</td>
<td>$5,403</td>
<td>$10,807</td>
</tr>
<tr>
<td>Human fatalities per collision</td>
<td>$1,002</td>
<td>$6,683</td>
<td>$13,366</td>
</tr>
<tr>
<td>Towing, accident attendance, and investigation</td>
<td>$125</td>
<td>$375</td>
<td>$500</td>
</tr>
<tr>
<td>Hunting value animal per collision</td>
<td>$116</td>
<td>$397</td>
<td>$387</td>
</tr>
<tr>
<td>Carcass removal and disposal per collision</td>
<td>$50</td>
<td>$75</td>
<td>$100</td>
</tr>
<tr>
<td>Total</td>
<td>$6,617</td>
<td>$17,483</td>
<td>$30,760</td>
</tr>
</tbody>
</table>

Highway records indicate that bighorn sheep are the cause of frequent WVCs in certain sections of Highway 3 within the study area. For this report’s cost–benefit analyses, a conservative average bighorn sheep–vehicle collision monetary cost value of $6617 (2007 $) is used (the equivalent to deer). This is a conservative estimate since the average bighorn sheep weighs more than the average deer and thus is more likely to cause higher vehicle repair costs per collision, as well as higher average human injuries or fatalities per collision. In addition, the average hunting value for a bighorn sheep is typically higher compared to deer.

Cost-effectiveness Thresholds

For mitigation to be cost-effective there needs to be a break-even point or a dollar value threshold. Huijser et al. (2009) thoroughly detailed these values for deer, elk and moose in North America. The number of deer, elk, and moose vehicle collisions per kilometer per year was compared to the actual cost of different mitigation measures and the realized effectiveness of each technique. For example, if a road section averages 4.4 deer–vehicle collisions per kilometer per year, a combination of wildlife fencing, under- and overpasses, and jump-outs would be economically feasible, because the threshold value of 4.3 is exceeded (Table 6). The threshold value for less costly mitigation of fencing, jump-outs and wildlife underpasses, however, is 3.2 deer–vehicle collisions per kilometer per year. Because we know the cost of different mitigation measures per year (Table 6) and their effectiveness at reducing WVCs (Huijser et al. 2007), we can calculate the break-even point for sections of Highway 3 with high WVC rates.
Table 6: Threshold values for different mitigation measures used to reduce deer–vehicle collisions by more than 80 percent (adapted from Huijser et al. 2009). Shaded area is referred to in “cost-effectiveness thresholds” section.

<table>
<thead>
<tr>
<th>Threshold values</th>
<th>Discount rate</th>
<th>Fence</th>
<th>Fence, underpass, jump-outs</th>
<th>Fence, under- and overpass, jump-outs</th>
<th>ADS</th>
<th>Fence, gap, ADS, jump-outs</th>
<th>Elevated roadway</th>
<th>Road tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ Cost (2007)/yr</td>
<td>3%</td>
<td>$6,304</td>
<td>$18,123</td>
<td>$24,230</td>
<td></td>
<td>$37,014</td>
<td>$28,150</td>
<td>$3,109,422</td>
</tr>
<tr>
<td>Deer/km/yr</td>
<td>3%</td>
<td>1.1</td>
<td>3.2</td>
<td>4.3</td>
<td>6.4</td>
<td>4.9</td>
<td>470</td>
<td>752.8</td>
</tr>
</tbody>
</table>

1 For explanation of discount rate, see Huijser et al. 2009.

2 ADS: Animal detection system

Monetary Costs for Ungulate–Vehicle Collisions at Mitigation Emphasis Sites

Table 7 and Table 8 summarize the costs at each mitigation emphasis site based on average annual collision rates for each ungulate species from Table 3 and Table 4 that are combined with the costs for each species from Table 5 in combination with the average monetary cost of $6617 used for bighorn sheep, where appropriate. In British Columbia, total annual monetary costs of ungulate–vehicle collisions varied between $1,323 at the Alexander–Michel 2 site and $28,329 at the Fernie–Morrisey 4 site (Table 7). Nearly one-third (7 of 22) of the mitigation emphasis sites in the British Columbia section of Highway 3 were in excess of $18,123 in annual monetary costs, making them excellent cost-effective candidates for infrastructure mitigation using underpasses, fencing and jump-outs. If underreporting of wildlife–vehicle collisions were accounted for, multiplying monetary costs by a factor of three would make ungulate–vehicle collision costs for most mitigation emphasis sites in Alberta and British Columbia much more expensive and therefore the cost-effectiveness of implementing highway mitigation would be more attractive at additional mitigation emphasis sites.

In Alberta, total annual monetary costs of ungulate–vehicle collisions varied between $6617 at the Rock Creek site (this does not include very high WVC rates occurring immediately to the east and west of this mitigation site) and $31,405 at the McGillivray Creek site (Table 8). Over one-half (5 of 9) of the mitigation emphasis sites in Alberta had annual monetary costs in excess of $18,123 per year.

Table 7: Costs of wildlife–vehicle collisions at each Highway 3 mitigation emphasis site in British Columbia (sites in grey are potentially cost-effective for the use of underpasses, fencing and jump-outs to mitigate ungulate–vehicle collisions).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deer</td>
<td>Elk</td>
</tr>
<tr>
<td>Trench 1</td>
<td>$5,294</td>
<td>$6,993</td>
</tr>
<tr>
<td>Trench 2</td>
<td>$9,264</td>
<td>$1,748</td>
</tr>
<tr>
<td>Trench 3</td>
<td>$19,189</td>
<td>$1,748</td>
</tr>
<tr>
<td>Trench 4</td>
<td>$13,234</td>
<td>$12,238</td>
</tr>
<tr>
<td>Trench 5</td>
<td>$7,279</td>
<td>$13,986</td>
</tr>
<tr>
<td>Trench 6</td>
<td>$14,557</td>
<td>$3,497</td>
</tr>
<tr>
<td>Elko-Morrissey 1</td>
<td>$5,955</td>
<td>$1,748</td>
</tr>
<tr>
<td>Elko-Morrissey 2</td>
<td>$7,940</td>
<td>$0</td>
</tr>
<tr>
<td>Elko-Morrissey 3</td>
<td>$3,970</td>
<td>$1,748</td>
</tr>
<tr>
<td>Fernie-Morrissey 1</td>
<td>$7,940</td>
<td>$1,748</td>
</tr>
<tr>
<td>Fernie-Morrissey 2</td>
<td>$6,948</td>
<td>$3,497</td>
</tr>
<tr>
<td>Fernie-Morrissey 3</td>
<td>$3,309</td>
<td>$1,748</td>
</tr>
<tr>
<td>Fernie-Morrissey 4</td>
<td>$5,955</td>
<td>$6,993</td>
</tr>
<tr>
<td>Hartley Creek</td>
<td>$5,955</td>
<td>$19,231</td>
</tr>
<tr>
<td>Hosmer</td>
<td>$2,647</td>
<td>$1,748</td>
</tr>
<tr>
<td>Hosmer-Sparwood 1</td>
<td>$5,294</td>
<td>$3,497</td>
</tr>
<tr>
<td>Hosmer-Sparwood 2</td>
<td>$2,647</td>
<td>$19,231</td>
</tr>
<tr>
<td>Hosmer-Sparwood 3</td>
<td>$5,294</td>
<td>$10,490</td>
</tr>
<tr>
<td>Michel Creek</td>
<td>$3,970</td>
<td>$1,748</td>
</tr>
<tr>
<td>Carbon Creek Bridge</td>
<td>$662</td>
<td>$0</td>
</tr>
<tr>
<td>Alexander-Michel 1</td>
<td>$5,294</td>
<td>$15,735</td>
</tr>
<tr>
<td>Alexander-Michel 2</td>
<td>$1,323</td>
<td>$0</td>
</tr>
</tbody>
</table>
Table 8: Costs of wildlife–vehicle collisions at each Highway 3 mitigation emphasis site in Alberta (sites in grey are potentially cost-effective for the use of underpasses, fencing and jump-outs to mitigate ungulate–vehicle collisions).

<table>
<thead>
<tr>
<th>Highway 3 - Alberta: Mitigation Emphasis Site</th>
<th>Average Estimated Costs of Collisions (in 2007 $)</th>
<th>Total Average Annual Costs (in 2007 $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crowsnest Lakes</td>
<td>Deer: $2,382, Elk: $6,294, Moose: $0, Bighorn: $16,873</td>
<td>$25,549</td>
</tr>
<tr>
<td>Crowsnest West</td>
<td>Deer: $5,426, Elk: $15,735, Moose: $0, Bighorn: $0</td>
<td>$21,161</td>
</tr>
<tr>
<td>Iron Ridge</td>
<td>Deer: $8,999, Elk: $7,867, Moose: $0, Bighorn: $0</td>
<td>$16,866</td>
</tr>
<tr>
<td>McGillivray Creek</td>
<td>Deer: $27,064, Elk: $1,573, Moose: $2,768, Bighorn: $0</td>
<td>$31,405</td>
</tr>
<tr>
<td>Crowsnest Central</td>
<td>Deer: $11,447, Elk: $1,573, Moose: $0, Bighorn: $0</td>
<td>$13,020</td>
</tr>
<tr>
<td>East Blairmore Bridge</td>
<td>Deer: $13,234, Elk: $0, Moose: $0, Bighorn: $1,191</td>
<td>$14,425</td>
</tr>
<tr>
<td>Leitch Collieries</td>
<td>Deer: $28,288, Elk: $0, Moose: $0, Bighorn: $0</td>
<td>$28,288</td>
</tr>
<tr>
<td>Rock Creek</td>
<td>Deer: $6,617, Elk: $0, Moose: $0, Bighorn: $0</td>
<td>$6,617</td>
</tr>
<tr>
<td>Crowsnest East</td>
<td>Deer: $21,638, Elk: $0, Moose: $0, Bighorn: $0</td>
<td>$21,638</td>
</tr>
</tbody>
</table>

Mitigation Measures

Mitigation emphasis sites are specific locations within the Highway 3 study area where opportunities for reducing wildlife–vehicle collisions and improving connectivity for all wildlife are highest, including fragmentation-sensitive species. Focusing highway mitigation efforts in these areas should improve motorist safety, reduce wildlife mortalities and improve habitat linkages and animal movement through transitional habitat along these highway segments.

From a field evaluation of the 31 mitigation emphasis sites, recommendations were grouped into actions that can be carried out in the short-term and long-term. Short-term mitigation consists of relatively simple, low-cost actions to reduce wildlife–vehicle collisions and improve the local and regional conservation values of the area. This type of mitigation may be combined with other highway construction or upgrade projects in the area (e.g., bridge reconstruction, culvert replacement, passing lanes). Recommendations for long-term mitigation would typically occur during major reconstruction and lane expansion of Highway 3 in the study area.

We developed recommendations for mitigation opportunities at each mitigation emphasis site along Highway 3. The relative importance of each site varies by species and local landscape attributes across the 180-kilometer highway corridor. Each site and conservation ranking (Table 1 and Table 2) was informed by field data on wildlife movement, wildlife mortality, expert opinion, and opportunities and limitations with respect to adjacent land use. A variety of mitigation measures are recommended, from simple to complex, some requiring a change in operations (e.g., de-icing alternatives), while others necessitate structural work (e.g., wildlife underpass construction).

In a recent report to the U.S. Congress commissioned by the Federal Highway Administration, Huijser et al. (2007) summarized 36 different animal–vehicle collision mitigation measures currently in use throughout the world. The recommendations for improving motorist safety and wildlife connectivity for Highway 3 include a total of 11 different proven or promising mitigation measures. Table 9 includes a list of the measures, their effectiveness in reducing WVCs (if data are available), the target of the measure (type) and the ranking category as presented in the Huijser et al. (2007) report.
Table 9: Wildlife mitigation measures, their focus and effectiveness.

<table>
<thead>
<tr>
<th>Mitigation measure</th>
<th>Effectiveness</th>
<th>Type¹</th>
<th>Category²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept feeding (salt licks)</td>
<td>N/A</td>
<td>Animal</td>
<td>Promising</td>
</tr>
<tr>
<td>De-icing alternatives</td>
<td>N/A</td>
<td>Animal</td>
<td>Promising</td>
</tr>
<tr>
<td>Variable message sign</td>
<td>N/A</td>
<td>Driver</td>
<td>Promising</td>
</tr>
<tr>
<td>Animal detection system</td>
<td>87%</td>
<td>Driver</td>
<td>Promising</td>
</tr>
<tr>
<td>Fencing</td>
<td>86%</td>
<td>Separate</td>
<td>Proven</td>
</tr>
<tr>
<td>Badger tunnel</td>
<td>86%</td>
<td>Animal</td>
<td>Proven</td>
</tr>
<tr>
<td>Underpass with water flow</td>
<td>86%</td>
<td>Animal</td>
<td>Proven</td>
</tr>
<tr>
<td>Underpass – wildlife</td>
<td>86%</td>
<td>Animal</td>
<td>Proven</td>
</tr>
<tr>
<td>Underpass – multi-use</td>
<td>86%</td>
<td>Animal</td>
<td>Proven</td>
</tr>
<tr>
<td>Overpass – wildlife</td>
<td>86%</td>
<td>Animal</td>
<td>Proven</td>
</tr>
<tr>
<td>Overpass – multi-use</td>
<td>86%</td>
<td>Animal</td>
<td>Proven</td>
</tr>
</tbody>
</table>

¹ Driver: Measures that attempt to influence driver behavior; Animal: Measures that attempt to influence animal behavior; Size: Measures that seek to reduce wildlife population size; Separate: Measures that physically separate animals from the roadway. From Huijser et al. 2007.

² Proven: Measures that should be implemented (where appropriate); Promising: Measures that appear promising, but require further investigation. From Huijser et al. 2007.

³ Not Available: data or studies on effectiveness.

RECOMMENDATIONS

A large amount of information has been gathered specific to each mitigation emphasis site based on site-specific information with regard to mitigation importance, target species, wildlife objectives and mitigation measures recommendations. Instead of reviewing each site, we highlight the most relevant sites with regard to a) regional conservation and connectivity, b) wildlife–vehicle collision reduction and c) immediate mitigation action that Alberta Transportation and British Columbia Ministry of Transportation can undertake. Listed below are several examples of short-term and long-term recommendations for a select group of MESs. The full list of 31 MESs and their short-term and long-term mitigation recommendations can be found in the unabridged report online at:

http://www.rockies.ca/crossroads/logistics.php

British Columbia

The average score for the matrix valuation of the nine sites in British Columbia was 3.27 (Table 1). Slightly less than half of the 22 sites (n=12) had scores equal to or above the average score. We discuss one example, Alexander–Michel 1 (3.8) of these sites in more detail below.

Alexander–Michel 1

This is the most critical habitat linkage in the entire Highway 3 corridor. It is the most important site from a conservation and management standpoint, to preserve for local and regional scale movements of wildlife, particularly fragmentation-sensitive species such as grizzly bears, wolverines and lynx. Alexander–Michel 1 is recognized as a site with high regional and local conservation value (=5). It has moderately high opportunities for highway mitigation (=4).

In the short-term mitigation alternatives should focus on improving the land-use security in the area and managing adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity. Potential opportunities in the long-term consist of bridge reconstruction or highway twinning (bridge construction) project. All bridge construction or reconstruction must be designed with wildlife movement (and hydrologic flow) in mind. Bridges should be designed with a wide span, allowing dry travel sections (7–10 m wide) above high-water mark and more than 4 m vertical clearance. Wing fencing (100–200 m depending on terrain) should be accompanied with an animal detection system at fence ends.
Alberta

The average score for the matrix valuation of the nine sites in Alberta was 3.2 (Table 2). Six of the nine sites (66 percent) had scores equal to or above the average score. We discuss Rock Creek, one of the MES and its mitigation recommendations in light of the respective attributes associated with local and regional conservation values and the safety of motorists traveling Highway 3. Specific mitigation techniques are italicized.

Rock Creek

Rock Creek has the highest matrix score for the Alberta sites (4.2). It is particularly important in terms of local conservation, land-use security and highway mitigation opportunities. Similarly, it is an area of very high rates of WVC (\(= 5\)), due to incorporation of high WVC rates on both sides of site. There is an existing 3 m-diameter steel culvert at the site, which Alberta Transportation plans to replace with a new below-grade structure in the near future.

In the short-term there are few mitigation alternatives other than improving the land-use security in the area and managing adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across Highway 3. Since this is an area with high WVCs, recommendations include *variable message signs* installed to warn motorists of the regular occurrence of wildlife on the highway and use of *de-icing alternatives* in winter rather than road salt. *Long term* mitigation could occur if existing fill is removed and the culvert is replaced with a new bridge structure, this is an excellent opportunity to improve terrestrial hydrologic flows in the area. A new bridge structure should be designed to maximize wildlife movement under Highway 3, allowing adequate space (\(> 3\) m wide) and substrate for wildlife travel. *Wing fencing* (minimum 200 m) should be used to guide wildlife to the bridge. An *animal detection system* can be placed at fence ends to warn motorists when animals cross the highway. *Boulders between fence and roadway and jump-outs* may be required depending on the situation. As indicated, this work could be done as a culvert reconstruction project or major highway reconstruction project.

CONCLUSION

A recent cost–benefit analysis for a variety of highway mitigation measures across North America found the average cost of building and maintaining a wildlife underpass with fencing and jumpouts (escape ramps for wildlife) is $18,123 km/yr. Although underpasses are often considered an “expensive” infrastructure investment for wildlife, nearly one-third of the monetary costs for the sites in British Columbia were estimated in excess of $18,123 km/yr and half of the MES in Alberta had estimated annual costs in excess of this threshold number. These costs indicate many of the MES along Highway 3 in the study area are excellent candidates for underpasses or other infrastructure investments. Further, if the underreporting of WVCs were accounted for, then investment in mitigation at even more sites would have been considered cost effective for using infrastructure investments. Focusing highway mitigation efforts in these areas could improve motorist safety, reduce wildlife mortalities, improve habitat linkage and animal movements across Highway 3 and be cost effective.

BIOGRAPHICAL SKETCHES

Tracy Lee, M.Sc. is a senior project manager with the Miistakis Institute. The Miistakis Institute is a non-profit charitable organization that brings people and ideas together to promote healthy communities and landscapes. Tracy acquired her M.Sc. from the University of Calgary, Resources and the Environment Program. Tracy's graduate work, in association with the Miistakis Institute, focused on the development and assessment of a citizen science project to monitor wildlife movement across a major highway. Prior to joining Miistakis over 10 years ago Tracy spent time working in Uganda, East Africa with the Jane Goodall Institute.

Dr. Tony Clevenger since 1996 has been directing long-term research assessing the impacts of highways and performance of their mitigation measures designed to reduce fragmentation of wildlife habitat. Since 2002, while continuing his Banff research and living in Harvie Heights, Alberta, he has been a research wildlife biologist for the Western Transportation Institute (WTI) at Montana State University. Tony was a member of the U.S. National Academy of Sciences Committee on *Effects of Highways on Natural Communities and Ecosystems*. He has published his results in leading international scientific journals (over 50 articles) and co-authored three books including the seminal work on this emerging scientific subject, *Road Ecology: Science and Solutions* (Island Press, 2003) and *Safe Passages: Highways, Wildlife and Habitat Connectivity* (Island Press, 2010). Tony uses his findings to educate transportation professionals and wildlife ecologists as well as guide the design of other highway projects. He has made his Banff research the highest profile and most scientifically productive wildlife-highway research project in the world. Tony is a graduate of the University of California, Berkeley, has a Master's degree from the University of Tennessee, Knoxville and a Doctoral degree in Zoology from the University of León, Spain.
**Dr. Clayton Apps, PhD, RPBio** is a consulting research ecologist who has been working and living in the southern Canadian Rockies over the past 20 years. His work specializes in research and modeling of wildlife-habitat-human relationships to support conservation planning. Clayton’s research has focused on wide-ranging species, with particular emphasis on spatial/temporal factors affecting movements, habitat selection, abundance, distribution and survival. A particular emphasis of Clayton's work is in understanding and predicting relationships of carnivores with habitat and human influence across scales to support effective conservation for these species and the natural ecosystems they represent.

**Dale G. Paton, BSc.** (*Anatum Ecological Consulting Ltd*) is a consulting conservation biologist, certified as Professional Biologist in Alberta and Registered Professional Biologist in B.C., with expertise in wildlife biology and ecological surveys. Over the last 18 years, he has completed work for private industry and the governments of Alberta, British Columbia, and Canada. Dale’s work history as a biologist has exposed him to the complicated nature of land use and management along with the variety of people and organizations that desire to use the land throughout southern Alberta and British Columbia. Dale’s current major project has been as the lead field biologist in the Montane Elk Study which is a collaborative project between the Universities of Alberta, Calgary, and Oregon with logistic and financial support from industry. Dale’s masters thesis is focused towards elk winter and summer seasonal range use, concluding with an assessment of the current degree of connectivity for elk migration linkage zones between seasonal ranges. A number of the elk herds cross Hwy 3 while on winter range, during migration and as they disperse to British Columbia and the United States.

**Dr. Michael Quinn** is the Associate Dean, Academic and a Full Professor in the Faculty of Environmental Design at the University of Calgary. His research and teaching interests include: road ecology, ecological design, resilience, regional planning and human dimensions of wildlife.

**Dave Poulton** is a lawyer and consultant based in Calgary, Alberta, who acts as Senior Advisor, Conservation Projects with the Yellowstone to Yukon Conservation Initiative. He holds Bachelor and Master of Arts degrees in Political Science from the University of Calgary, and a Bachelor of Laws from Dalhousie University. From 1999 – 2008 Dave was executive director of the Southern Alberta Chapter of the Canadian Parks and Wilderness Society (CPAWS).

**Rob Ament, M.Sc., Biological Sciences** is the Road Ecology Program Manager at the Western Transportation Institute at Montana State University (WTI). He has nearly 30 years of experience in field ecology, natural resource management, environmental policy and organizational development. He manages ten road ecology scientists with over 20 active research projects evaluating the impacts of roads on terrestrial and aquatic systems throughout North America at WTI. He has served on a variety of international, national and regional committees, boards of directors and advisory panels involving conservation issues.

**REFERENCES**


COMPARING THE ECOLOGICAL AND ECONOMIC OUTCOMES OF TRADITIONAL VS. PROGRAMMATIC, MULTI-RESOURCE BASED MITIGATION APPROACHES

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ABSTRACT

A study was undertaken to compare the ecological and economic outcomes of traditional mitigation verses progressive mitigation approaches which include multiple resource assessments. Our review of state programs shows the broad array of planning practices ranging from those that include little or no evaluation of landscape-level ecosystem services assessment, to those programs where landscape and social evaluation is a driving principle. We found that the best – and most practical – examples can and should form the basis for mitigation planning that targets the most socially, ecologically and economically beneficial mitigation locations. Characterizing the economic values which result from progressive mitigation approaches provides a mechanism to encourage policy makers, regulators, and transportation agencies to move towards implementing these approaches.

Traditional mitigation programs can be expensive to implement, provide limited ecological outcomes, and often cause significant delays in infrastructure project implementation. Even when traditional programs are efficient and incorporated into programmatic agreements, as is the case in Florida, they usually fail to take advantage of the full array of economic and ecological outputs available to restoration projects. To implement progressive approaches, programmatic agreements must have the flexibility to take advantage of the most up-to-date information, and mitigation programs need to get credit for increased ecological and economic outputs from mitigation that restores multiple services. Projects in Maryland, Oregon and elsewhere in the country are working to create tools and mechanisms for mitigation-based ecosystem service crediting.

Transportation agencies have demonstrated that they can make significant improvements in the delivery of new projects when programmatic agreements are developed. In this project, we document the significant increase in economic, social, and ecological outputs that can be gained if mitigation can be focused in areas in which these benefits are most efficiently generated. Where there appears to be fewer regulatory impediments to implementing progressive mitigation approaches, it is less clear that sufficient incentives exist for transportation agencies to support these progressive approaches.

INTRODUCTION

When proposed for permitting under the Clean Water Act (CWA) §404 and Endangered Species Act (ESA) §7 and §10 programs, many transportation, infrastructure, and development projects cause impacts to wetlands, streams, and the habitat of sensitive species. In these cases, state and regional transportation agencies work with federal and state regulatory agencies to avoid and minimize adverse impacts to aquatic resources and habitat. Any remaining and unavoidable impacts to these resources must be compensated for through mitigation by transportation agencies. For many reasons, the approval of and implementation of compensatory mitigation often is a barrier to project implementation.

A wide range of approaches can be applied to the process of selecting and designing compensatory mitigation sites. These different approaches offer a wide variety of ecological and economic outcomes. The different approaches to compensatory mitigation site selection and design can generally be grouped into one of three categories: traditional, “midway,” and progressive.
Traditional approaches to compensatory mitigation are those that allow a permit applicant or entity conducting compensatory mitigation (e.g., a mitigation bank) to propose compensation sites on a project-by-project basis, usually based on best professional judgment and with little or no analysis of landscape or watershed functional needs. Sites selected using traditional approaches to compensatory mitigation are often chosen opportunistically to either minimize costs to the permittee or to keep the mitigation as close to the impacts as possible, rather than to maximize environmental outcomes.

Midway approaches are those that involve some evaluation of landscape setting, but do not include comprehensive watershed- or landscape-scale planning. Examples of these approaches generally undertake single-priority analysis, such as watershed plans that assess a single aquatic resource function or service. The midway category also includes the use of qualitative mitigation guidelines that describe the types of compensation projects that resource agencies prefer, and decision-making frameworks to guide the selection of appropriate locations for compensation projects, but neither use detailed analyses of watershed or landscape needs to select compensatory mitigation sites.

Progressive approaches to compensatory mitigation are those that seek to use a strategic, analytical approach to compensation site design and selection that relies on a robust analysis of a suite of data on the watershed/landscape in which the compensatory mitigation project is being proposed. These approaches, whether applied through a mitigation or conservation bank, in-lieu fee program, or other compensatory mitigation mechanism, seek to characterize a watershed or ecosystem’s functional needs in order to site and design compensatory mitigation projects that will improve the overall condition of a hydrologic or ecological unit.

The most comprehensive of these progressive planning approaches consider multiple ecosystem functions or services. In the case of watershed planning, they address the entire suite of aquatic resource functions or services. Landscape planning efforts address the habitat needs of multiple species. These watershed- or landscape-scale evaluations allow permittees to move beyond project-by-project compensatory mitigation site selection; more comprehensive analyses of impacts from infrastructure and development are merged with conservation planning to proactively identify priority areas for ecological and economic investment. The use of priorities for project or bank siting is an essential characteristic lacking in most mitigation programs. It is important because the location of compensatory mitigation – its placement within the larger ecosystem – is critical for both the ecological success of the mitigation, and for the mitigation project’s ability to deliver priority off-site ecosystem services and valuable social outcomes.

Progressive mitigation programs that use a multi-resource evaluation of the ecological functions and the economic benefits provided by ecosystems present a way to maximize investments in ecological restoration, creation, enhancement, or preservation. Transportation agencies are in a unique position to implement progressive mitigation programs, as infrastructure development plans are generally known in advance of impacts. This paper attempts to better characterize the economic benefits of progressive mitigation and to assist in providing incentives for transportation agencies and regulatory agencies to implement them more widely. It reviews some progressive programs underway across the country and examines some barriers for their broad scale implementation.

ECOLOGICAL AND ECONOMIC BENEFITS OF PROGRESSIVE MITIGATION

Progressive mitigation approaches address the role of wetlands, streams, habitats, or other land uses in the geographically broader systems of biophysical production functions. Biophysical inputs are environmental features or conditions that are converted, via natural processes, into different environmental features or conditions, such as a wetland converting rainfall into late season stream flows. These converted environmental features or conditions are the outputs of the physical process. We refer to biophysical processes that transform inputs into outputs as biophysical production functions. When these broader systems of biophysical or ecological production functions are appreciated and taken into account, mitigation is more likely to deliver better ecological outcomes (National Research Council, 2001).

Ecological production functions as described above translate into ecosystem services or ecologically-based outputs that are valued by society. Since progressive approaches to compensatory mitigation support higher levels of ecological production function than traditional approaches, progressive approaches can result in greater ecologically-based benefits to society in addition to the inherent ecological benefits. Currently, the societal value of ecological production functions is rarely taken into account in the selection and design of compensatory mitigation projects (National Cooperative Highway Research Program 2010a, Ruhl and Gregg 2001), even though they provide valuable services to nearby human populations (Engel et al. 2008). For instance, in addition to traditionally valued ecosystem services such as timber and fish production, wetlands are well-known for their ability to filter excess pollutants and nutrients, reduce flood hazards, absorb storm surge, and provide unique recreational or scientific opportunities (Mitsch and Gosselink 2000; Zedler 2003). Biodiversity protection for endangered species supplies additional value for human populations (Loomis and White 1996). Species are often valued “for their own sake” particularly when threatened with extinction.
Effective Mitigation and Costs of Impacts

In some cases species are commercially valuable when caught or harvested. In other cases, recreational benefits (from hunting and angling, birding, hiking) are dependent on the existence and abundance of particular species. More ecologically effective mitigation can contribute to the preservation of these tangible values provided by aquatic resources, and imperiled species. Figure 1 is a simple image showing how mitigation is linked to ecological and economic outcomes.

A mitigation project that changes land cover (or hydrology) triggers subsequent changes in surface water flows (timing, speed, volume) via hydrologic processes. Changes in the hydrograph will occur both near the mitigation site itself, and across a potentially much larger area. In other words, these hydrological changes (one of the services produced) are "delivered" off-site. Not only that, these "off-site" effects will often trigger additional, subsequent ecological effects, also off-site. For example, changes in the hydrograph will affect habitat conditions for aquatic, avian, and other species via a range of chemical and biological processes. The resulting changes in species abundance yield yet another service that is delivered off-site.

Appreciation of, and planning around, these off-site and systems driven services is what makes progressive mitigation planning so potentially valuable. Progressive mitigation planning relates biophysical cause with effect when the cause-and-effect relationship is spatial. We call these relationships spatial production functions, because they tell us about how changes in conditions in one location (good or bad) affect the delivery of ecosystem goods and services in another. Examples of these spatial production relationships describe the dependence of:

- Species on the landscape configuration needed for their reproduction, forage, and migration;
- Surface and aquifer water volumes and quality on land cover configurations and land uses;
- Flood and fire protection services on land cover configurations;
- Soil quality on climate variables and land uses; and
- Air quality on pollutant emissions, atmospheric processes, and natural sequestration.

In particular, the pattern of conservation lands on the landscape can significantly impact both the value of the ecological and economic attributes. In the Willamette Basin study in Oregon, the pattern of development and conservation on the ground dramatically altered the economic and ecological outputs provided by alternate landscapes (Polasky et al. 2008). Progressive mitigation assessments build into their evaluation criteria and scoring these kinds of spatial relationships and their implications for the location of the most productive mitigation projects.

Traditional and many progressive approaches to compensatory mitigation do not evaluate ecological outcomes and benefits in a way that includes mitigation’s effect on the production of ecosystem goods and services. To do this it is necessary to evaluate ways in which site-specific gains/losses interact with broader systems of biophysical production. Measuring ecosystem functions, the spatial scales on which they operate, and their subsequent social value is a
difficult and tenuous task (Kremen and Ostfield 2005). However, even rudimentary methods of assessing the social value of various ecosystem functions can help to integrate the economic benefits of compensatory mitigation projects into policymaking and regulatory decision-making.

From an economic perspective we can make several broad statements about the value of ecosystem goods and services:

- The scarcer an ecological feature, the greater its value.
- The scarcer are substitutes for an ecological feature, the greater its value.
- The more abundant are complements to an ecological feature, the greater its value.
- The larger the population benefiting from an ecological feature, the greater its value.
- The larger the economic value protected or enhanced by the feature, the greater its value.

For example, the value of irrigation and drinking water quality depends on how many people depend on the water— which is a function of where they are in relation to the water. Flood damage avoidance services are more valuable the larger the value of lives, homes, and businesses protected from flooding. Species important to recreation (for anglers, hunters, birders) are more valuable when more people can enjoy them. Economic valuation studies have found that wetlands also can generate aesthetic benefits (Mahan et al. 2000) contributing to an increase in property values (Doss and Taff 1996), thus wetlands in close proximity to larger housing communities would have increased value.

A number of case studies have demonstrated surrogate goods and services that are more easily measured can be used to generate approximate ecosystem service values (e.g. Costanza et al. 1997, Sutton and Costanza 2002). Nonetheless, we still don’t have a precise ecological understanding of the many natural benefits provided by an ecosystem; nor do we have a widely applicable, easy, and inexpensive, methodology for measuring the value of ecosystem services (Kremen and Ostfield 2005). However, a number of emerging tools are attempting to fill this void by allowing decision makers and corporate entities to identify the value of ecosystem services and the specific populations they serve in an effort to better target restoration or preservation (Waage et al. 2008). Several of these ecosystem service valuation tools are available or currently in development which may be useful to practitioners in resource agencies or transportation planning. These tools may help decision-makers prioritize natural resources based on the quality of their ecosystem services, either through avoidance, minimization, or compensation, and, in so doing, will allow for mitigation decisions to provide the most economic value to society.

**COST-SAVINGS OF PROGRESSIVE MITIGATION**

Progressive mitigation approaches expand the spatial and temporal scope of decision-making, supporting the consideration of multiple options to replace ecological functions and ecosystem services lost at an impact site (National Research Council 2001). The cost of mitigation varies with land values as well as the costs of restoration and creation. Progressive mitigation approaches that utilize regional, quantitative-based analyses provide more mitigation options to consider and therefore can provide costs savings around land acquisition, restoration, construction, water right acquisition and opportunity costs (Louis Berger & Associates, Inc. and BSC Group 1997; Drechsler and Watzold 2009).

Progressive approaches to mitigation support more coordinated, efficient decision making among transportation and regulatory resource agencies, as well as consolidation of regulatory permitting processes, and other administrative and transactional processes related to mitigation. For example, progressive compensatory mitigation encourages increased use of consolidated, off-site compensatory mitigation sources, such as mitigation banks, conservation banks, or in-lieu fee programs, presenting opportunities to capture economies of scale and reduce compliance costs for permittees (U.S. Department of Defense and U.S. Environmental Protection Agency 2008; U.S. Fish and Wildlife Service 2003). In two study areas in California, Thorne et al. (2009) observed a decrease in parcel price per hectare as potential mitigation sites size increased. Large-scale wetland and stream restoration projects may additionally capitalized on scale advantages by reducing the restoration planning, design, construction, and operation costs (Silverstein 1994; Sapp 1995). In addition, interagency collaboration and regulatory consolidation expedites mitigation permitting, reducing transportation project delays, and their associated costs. As an example, in Montana, cost- and time-savings are anticipated from having transportation and resource personnel address multiple projects concurrently, lowering the possibility of encountering significant obstacles to road expansion late in the project, and reducing regulatory time for permitting (Hardy et al. 2007).

As cited in *EcoLogical: An Ecosystem Approach to Developing Infrastructure Projects*, utilizing holistic innovative mitigation planning in advance of impacts, can afford additional costs savings through the early acquisition of land especially as the price of land rises over time (Brown 2006, Thorne et al, 2009). Many state departments of transportation (DOTs) confirm generating substantial cost-savings through consolidated mitigation planning, increased
flexibility in site-selection, and advance purchase of valuable mitigation parcels (National Cooperative Highway Research Program 2010a). In fact, late evaluations of the environmental impacts of road project development are the leading cause of expensive holdups in road construction (Transtech Management, Inc., 2003).

Programmatic mitigation utilizes processes that support a collaborative, landscape scale approach to mitigation. These collaborative, holistic, landscape scale approaches allow transportation and resource agencies to eliminate redundant investments, share data, and identify potential mitigation sites more effectively, which along with the use of consolidated, off-site compensation, can reduce field site visits and time spent approving and monitoring ecosystem restoration. Collaborative, ecosystem-scale approaches to mitigation also lower overall financial expenses by establishing regulatory assurances and thus reducing vulnerability to litigation or punitive damages, while also allowing transportation agencies to more accurately forecast expected project costs and their associated environmental compensation components. (National Cooperative Highway Research Program 2010a, Brown 2006).

In states with programmatic permitting processes and a statewide mitigation program that focus on achieving multi-resource, multi-benefit outcomes, research has demonstrated that many benefits can be achieved. These include improved impact avoidance, earlier identification of enhancement opportunities and permit needs - supporting efficiencies, and more accurate cost estimates and schedules (National Cooperative Highway Research Program 2010a). There are many examples of transportation programs that have adopted a streamlined, ecosystem-based approach to infrastructure planning and experienced substantial transaction cost- and time-savings as compared to traditional, project-by-project compensatory mitigation. In 2001, for example, the NCDOT reported that 55 percent of its transportation developments were delayed by wetland mitigation requirements; after ramping up streamlined transportation planning and mitigation, the EEP reports that no NCDOT Transportation Improvement Projects associated with EEP are experiencing delays (Venner 2010a).

As part of the research, we evaluated differences between some traditional mitigation programs, such as those from Florida and Ohio, a midway program from Minnesota, and some progressive projects underway in Maryland and Oregon. The Florida program is illustrative of how a very good traditional mitigation program is unable to take advantage of the economic benefits available if ecosystem service outputs can be used to help in identifying or prioritizing the locations of mitigation banks. A program in Oregon is also discussed in more detail. The Willamette Partnership’s Counting on the Environment is an example of a progressive approach working to develop tools for ecosystem services accounting suitable for use in compensatory mitigation.

**FLORIDA’S TRADITIONAL WETLAND MITIGATION PROGRAM**

Traditional wetland compensatory mitigation in Florida was conducted through on-site, permittee-responsible mitigation, mitigation banks, and public offsite mitigation areas, which operated similarly to traditional in-lieu fee mitigation programs. The documentation we reviewed provides no explanation of site selection methodologies for traditional mitigation projects in Florida.

A number of Florida studies used biophysical outcome measures to evaluate the success of compensatory mitigation. The most comprehensive study is Reiss et al.’s 2007 assessment of the ecological and regulatory success of 58 wetland assessment areas within 29 mitigation banks across the state. The analysis of ecological success included use of a number of on-site and off-site measures, including the Uniform Mitigation Assessment Method (UMAM), Wetland Rapid Assessment Protocol (WRAP), two Hydrogeomorphic Wetland Assessment (HGM) guidebooks, Florida Wetland Condition Index (FWCI), and Landscape Development Intensity (LDI) Index. UMAM generates functional scores for location and landscape support, water environment, and community structure, which potentially could be used to evaluate a site’s ecosystem goods and services. WRAP seems particularly conducive to analysis of the social benefits resulting from a mitigation site, including scoring categories for wildlife utilization, overstory/shrub canopy, vegetative ground cover, adjacent upland support/buffer, field indicators of wetland hydrology, and water quality input/treatment.

Researchers have conducted a number of other local and regional studies recording qualitative or quantitative biophysical outcomes of traditional wetland compensatory mitigation projects in Florida. Lowe et al. (1989) evaluated the success of 29 wetland creation sites in the St. Johns River Water Management District (WMD) based on their success in meeting regulatory conditions of permits/consent orders and creating viable wetland habitat, as judged through qualitative assessments of a site’s wetland species coverage, hydrology, and ability to support appropriate macro-invertebrate and fish populations.

Erwin (1991) examined 196 wetland impact permits in the South Florida WMD and evaluated the regulatory compliance and ecological effectiveness (surface hydrology, vegetation) of the 40 permits that required mitigation. A 1991 study by the Florida Department of Environmental Regulation (FDER) reviewed 119 wetland creation sites
required by 63 Florida Environmental Resource Permits (ERPs) for adherence to permitted design and the ecological success of the site, as judged by whether a site is, or appears on a trajectory to become a functional wetland of the intended type. Streever et al. (1996) compared 10 created and 10 natural wetlands in central Florida in 1993 to assess differences in dipterans in freshwater herbaceous wetlands. Shafer and Roberts (2008) returned to 18 tidal mitigation sites in central/southern Florida in 2005 that were originally evaluated in 1988. Their research reassessed mangrove community composition and stand structure in 10 of these wetland mitigation sites to chart long-term trends in the development of vegetation at the site. Finally, in 2000 the Florida Legislature’s Office of Program Policy Analysis and Government Accountability released a report that provided an overall status of wetland mitigation in the state including data on permit compliance (Florida Legislature Office of Program policy Analysis and Governmental Accountability 2000). All of these studies confirm the widespread understanding that in spite of mitigation requirements, laws, and the state’s best efforts, a long-term erosion of wetland functions continues to occur. This is important because it is the major reason that regulators make mitigation implementation a slow and arduous affair.

Florida has had some studies relating the biophysical outcomes of wetland mitigation to their value as ecosystem services. Ruhl and Salzman (2006) examined the socioeconomic effects of wetland mitigation banking throughout the state. The authors collected permitting information for all active and sold-out wetland mitigation banks in Florida, and for the 24 banks with adequate information, analyzed demographic trends in population density, median income, and minority population induced by banking. Boyd and Wainger (2003) performed a more detailed case study of the effects of a single mitigation bank, the Little Pine Wetland Mitigation Bank on the value of wetland ecosystem services, as assessed through landscape indicators describing ecosystem service values. The authors used landscape indicators to assess services for improved drinking water quality/abundance, reduced flood damage, improved aquatic recreation, and open-space recreation, aesthetic, or species existence benefits. They found that the site scored poorly for many of the values analyzed, but well for species and recreational values.

In general, the studies and measures indicate that the Florida mitigation program for wetlands is as effective as most wetland mitigation programs in the country. We were interested in examining how the lack of priorities in siting mitigation might be impacting the ability of banks in delivering services and their corresponding economic values. For this analysis, we were able to take advantage of a comprehensive study undertaken by Florida State University’s Natural Area Inventory (FNAI). As part of the Florida Forever project, FNAI developed updated statewide conservation priorities for all species and habitats and other ecosystem values across the state. The project created data and online tools to be used for prioritization of acquisition and protection of conservation areas. Relevant to identification of mitigation priorities would be the 15 maps of spatial data identifying strategic conservation areas, rare species, under-represented ecosystems, large landscapes, natural floodplain function, functional wetland and other priorities. Figure 2 is an example of one of these data sets, the priority aquifer recharge areas (Florida Natural Areas Inventory 2011).

Since data on conservation priorities in the state have already been developed by credible sources, the use of a regional ecosystem framework to guide mitigation efforts in Florida would require extremely limited costs related to data development or analysis, most costs being limited to the process of

![Figure 2. Florida Forever map showing Aquifer Recharge Area priorities from Advanced Geospatial, Inc. and Florida Natural Areas Inventory (Florida Natural Areas Inventory 2011).](image-url)
deciding on the most effective or important resources to evaluate. Table 1 is the results of an analysis of the overlap between the different services provided by priority conservation sites, and the current network of wetland mitigation banks in Florida. Most of the priority coverages have three categories, and so this table only shows the overlap for the top three priorities. A few coverages, including the Aquifer recharge areas shown above, have five or six priorities, but only the first three are shown. Also, in June of 2011, FNAI updated their FNAI Habitat Conservation Priorities map to take advantage of new data, and this new data is not included in this analysis, although the changes are not likely to change the analysis shown in Table 1 in a meaningful way.

Table 1. An evaluation of Florida mitigation banks for “Florida Forever” measures. Data courtesy of Gary Knight, Director, Florida Natural Areas Inventory, Florida State University.

<table>
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<th>MEASURES</th>
<th>Acres</th>
<th>%</th>
<th>MEASURES (continued)</th>
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<td><strong>C4: Natural Floodplain Function</strong></td>
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<td><strong>C5: Surface Water Protection</strong></td>
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<td><strong>C7: Fragile Coastal Resources</strong></td>
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<td>68,510</td>
<td>51%</td>
</tr>
<tr>
<td>Dry Prairie (G2)</td>
<td>0</td>
<td>0%</td>
<td>Total Acres</td>
<td>16,295</td>
<td>12%</td>
</tr>
<tr>
<td>Seepage Slope/Bog (G3)</td>
<td>0</td>
<td>0%</td>
<td>Total Acres</td>
<td>16,295</td>
<td>12%</td>
</tr>
<tr>
<td>Sandhill (G3)</td>
<td>876</td>
<td>1%</td>
<td>Total Acres</td>
<td>16,295</td>
<td>12%</td>
</tr>
<tr>
<td>Sandhill Upland Lake (G3)</td>
<td>223</td>
<td>&lt;1%</td>
<td><strong>D3: Aquifer Recharge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upland Hardwood Forest (G4)</td>
<td>0</td>
<td>0%</td>
<td>Priority 1</td>
<td>604</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Pine Flatwoods (G4)</td>
<td>11,672</td>
<td>9%</td>
<td>Priority 2</td>
<td>3,310</td>
<td>2%</td>
</tr>
<tr>
<td>Total Acres</td>
<td>13,909</td>
<td>10%</td>
<td>Priority 3</td>
<td>12,380</td>
<td>9%</td>
</tr>
<tr>
<td><strong>B5: Landscape-sized Protection Area (Yes/No)</strong></td>
<td></td>
<td></td>
<td>Total Acres</td>
<td>16,295</td>
<td>12%</td>
</tr>
<tr>
<td>Priority 1</td>
<td>yes</td>
<td></td>
<td>Total Acres</td>
<td>16,295</td>
<td>12%</td>
</tr>
<tr>
<td>Priority 2</td>
<td>yes</td>
<td></td>
<td>Total Acres</td>
<td>16,295</td>
<td>12%</td>
</tr>
<tr>
<td>Priority 3</td>
<td>yes</td>
<td></td>
<td>Total Acres</td>
<td>16,295</td>
<td>12%</td>
</tr>
</tbody>
</table>

*Number of acres of each resource in mitigation sites and percentage represented are listed except where noted. Only Priorities 1 - 3 included. Some resources priorities are 1-6.
The fact that existing mitigation banks only include 14% of FNAI Habitat Conservation Priorities, 10% of Under-represented Natural Communities or 3% of Fragile Coastal resources is not surprising, as these values were not considered in any way in identifying potential mitigation areas, although there is little doubt that a much higher percentage of each of these values could have been obtained if incentives for including them were included in the Department of Environmental Protection’s rules. It is more disturbing that in the areas in which related wetland functions should be strongest, such as aquifer recharge and natural floodplain function, only 12% of the area of banks occur within any of the top three priority areas, while only 34% occur in locations that provide priority surface water protections. Barely half occur in areas with locations that were identified as priorities for wetlands functions. Clearly the existing mitigation banks, regardless of whether they are meeting their regulatory objectives, miss a great opportunity to expand the ecological and economic benefits available by locating in the right places.

The Florida Department of Transportation’s (FDOT) Efficient Transportation Decision Making (ETDM) web-based permitting system may actually create barriers to taking advantage of the additional ecosystem services provided by a more ecoregionally-based mitigation approach. One of the most direct costs of implementing transportation projects is the cost in both staff and delays related to the acquisition of the necessary permits. Florida’s ETDM is an award winning web-based tool designed to streamline the process of planning and implementing transportation projects, and over the last seven years since its implementation, it has been shown to be remarkably effective in shortening the time for permits and project implementation (Roaza 2007).

However, for FDOT to create the interagency agreements needed to build the ETDM, it was necessary to complete complex and intense negotiations with the regulatory community, which also takes both time and money (Venner et al. 2010b). As a result, the ETDM does not allow for much flexibility, and to make changes necessary to implement an ecoregionally based mitigation approach would both involve additional expense and potentially slow new project development. Many view the benefits in speed and cost of transportation project implementation over the benefits of developing these, and almost any programmatic regulatory agreement, particularly if mitigation is involved (Achterman et al. in press). However, the ETDM is an example of how the initial costs of implementing a program can limit its long-term effectiveness and expandability. In other words, the inherent cost due to negotiation of a complex programmatic system for permitting, especially if it is web based, provides incentives for not including new types of information and for not changing the existing information operating the system.

For example, much of the information on threatened and endangered species used in ETDM came directly from the Florida Natural Areas Inventory (FNAI). The data used was the best available at the time, approximately 2003. Yet extensive and much improved information has been developed by FNAI since that time. In particular, FNAI has been working with NatureServe to create species distribution maps (SDM) for at-risk and threatened and endangered species, identified in recent studies (Achterman et al. in press) as critical data which can improve both the ability to avoid endangered species early in the planning process, and to target areas with endangered species during mitigation planning. Developing SDMs is not without initial costs, but in Florida FNAI has obtained funding to develop initial SDM for all priority species to assist in conservation planning. Using them requires renegotiating the programmatic, which FDOT is unwilling to do. ETDM therefore is a methodology that speeds transportation project implementation without considering the ecological or economic benefits of using new data or methodologies. It therefore removes any incentives for adopting new data or methodologies, or even for evaluating their utility.

**WILLAMETTE PARTNERSHIP’S COUNTING ON THE ENVIRONMENT PROJECT**

The Willamette Partnership is a diverse, collaborative non-profit initiative focused on developing markets that use detailed accounting procedures for multiple types of ecosystem service credits to promote environmental stewardship. Perhaps the most defining characteristic of the Willamette Partnership is development and application of science-based ecosystem service accounting protocols. These protocols are designed to measure and track the functions and values associated with improvements and impacts to separate ecosystem services. The Partnership is currently developing protocols for measuring improvements and damages for wetland habitat, prairie habitat, salmon habitat, nitrogen and phosphorus loadings, and thermal pollution offsets. Several site-based calculation methods have already been approved, including those for salmon, prairie, wetlands (the Oregon Wetland Assessment Protocol), and water temperature. The Willamette Basin has been home to the most advanced and detailed efforts to date to integrate the economic values of ecosystem services into multiple regulatory programs requiring compensatory mitigation (Achterman et al., in press, Nelson et al. 2009).

The Partnership’s General Crediting Protocol (Willamette Partnership 2009) provides the procedures for using these ecosystem service accounting procedures. It also references priority areas for ecological improvements to salmon, prairie, and wetland habitats, and water temperature impairments; working to create financial incentives for working in areas that are likely to achieve the greatest ecological benefits. The Partnership identifies priority rivers and streams for...
improved salmon habitat based on National Marine Fisheries Service (NMFS) data, investment priorities for prairie
habitat and thermal pollution mitigation based on the Willamette Basin Synthesis Map, and priorities for wetland
mitigation based on the wetland priorities identified in the Synthesis Map or areas surrounded by high-function
wetlands as determined by Oregon’s rapid wetland assessment method, the Wetland Assessment Protocol.

Since the primary wetland compensatory mitigation activity is wetlands restoration, the project incorporated a Wetlands
Restoration Planning Tool (Oregon State University 2010) that helps users identify the most appropriate sites and
wetland types to target for restoration. Datasets used in the tool include the statewide wetland layer, rare wetlands,
restoration targets based on 8-digit HUCs, locations of wetland mitigation banks, Oregon Wetland Reserve Program
sites, wetland priority sites for the Willamette Valley, and hydric soils. The Willamette Partnership has been focused on
helping to create markets for ecosystem services, and much of their mitigation activity and planning were thus driven
by a “markets” approach, which tends to demand both transparent criteria for measuring environmental improvements
and damages and an assessment of benefits associated with alternative mitigation outcomes. However, regulatory
agencies have been unable to integrate these new processes into their daily regulatory approaches, in spite of a multi-
year effort to engage them in the development of the ecological measures and their strong interest in moving towards
progressive mitigation approaches with multiple values. This appears to be due to the combination of funding
limitations, current work-loads, and the single regulatory resource focus each agency has.

BARRIERS TO IMPLEMENTATION OF PROGRESSIVE MITIGATION

Moving from traditional, project-by-project compensatory mitigation procedures to adoption of a holistic, landscape
approach that incorporates natural resource concerns into early stages of transportation planning is challenging.
Barriers to implementation of these progressive mitigation strategies consist of resource constraints and institutional
constraints. While progressive mitigation strategies present opportunities for long-term efficiencies and cost-savings,
transitioning to more holistic approaches requires a modest but real initial investment. In particular, data limitations
need to be overcome. For example, in the context of ESA §7, available data does not adequately depict how projects
will impact listed species; and for CWA §404 permitting, wetlands data do not currently support the development of a
wetlands mitigation catalog that incorporates multiple ecosystem values (Achterman et al, in press). Funding for
database investment, staff training, staff time, collaboration, and adaptive management is also needed for transitioning
resource agencies to new regulatory roles and transportation agencies to new planning procedures.

Institutional barriers to early consideration of transportation-related impacts and mitigation are the second major
obstacle to moving beyond traditional, project-by-project mitigation approaches. These include internal resistance
within regulatory and transportation agencies, political pressure from those currently benefitting economically from
traditional approaches. In addition, staff turnover, both at agencies and at regularly utilized consulting firms provides a
barrier, and leads to a lack of understanding of the values and methods of providing resource related information to
transportation planners early in the transportation planning process.

Progressive approaches require the development of some type of a regional ecosystem framework; and creating a
framework or adopting a methodology that can be widely accepted is the primary barrier to overcome. To some extent,
coming up with the upfront investment required in data analysis and planning is a policy problem, rather than a
transportation or metropolitan planning organization. Cost benefit studies in Oregon, Florida and elsewhere have shown
that even paying for upfront data development costs and all the costs of developing a programmatic agreement can
provide significant economic returns if an agency plans significant transportation investments in developing new
projects or updating existing projects (Oregon Department of Transportation 2008).

As with all projects, in developing alternative mitigation strategies, it is more efficient to take advantage of existing
tools. For example, State Transportation Infrastructure improvement plans required under SAFETEA-LU (Safe,
Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users) facilitate progressive mitigation
approaches and advanced mitigation by requiring 5-year forecasts of transportation-induced impacts. For efficiency,
regulatory planning can occasionally utilize and often build on existing conservation/watershed plans, rather than
require the development of a new regional ecosystem framework (Weber and Bulluck 2010; Bryson et al. 2010).

STEPS TO SUPPORT THE PROGRESSIVE APPROACH

Aside from the improved environmental and economic outcomes which research indicates are likely to occur using a
progressive approach, there are a number of other specific benefits which can be obtained. These include addressing
water quality threats, delivering improved water quality, mitigating floods, increased species benefits, increased
recreational opportunities and increased land values for properties adjacent to new natural areas. If the social and
economic value of ecosystems, not just acreage or functions, is to be preserved, then sites’ relative ability to generate
benefits must be understood by policy makers as well as regulators and transportation decision makers. Data and methods already exist to foster appreciation of landscape characteristics that contribute to the quality of ecosystem functions and services produced at a particular offset site. If applied, these data and methods are likely to yield compensatory mitigation projects that produce greater ecological and social benefits.

The most critical step for policy makers is to assure that an acceptable watershed/landscape – scale mitigation plan is adopted and that this plan is a structural part of the regional ecosystem framework (REF) or watershed plan, or at least consistent with the REF. Both of these are different from the detailed, site mitigation plans that the Army Corps of Engineers requires for mitigation site designs. Whenever possible, plans should include standardized methods. National decision makers should attempt to standardize methods for creating a national conservation ‘blueprint’. This would greatly facilitate local efforts to adopt a watershed or landscape – scale mitigation plan, which is the critical step towards prioritizing compensatory mitigation sites.

Defining what is required for an acceptable REF or watershed strategy can only be done by policy makers. One of the greatest problems related to implementing standards for general, multiple resource conservation planning is that there are usually no clear authorities for these standards at the state and federal levels. State and federal agencies are generally given a legislative mandate to focus on a particular resource. As such, no agency generally has the authority to evaluate multiple regulated resources, such as water quality, water quantity, wetlands, endangered species and biodiversity. In addition, when creating an integrated REF or a Watershed Strategy, some communities will choose to include access to parks, recreational opportunities, lands for new development, or other potentially competing land uses in their conservation strategy. While these are perfectly valid considerations in a land use plan, they can make it more difficult to create a REF that will address the critical needs of regulated resources.

An additional potential policy solution to increase alternatives for mitigation sites is to grant larger geographic service areas to mitigation providers using progressive mitigation approaches. Mitigation banks, conservation banks, or in-lieu fee programs with increased geographic flexibility will have more options for sites to select aquatic resource or endangered species offsets. In addition, granting larger service areas to mitigation providers that utilize progressive mitigation approaches increases the marketability of their credits and may promote financial investment in these approaches. Larger service areas will allow relocation of mitigation further from losses, which may lead to systematic geographic transfers of natural resources, as happens with urban-to-rural migration of wetland offsets. While larger geographic service areas do not always encourage higher quality compensatory mitigation, they will inevitably increase the number of potential locations for mitigation (Womble and Doyle, in press).

The method used in the Maryland Water Resources Registry (Bryson et al. 2010) and Virginia Wetlands Mitigation Catalog (Weber and Bulluck 2010) to assure that sufficient mitigation and restoration opportunities exist to evaluate and rank all potential mitigation sites based on the quality of their different potential ecosystem functions. As a result, every potential mitigation site can be ranked and the various services it can generate can be evaluated. When this type of comprehensive information is available and vetted by (or in this case created by) regulatory agencies, policymakers should institute enough regulatory flexibility to allow mitigation providers to choose high-priority offset locations. If EPA moves the Watershed Resources Registry across the nation, it should be relatively straightforward to integrate into a regulatory framework.

The implementation of a programmatic agreement to institutionalize a progressive mitigation strategy is critical, and can be a long and difficult process to develop. Once these agreements and the strategies are implemented, decision support tools can significantly improve transportation and land use planning in the watershed or the region, reducing the cost of the planning and likely improving ecological outcomes. Currently the process of creating a programmatic agreement is usually very time consuming and difficult. As a result, transportation and regulatory agencies often choose not to take advantage of the fact that programmatic agreements can provide both economic and ecological benefits in the long run. Policy makers must address this issue, both by providing initial support for the development of the data to move progressive approaches forward and to provide support for transportation agency staff and regulatory agency staff to pursue programmatic agreements.

Lastly, complex decision support tools built on programmatic agreements are difficult to modify (NCHRP 2011). Currently, there are few incentives available for any entity that has created a decision support tool, such as Florida’s ETDM, to modify the tool in light of new types of data. ETDM, like most well designed decision support tools, was created to allow for updated versions of the key data layers that were used in its design. However, if a critical data layer, such as observations of state and federally listed species can be replaced with a more useful but very different coverage, such as a geodatabase of likely distributions of state and federally-listed species, the ETDM would need to be modified. The problem with any modifications of the ETDM related to regulatory resources is that the programmatic agreements may need to be renegotiated. The time and expense of any negotiations with regulatory agencies creates a
major disincentive for any significant changes in decision support tools, even if they are done to improve outcomes to the regulated resources. Because iterative decision support tools are difficult to establish and maintain, agencies are not going to be inclined to change current processes, especially if they appear to be working well. Policymakers can institute new incentives to allow agencies to promote acquisition of these flexible, iterative decision support tools.

CONCLUSIONS

Progressive mitigation planning involves better information and more complex analyses, therefore the initial costs of these progressive approaches will be more expensive. But, the ecological and economic benefits of this mitigation planning, combined with the potential cost savings to implement the programs, are likely to outweigh the additional, upfront analytical costs necessary to establish a progressive approach to compensatory mitigation planning (National Cooperative Highway Research Program 2011).

Progressive planning can and should constrain the location of acceptable mitigation projects by identifying which options may yield the greatest ecological and economic benefit. Ideally, progressive planning favors sites with the greatest net benefit, meaning land acquisition costs as well as restoration and creation costs are taken into account. However, it is possible that the cheapest lands will not yield the largest net benefit, which implies that acquisitions costs may be higher under a progressive planning approach. Nevertheless, with a net benefit approach to site selection that takes into consideration the benefits of improved ecosystem services, the gains from progressive planning will likely always be greater than any additional land acquisition costs.

In particular, measures to characterize the economic values of improved ecological outcomes, and to make these values clear to the regulatory community are essential to move this effort towards widespread implementation within the United States. Overall there is compelling evidence that if transportation and natural resource agencies continue to work together in developing a progressive, landscape-scale approach to the compensatory mitigation process using a combination of the methods and processes outlined in this guide, significant ecological, economic, and societal benefits can be achieved.

ACKNOWLEDGEMENTS

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BIOGRAPHICAL SKETCHES

Jimmy Kagan is the Director of the Oregon Biodiversity Information Center, where since 1985 he has overseen the development of the heritage databases, developed statewide and regional vegetation maps and classifications, and completed ecological and botanical inventories. He also directs the Institute for Natural Resources – Portland at Portland State University. He is currently the Co-PI of a Landscape Assessment and Fire Treatment Prioritization in the West stimulus project as well as a National Transportation Research Board Project to address the scientific and technical obstacles to the adoption of integrated conservation and transportation planning. In addition to his peer reviewed publications, he has been has been the primary author of three editions of the Oregon Natural Heritage Plan, the 2010 Oregon Natural Areas Plan, and six editions of Rare, Threatened and Endangered Species of Oregon (1983-2010). Before managing the Biodiversity and Natural Heritage Information Centers, he was the director of preserve design for The Nature Conservancy of Oregon. He has a MS in Plant Ecology from the University of Oregon, a BS in Science and Education from Portland State University and a BA from the Evergreen State College.

Jim Boyd is an economist dedicated to improved conservation and environmental protection. He is a Senior Fellow at Resources for the Future, Washington DC and directs its Center for the Management of Ecological Wealth. His work emphasizes the economic importance of natural systems and the need to better coordinate economic and ecological research to improve conservation, restoration, and natural resource management decisions. In 2007-2008 he was a Visiting Professor of Human Biology at Stanford University. Prior to that he was the Director of the Energy and Natural Resources Division at Resources for the Future. He received his PhD from the Wharton School, University of Pennsylvania, in 1993. He has served on National Academy of Science, U.S. EPA Science Advisory Board, and numerous other government and private advisory panels, including the U.S. EPA’s Committee on Valuing Ecological Systems and Services.
Jessica B. Wilkinson guides ELI’s program of research on wetlands and biodiversity policy. The primary focus of her research relates to compensatory mitigation, with a particular emphasis on wetlands mitigation. Wilkinson has undertaken research in support of the federal interagency Mitigation Action Plan Workgroup, has designed and carried out training courses related to mitigation, and has facilitated numerous national policy dialogues with a diverse range of stakeholders. Jessica has a Masters in Environmental Management from Yale, and a BA from Barnard College at Columbia University.

Shara Howie is the Sector Relations Manager for NatureServe’s Conservation Services Division and works out of the Boulder, Colorado office of NatureServe. Shara has over 12 years of experience in the development and maintenance of conservation data and data management systems. She has extensive experience as a program and project manager supplying U.S. and Canadian federal agencies and other organizations with conservation data, analyses and other conservation services in collaboration with NatureServe’s international network of member programs (Natural Heritage Programs). Shara is the lead on transportation related work with a primary focus on integrating conservation data and expertise into transportation decision making. Before joining NatureServe in 2001, Shara worked for The Nature Conservancy’s Science Division for 10 years and, prior to that, at the Smithsonian’s Botany Department for 3 years. Shara has a Bachelor’s Degree in Biology from George Mason University, and has experience and training in facilitation and mediation.

Philip Womble is a Research Associate at the Environmental Law Institute (ELI) with two years of experience in evaluating the law, policy, and science of emerging markets for ecosystem services, including particular emphases on aquatic resource compensatory mitigation and water resources management. Prior to joining ELI, at the UNC-CH Institute for the Environment, Mr. Womble assembled a comprehensive listing of geographic service areas used for mitigation banks in all 38 Army Corps regulatory districts and relevant states. At ELI, he currently is a supporting researcher for a Wetland Program Development Grant (WPDG) to identify and analyze state and local methods to prioritize aquatic resources restoration and conservation opportunities. As part of an additional WPDG, he managed ELI’s analysis of the U.S. Army Corps of Engineers’ determinations of no jurisdiction to determine specific types of aquatic resources that are no longer regulated under the Clean Water Act following the U.S. Supreme Court’s ruling in Rapanos v. United States. Mr. Womble’s research also supported ELI and The Nature Conservancy’s aquatic resource compensatory mitigation watershed approach pilot projects. His additional research focuses include water quality and water quantity management. He holds a B.S. in Environmental Sciences from the University of North Carolina-Chapel Hill (2010).

Joanne R. Potter is a Principal with Cambridge Systematics, specializing in interdisciplinary approaches to transportation, climate change, and sustainability. Ms. Potter works to support agencies in integrating complex environmental issues into transportation decisions to achieve sustainable solutions. Ms. Potter was Project Manager for: U.S. DOT Report to Congress on Transportation’s Impact on Climate Change and Solutions (April 2010); Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions (July 2009); a climate change vulnerability and risk assessment of transportation infrastructure in New Jersey; and the PM and lead author for The Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study Phase I (March 2008). She is currently supporting SHRP 2 - CO9: Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process. She is also PIC for a Caltrans project to prepare a guidebook for incorporating climate impacts into regional transportation plans. She is supporting National Cooperative Highway Research Program 8-74: Sustainability Performance Measures for State Departments of Transportation and Other Transportation Agencies. She was Principal Investigator of National Cooperative Highway Research Program 25-25 (32), which examined state DOT practices in integrating environmental information and transportation planning, Joanne is a member and former Chair of the TRB Committee on Transportation and Sustainability, and a member of the ITE Advisory Committee on Sustainability. She holds a Master’s degree in City Planning from the Massachusetts Institute of Technology (1994).

REFERENCES


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