Supplementary Materials

to the Report: "New Business Decision-Making Aids in an Era of Complexity, Scrutiny, and Uncertainty: Tools for Identifying, Assessing, and Valuing Ecosystem Services"

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Background Materials on Ecosystem Services Tools

The 2010 comparative ecosystem services tool application study was premised on each tool using the same study site, data sets (insofar as possible, given the data requirements of the tool), and a common set of questions to which each tool responds. The objective was to understand both details associated with tool applications and relative insights that the tools yield in the context of four key parameters:

» Water provisioning
» Carbon sequestration
» Cultural services
» Biodiversity

BSR's Ecosystem Services, Tools, and Markets Working Group asked each of the tool developers to write up the following items:

Component #1 – Overview of the Tool's Application to San Pedro Watershed
Document the process of preparing the tool for this application to the San Pedro Watershed, including discussion of the key elements outlined below.

Component #2 - Tool Description
Provide key, up-to-date information about your tool, in the table format provided below.

Responses are appended below in "raw" form—unedited, as submitted by tool developers—in order to inform discussions at the October 2010 roundtable.

ARIES

Component #1 – Overview of ARIES' Application to the San Pedro Watershed

1.1 Data needed for tool application.
The ARIES carbon, recreation, water supply and aesthetics models use data from a variety of academic, agency, and other research institutions. Carbon models use the following data: tree canopy cover (from NLCD for the U.S. & UMD-GLCF globally), land cover from SWReGAP for the U.S. and CONABIO for Mexico, climatic data from PRISM at Oregon State for the U.S. and WORLDCLIM for global data, soils data from SSURGO/STATSGO for the U.S. and UN-FAO globally, slope data from the SRTM, fire return interval data from SWReGAP and TNC, carbon sequestration and storage data from the NBCD for the U.S. and ORNL, NBII, and FAO globally, and anthropogenic emissions data from the VULCAN project for the U.S. and LANDSCAN population density and per capita emissions from EIA for the global scale. For water models, we used: climatic data from PRISM & WORLDCLIM, springs data from ALRIS, hydrologic modeling results from SWAT (available via the USEPA San Pedro Data Browser), impervious cover from NLCD and UMD-GLCF, a manually-created surface diversions layer, and well locations and total use from ADWR's Wells-55 database, along with soils, climate, tree cover, and land use data sources mentioned above for carbon. For aesthetics, we used elevation data from SRTM, highways from ALRIS, transmission lines from the USEPA San Pedro Data Browser, land cover types from SWReGAP, housing locations and values from Pima and Pinal County GIS departments, land ownership from ALRIS, and riparian condition class from Julie Stromberg's work on the San Pedro, and population density data from the Census Bureau. Recreation models used biodiversity data from UA-USGS, species habitat data from SWReGAP, trails data from SPRNCA, and previously-noted data for population density, land cover, land ownership, and access. Finally, data to parameterize the ARIES models were obtained from the literature and an expert workshop convened in Tucson from Sept. 21-23, 2010. All data sources and model assumptions will be fully documented as part of the project report for the BLM-USGS Ecosystem Services Valuation Pilot, to be produced in the winter of 2010-2011.

1.2 Data acquisition methodology or process of identifying and sourcing data for your tool, specifically citing public agency data sets used and/or documenting the methodology used in gathering primary data.
Data are downloaded, placed onto the ARIES server, and pre-processed as necessary (a different process for each data layer, but potentially including reprojection of certain data, rasterization of large data layers, and mosaicing other data layers), tagged with the proper ARIES modeling concept (to enable it to be accessed seamlessly by ARIES models), and placed onto the ARIES Geoserver. The Geoserver handles all future data management, and once the initial pre-processing is completed, data are available for all future ARIES applications. This iterative process to build up the ARIES database means that future applications become progressively easier – for instance, future applications in the Southwestern U.S. will already have significant data requirements completed as a result of the San Pedro project.

1.3 Process for uploading data and preparing for tool application including data preparation.
See above.

1.4 Time implications to source and/or prepare data for inputting into the tool, particularly highlighting staff time implications at what level of staff experience.
Perhaps five weeks of time (ca. 200 hours) were needed to collect and prepare data for the ARIES models, run the models, and begin to improve them to "second generation" status using expert input from the Tucson workshop. Additional time was needed to develop agent-based ecosystem services flow models for services that had not been previously developed. Further work will continue to refine the models and results and integrate them into the online ARIES browser. The above work was completed by the ARIES technical team, who have substantial past experience developing case studies and ecosystem services models using the ARIES system. Once data are input and the system becomes fully operational, minimal time is needed to run an ARIES session for an existing case study region. The user simply accesses the pre-developed data and models using the online interface.

1.5 Challenges encountered in sourcing and/or inputting data, noting whether these challenges were unique to this site or should be planned for in the future.
When collecting and inputting spatial data, there are almost always numerous small barriers to quick implementation of ARIES, ranging from incomplete metadata, incorrect projections, the need to preprocess certain data, proper handling of transboundary data, etc. Once these barriers are overcome, however, the data and models become consistently available as part of the ARIES system, with no further work needed on the part of the user. Ongoing work will be needed as part of the San Pedro to continue testing and refining the tool,

integrate existing models (e.g., MODFLOW groundwater model), add functionality, etc. Many of these features are under development but are not yet part of the online ARIES tool.

1.6 Answers to corporate-relevant 'questions' posed to each tool, including:

1.6.1 *New Project Siting / New Project Development*[1]

Where would be the ideal site for a new residential project in order to have the least impact ecosystem services?[2] *Why?*

An ideal project site would minimize impacts to "sources" of key ecosystem services (e.g., areas of high carbon sequestration, high biodiversity for recreational values, high-quality views, and areas of high precipitation, infiltration, and groundwater recharge). It would also minimize impacts to beneficial "sinks" of ecosystem services (areas of infiltration and groundwater recharge) and avoid creating new detrimental "sinks" of ecosystem services (highways, visual blight, areas of increased high intensity fire risk). Generally, this would entail avoiding disturbance to areas of high carbon storage, avoiding creation of additional road infrastructure, and most importantly in minimizing additional water demand (i.e., requiring as few new wells and groundwater extraction requirements as possible).

1.6.2 *Existing Infrastructural / Project Expansion*
Where (and if possible how) would you expand growth of residential units on the US side of the border? Why?
See above – answers to this question would be nearly identical to the development of new projects. Although not explicitly considered in the ARIES models, existing expansion that is near currently developed areas would reduce the landscape and habitat fragmentation resulting from highly dispersed development.

1.6.3 *Land Management*
What are the areas where focused ecosystem service-related investments would offer potential benefits?
What are the recommended investments?
What ROI (quantitative or qualitative) would be realized on what time frame (e.g., payments from environmental market transactions, real estate sales, etc.)?
What might be ways to avoid regulatory exposure in light of:
Endangered species habitat sites?
Indigenous peoples / Native American claims sites?
Other?

Similar to the answer to question 1.6.1, investments might be made to maximize carbon sequestration and storage and minimize water demand in the watershed (which also reduces the threat brought on by excessive groundwater pumping, with potentially serious detrimental effects on biodiversity and associated ecosystem services). Avoided regulatory exposure can most significantly be avoided by avoiding dewatering of the San Pedro's riparian ecosystem by limiting expansions to extraction, increasing water conservation, and bringing the San Pedro's water budget into balance. Given the complex nature of the San Pedro's groundwater and the simplistic way ARIES deals with groundwater, its value to support decision-making about groundwater will probably remain limited until it can incorporate existing groundwater models (i.e., local applications of the MODFLOW model). All these decisions will likely require increased political will to change economic incentives regarding water use and balance the San Pedro's water budget.

1 Tools for analyzing ecosystem services will be compared through an exercise in siting new or expanding existing projects. Any scenarios considered in this exercise are purely hypothetical, and are not intended to contribute to a proposal subject to a current or future land use decision by an agency of the federal government.

2 The rationale for this hypothetical case is that several large-scale residential development projects were proposed for communities in the San Pedro watershed, including Benson and San Manuel, prior to the collapse of the real estate bubble. These proposed projects would accommodate retirees or long-distance commuters to places such as Tucson or Sierra Vista. Although induced commercial development would likely follow large-scale residential development, the San Pedro valley is likely too sparsely populated to currently support large-scale commercial ventures. In light of this context, the tool developers have been asked to apply tools to the following hypothetical case, in which there would be disturbances to the Chihuahuan desert scrub as the primary existing vegetation type. Specifically, the specifications for consideration are of a proposed 500 acre and 1,000-unit housing development near Benson, Arizona, with specific locations near the intersection of Interstate 10 and Arizona Highway 80 or 90. The assumed water use would be 312 gpcd (gallons per capita day) for 2.56 people per home in unincorporated areas (ADWR 2005, cited in 2007 Section 321 Report), which represents 894.5 acre feet per year in new demand from 1000 new housing units, plus induced commercial demand.

1.7 Reflections on corporate applications of your tool, such as:

1.7.1 Appropriate conditions and contexts in which to apply the tool. [3]

ARIES is highly useful for evaluating the spatial context of ecosystem services, and enables modeled results that account for the location and nature of supply and demand via source, sink, use, and flow models for ecosystem services of interest. ARIES is also useful in cases where existing models are poorly developed or uncertainty is high – cases where probabilistic, Bayesian modeling is more advantageous than deterministic models. ARIES can compare specific scenarios for land use, population growth, and land management, and relate these to levels of ecosystem service provision given both changes to the landscape and to user populations and preferences for particular ecosystem services. The explicit attention to ecosystem services impacts and demand in ARIES lends itself extremely well to analysis of potential PES systems, where beneficiaries can be located, as well as areas of potential environmental risk and exposure. ARIES thus supports a range of elements common to the "business case for ecosystem services:" areas of opportunity for investment and markets, identification and mapping of potential regulatory and legal risk, and maintenance of positive impacts to surrounding communities that can be highlighted as part of corporate "license to operate."

1.7.2 Relationship between environmental impact and ecosystem services, particularly in terms of how this tool might 'interface' with pre-existing corporate tools and processes for assessing impact.

ARIES can couple with other tools, in particular those to scope ecosystem services-based decisions (i.e., ESR), to estimate economic values (i.e., Defenders of Wildlife Wildlife Habitat Benefits Estimation Toolkit), or to map potential impacts to biodiversity (i.e., IBAT).

1.7.3 Building the business case of how this tool may improve corporate environmental systems and processes for decision-making.

ARIES lets the business user move beyond basic environmental compliance in looking at wider-scale impacts, both beneficial and detrimental, associated with existing and proposed corporate operations. Results of an ARIES session are a series of maps showing ecosystem services tradeoffs across the landscape, which come with attached uncertainty estimates that show the range of confidence in the modeled results, showing a more realistic picture of ecosystem services than a single output value, which can inspire false confidence in model results for complex coupled human-natural systems.

Component #2 – ARIES Tool Description

"ARIES is a next generation web application designed to make environmental decisions easier and more effective. ARIES helps to map and quantify environmental assets and what factors influence their value, in a geographical area of your choice and according to your needs, and to explicitly map the linkages between ecosystems providing a given ecosystem service and particular groups of human beneficiaries.

Created by a partnership of international experts, NGOs, and academics, ARIES pairs user and expert knowledge with advanced artificial intelligence to construct a model of your case study, making sure that no relevant data or knowledge is overlooked. The result of an ARIES user session is an environmental asset portfolio that describes in depth the spatial distribution of the natural assets in your area, their potential and realized economic values, and the causal relationships that link the values to each other and to actual or potential policies. All the decisions taken during an ARIES session are yours, and the portfolio includes documentation and references to justify each and every operation, dataset, or model used to create it."

- Excerpted from web page description: http://esd.uvm.edu/ and http://www.ariesonline.org

[3] Such as within corporate Life Cycle Assessment models, product development, capital projects, measuring performance against baseline in terms of moving towards environmental goals, cumulative impacts, incremental effects, conducting asset portfolio review for surplus / idle properties, clarifying both stakeholders' interests, identifying corporate license to operate issues, or other applications.

(Note: All of the following material is direct quotes from the lead tool developer, Ferdinando Villa, who has written out responses to all of the Working Group's key questions.)

Understanding the Tool	**Objectives:** • Making environmental decisions easier and more effective by helping users map and quantify environmental assets and what factors influence their value, in a geographical area and according to priorities defined by the user (anywhere in the world). **Intended Users:** • The tool is intended to be generalizable to a variety of ecosystem services in any region in the world yet comprehensive in its modeling approach, and is designed in a way that interfaces can be created around specific user workflows without knowledge of the engine internals. Therefore, the same toolkit can be used in different ways and with different levels of sophistication according to user goals. Customization does *not* require academic expertise. • In the first round of funding, we will produce a comprehensive portal for scientists (with worldwide coverage and a complete set of ecosystem service modules) and a simpler interface for each of the specific case studies (Madagascar, Western Washington state, and Veracruz) that will only show choices and data relevant to the case study. • Beyond these three case studies, additional local case studies have been completed or are in progress for the San Pedro River, Arizona; Orange County, California; Vermont; and the Dominican Republic. • All interfaces will drive sessions in the same ARIES server installation. • Portals can reside on different machines than the one ARIES runs on, making it possible for partners to "own" their own incarnation of an ARIES service and make it look the way they want. • We plan at least three different functionality groups for different portals: (1) the high-end ES assessment and valuation explorer; (2) a PES (Payment for Ecosystem Services) entry point; and (3) an enhanced economic valuation database capable of suggesting value transfer functions to adapt existing value estimates to different contexts. • In addition to case-specific interfaces, we're pioneering a paradigm of "adaptive interface" that uses Artificial Intelligence (AI) to learn the user priorities and refine the workflow accordingly. • Because ARIES produces Bayesian decision models that can be calibrated independently and used as modules of others, we're also investigating the idea of producing decision models that can be used as modules for other decision support systems. **Outputs** • *Continuous feedback* in terms of: - spatial maps of values, - aggregated statistics (in the form of tables and diagrams) - a detailed list of all the sources used in the assessment and valuation - a synopsis of the decisions taken by the rule engine when building valuation models used to produce the results, and of [a rationale as to] why these choices were made - a browsable list—in graphical form—of the probabilistic models built by the system during the course of an ARIES session • *Final report* including: - results - sources - recommendations • *Future Options*: We're currently studying the reporting needs of different user groups to determine whether a form of "adaptive reporting" with some automated scenario generation facilities could be worth pursuing.
Considering Analytical Parameters of Tool	**Ecosystem Services Included:** • Uses the "ecosystem service" notion merely as an aggregation and reporting device • Prefers to divide the field of environmental valuation into quantifiable and spatially mappable benefits (about 50 at the time of this writing). • Each ecosystem "service" is just an aggregation of potential or expressed benefits, each of which has a provision, usage, and value map associated. • The capability to map ecosystem services benefits related to the following broad classes of ecosystem services are complete or in progress: 1) carbon sequestration and storage; 2) flood regulation; 3) sediment regulation; 4) water supply; 5) proximity to open space; 6) scenic viewsheds; 7) recreation; 8) subsistence fisheries; 9) coastal protection.

	Omitted Ecosystem Services: • Our aim is a comprehensive coverage of [ecosystem service] benefits • Also including and extending the "conventional" taxonomy of ecosystem services from the Millennium Assessment categories to more specific, well-defined, and easier to value economic endpoints conceptualized by Boyd et al and increasingly recognized as important to conceptualizing ecosystem services. • As ARIES is based on mutually exclusive and logically consistent definitions of the services (designed to reduce confusion surrounding the traditional concern about double counting) and drive the assessment engine and user interface, the addition of new services and new definitions of the same services does not require modification of the system's algorithms. • We expect the number and identity of the services assessed to evolve in time, tracking developments in ecosystem services science. **Any Services being used as proxies for others?** • No • The ARIES team spent a year working on the redefinition of the ecosystem service concept so that proxy and "supporting services" would appear as what they are: academic definitions with little practical use. • All the benefits investigated in ARIES are characterized by mapping the spatial linkages between their provision and their usage, using probabilistic models built from the available data and the site-specific knowledge solicited by the system and provided by the user. **Plans to build out the tool to include other ecosystem services?** • ARIES has been available in a pre-Beta release since January 2010 and will have full Beta release by late 2010. • We have created logical models for all the known benefits and are aiming to incorporate the full array of service analysis modules in the production system.
Assessing Data Requirements, Quality & Costs of Application	**Data Requirements?** • Each [ecosystem service] benefit (of which there are about 50 at this stage) has its own unique data requirements designed to capture the locally important ecological factors underlying ecosystem service supply and socioeconomic factors underlying ecosystem service demand. • Models in ARIES are built during a session and are data-driven, so data requirements may be different for the same service in different areas or under a different scenario of usage. • In general, global high-resolution layers of basic data—such as precipitation, soil type, land cover, slope etc.—are important for most [ecosystem] services and are available for most of the variables used by the system. These data currently reside on the ARIES system where they can be accessed by any models calling on that particular data source. • Other data (such as social data and environmental performance indices) are available at smaller spatial extent (typically at a country-level scale). For the seven case study regions, many localized data sources are available to meet ARIES modeling needs. • ARIES can mediate resolutions and extents automatically, so user-provided data can be integrated easily. **Data Scarcity Contexts & ARIES?** • The modeling framework used in ARIES (probabilistic Bayesian network models) makes it possible to operate in conditions of data scarcity: - missing data do not break the model - they merely enter the models as unknowns - the effect: enlarging the confidence interval for the predictions. • New evidence in the form of data can be submitted at a later time to improve the estimation. • Therefore, lack of data is less of a problem than with deterministic models (all the other existing toolkits). **Pre-Existing Databases – Sources:** • Depends on what ecosystem services are analyzed, in what area and with what user priorities. • ARIES provides and maintains base layers for all the variables that are available to us and our partners. When possible, layers will be directly taken from their authoritative sources (e.g. USGS for US land cover data etc) and cached on the ARIES servers, to ensure reliable accessibility and up to date content. Secondary data layers will be computed in the background on the ARIES servers, using idle time of the system. • In many cases, data are available globally at a relatively coarse resolution (e.g., 1 degree^2 or 1

km^2) and the same data are available for selected areas at much higher resolutions (e.g., 30 m^2 or 90 m^2).
- ARIES will transparently choose the best available data for an area.
- We are aiming to provide at least basic data coverage for the whole globe.
- We aim to expand high-quality coverage with time and new partnerships.

Valuation Data:
- ARIES will rely on our previous Ecosystem Service Database project for valuation data to use in secondary valuation when monetary estimates are requested.
- New data collection activities are currently underway to ensure its completeness.

Issues with Database Sources, if any?
- Issues are specific to each data source.
- Some data that ARIES will use are not made available to the public by their sources, but the ARIES consortium has developed agreements to use the data sources to conduct analyses while respecting the privacy needs of the data provider.
- When public, the source data will be viewable through a “sources” window in the ARIES interface.

Embedded Assumptions within Databases?
- Cannot be answered in general.
- All data types and each individual data layer contain assumptions, which vary widely but will be documented and available for the users’ viewing.
- Users will have a full description of the data used and their sources, and will be able to verify the data and in most cases download them through their authoritative sources.

User provided Data:
- ARIES does not require the user to input data
- However, users may opt to submit information they have to fill in data gaps or provide more up to date or higher resolution information.
- ARIES is capable of automatically mixing and harmonizing information of various resolutions, extent and representation (e.g. vector and raster files) as well as non-spatial data from tables and spreadsheets, so the time and difficulty of submitting data is reduced compared to other systems.

Data Quality
- ARIES will use the best information available from its authoritative sources and is not tied to specific data, given ARIES’ capability of using machine reasoning to mediate and integrate heterogeneous data sources without a need for preliminary “data preparation”.
- Many key data layers are of very good quality.
- Also, for ARIES all numbers and rankings always come with uncertainty measurements attached, and any error from the data sources is carried along and compounded along the computation steps
- Overall -- the user is always made aware of what data determine accuracy loss and of how much each estimate can be trusted.

Sensitivity Analysis included?
- At specific entry points into ARIES, the user will be able to construct and explore scenarios (e.g. of climate change) by selecting factors and stressors that apply to the situation under study. This phase is guided by the knowledge base and the rule system (questions will be asked to ensure that users want to explore each factor). When those factors are requested, the model will be updated to include them and all the accessory variables that link them to the current model; the system will then present an interface with sliders or other input widgets to allow exploring changes in each variable. Each change produces a new set of results that users can save and compare with the baseline.

Capability for Technologies to Feed Data into the Tool:
- Yes
- See above (user input) and below (sensor data integration).

Designed to Interface with GIS, Carbon Measurement Technologies, Mesh Networks or other Technologies?
- ARIES leverages some of the most innovative technology of semantic databases and

	semantically mediated representation. • As a result, all the data operations within ARIES, including GIS processing, are automatic and driven by machine reasoning. • The ARIES infrastructure provides all GIS algorithms it needs to process spatial data. • There is no planned use of sensor data in the current incarnation, but some partners are using ARIES technologies to semantically integrate sensor networks and this technology will be ready for adoption in ARIES when the opportunity arises. **Exploring Potential Technology Interface Points or Partnerships with Large Database Firms?** • All necessary database technologies are easily available, stable and well-tested. • Whatever amount of data we will be able to build into the system, it's unlikely that we'll ever need petabyte storage. • If the number of users becomes very large, there will be a need for larger computational capacity on the servers, which would require such partnerships, but we can't know at this stage. • The kind of partnership we're trying to create at this moment (through the ARIES consortium) is mostly with data providers, to ensure the currency and accuracy of the results in the long term. **Anticipated Resource (human or otherwise) Requirements of the Tool?** • ARIES is designed to be accessible to users without requiring extensive time or training. • Collaborators with ARIES developers (through the ARIES consortium) would be likely to produce more precise results. • In this case local users would take the time to provide local data sources and incorporate local knowledge into the system alongside ARIES developers. • Yet to simply use the system does not require significant time and resource commitment.
Accessing the Tool	**Tool Availability?** • Very easily and broadly available online – only requirement for access will be an internet browser (such as Firefox or Internet Explorer). • Internet "entry points" will be provided by the ARIES consortium or its partners in the form of a web application accessible through a modern browser • Different entry points will incarnate user workflows aimed to provide different kinds of assessment or service. **Requirement to work with the Tool Developers directly as the 'Delivery Mechanism'?** • No. **Future Availability / 'Delivery' Plans for the tool? On what timeline?** • *For non-profit partners (including governmental and non-governmental institutions) and to educational institutions:* Free access • *For-profit users, contracting users, and consultants:* The ARIES consortium will explore subscription mechanisms and conditions of use • Each toolkit and specific area of use may be handled differently.
Assigning Values within the Tool Application	**Does the tool / methodology assign value to ecosystem services?** • Yes, that is one of the main rationales for the toolkit – assisting decision-making requires attribution of some form of value. **Approach of the Tool to Valuing Ecosystem Services?** • Ecosystem services (particularly when seen as collections of potential or actual benefits, as ARIES does) only exist if the ecosystem provider and the social consumer coexist in the same time and space at appropriate scales. The value is the quantification of how important and unique the benefit is to satisfy the consumer's need for it. • Monetary value is only relevant in some situations. • ARIES will leave the user in charge of defining the kind of value estimate desired. • Abstract value units will always be generated, using a multiple criteria analysis that computes the concordance of the ARIES model outputs with stated user priorities and assigns a relative value estimate (0 to 1) to different areas of space. At the user's request, ARIES will search its extensive database of published primary valuation studies for candidate studies that approximate the social, economic and environmental contexts of the area under consideration, and propose the values to the user as candidates. If the user selects one or more studies as suitable candidates for benefits transfer (secondary valuation), ARIES will produce a transfer

	function based on a database of statistical indicators stored for the areas and a pre-trained neural network that maps those indicators to ranges of monetary values. The results will be used to recalibrate the abstract value map and produce maps of the range of monetary values for the area. A report will detail the transfer functions, the sources used for transfer of values, and the rationale behind their choices in clear English. **How does the tool avoid double-counting?** • The notion of double counting is the result of a short-sighted definition of what ecosystem services are. If ecosystem services are seen as collection of specific, quantifiable, spatially mappable benefits, and each benefit identifies univocally its ecosystem provider and social consumer, then no double counting is possible because all benefits are uniquely characterized and quantified. Fish will be quantified according to the provision of and the need for fish, water according to the provision of and need for water. The link between them is a functional one, as the spatial connection between ecosystem processes and human consumers has common variables (clean water is needed by fish); however, this does not affect the **quantification** of the benefits, but rather the dynamics of provision and its reaction to stressors. It would affect the value only if the value was to be attributed directly to the provision **process**, which is wrong, even if it is often implied in the literature. Value only reflects the essentiality of a good relative to some human needs. • ARIES always characterizes the full set of spatial linkages between ecosystems providing a service and their human beneficiaries for all benefits (based on data, stored knowledge, and user input) and provides a probabilistic model that can adjust its outputs when particular scenarios of change are applied; benefits and their values are always calculated as the last step. • Double counting is only a problem if commonplace but weak definitions are adopted. • ARIES is a knowledge-driven system that contains strong definitions for all benefits resulting from all services.
Exploring Stakeholder Engagement	**Guidance on Tool Use within Stakeholder Engagement and Facilitated decision-making processes?** • ARIES is being developed in close collaboration with stakeholder and decision-maker focus groups. • ARIES will produce Bayesian network models and influence diagrams. • This is the same kind of technology that is used in many contexts (corporate and otherwise) as a primary decision-making aid. • ARIES uses a logical model of choices by policymakers to drive its workflow and the interface and to adapt both to specific decision contexts. This will drive the adaptive learning of the user priorities, and will ensure that relevant and understandable questions are asked, and irrelevant or inappropriate ones are not. • It is expected that the decision models generated by ARIES will be embeddable in larger-scale decision models used by specific decision makers. • **Does the Tool have a Process for including Public Input into Assigning Ecosystem Service Values?** • No such thing has been discussed so far with the current case studies, as none of the partners have raised the issue. • As the attribution of final values is based on a multiple criteria model, linking ARIES to a portal where input is gathered and processed would be straightforward. • The ARIES consortium will be in charge of defining scenarios of application. • Prospective interested users can steer development priorities for ARIES by becoming part of the consortium. **How does the tool Address or even Balance Multiple Stakeholder Values of Ecosystem Services?** • ARIES incorporates a spatial Multiple Criteria Assessment method that ranks results according to stakeholder priorities. • Priorities are always explicit and can be modified by users, defining all the stakeholder scenarios necessary to a full assessment of the case study. **Is there a default weighting across services? If so, how?** • The initial weights in a session are attributed based on expert system rules (e.g. if the user tells us that droughts are a common occurrence in the area, water provision will be weighted higher). • All the weights are explicit and under control of the user in a pair-wise comparison matrix.

	• Users will have full control of the weighting coefficients.
Applying within Existing Corporate Decision-Making Processes	**Tool Designed to Fit within Corporate EMS' and/or EIAs?** • Not at this point. **Tool 'Match Up' with Existing Corporate Data Gathering and Decision-Making Processes?** • These pre-existing local data could be used as inputs to improve the accuracy of ARIES value estimates, where they are relevant to provisioning of ecosystem services of interest. **Tool Useful for Evaluating Corporate Land Holdings for their Value in terms of Ecosystem Services not currently accounted for in traditional real estate accounting?** • Yes, for all ecosystem services developed so far. • ARIES is designed to eventually account for the economic value of land (via ecosystem services) under corporate or other ownership. **What is the business case for corporate use of this tool?** • Corporations can identify value in managing their lands, consuming resources or releasing pollutants in a manner that is consistent with maintaining public benefits provided by ecosystem services. • Corporations can also minimize risk associated with damage to any of the above public benefits provided by ecosystem services. **What are the incentives that a company would have to evaluate ecosystem services and utilize this tool to do so?** • Reduce liability in the event of damage to public benefits provided by ecosystem services • Improve company's "green image"/branding • Help companies better identify cases where it may be beneficial for them to protect ecosystem services outside of corporate land holdings (i.e., various beverage companies have paid landowners to protect the quality of their water sources that these companies rely on for their products) • Provide possible financial compensation for sound management of lands providing valuable ecosystem services, either directly (i.e., allowing companies to receive payments for ecosystem services) or indirectly (i.e., receiving tax benefits or other favorable treatment).
Identifying Assumptions within Tools	**Assumptions Underlying Tool Approach and Methodology?** • ARIES is based on a full redress of the notions of ecosystem services, rooted in the best existing science, but aimed to make it computable and quantifiable, as well as amenable to machine reasoning. • The logical models in ARIES contain the formal statement of the notion of ES used in ARIES, and the final system will contain a graphical browser that will clarify all notions behind all computed knowledge. • The assumptions behind all this are too numerous to mention, but a good text in Ecological Economics should provide the background along with the definition of ecosystem services explained above. **Assumptions Underlying** *Economic Values of Ecosystem Services in the Tool?* • As ARIES does not perform primary valuations (obviously no system could), the assumptions underlying the economic valuation in ARIES are the same of the source studies from which candidate values are chosen. • ARIES adds the transfer function that is generated on the basis of a large portfolio of socio/economic/environmental variables. The function is empirical, mapped to the variables using a neural network that recognizes patterns of association without trying to explain them.
Exploring Broad-Based Application	**What kind of subject matter expertise would a tool user need to effectively apply the tool?** • We're hoping that the toolkit will be usable by anyone who understands the problem and has basic familiarity with scientific and geographic visualization. • We're working with a usability engineer to ensure the most transparent interface design and a smooth user workflow. **Would the tool benefit from broader participation, uptake, engagement with other tool developers?** • Yes, participation with other experts in ecosystem services science and management can help in improving our conceptual models of ecosystem service provision, building consensus on how ecosystem services are provided. • If other groups are willing/able to provide local data and ecological knowledge, the ARIES system could be expanded to more quickly be of use at a wider variety of sites around the world.

Understanding the Value Proposition	• See above

ECOAIM

Component #1 – Overview of EcoAim's Application to the San Pedro Watershed

1.1 Data needed for tool application.
For biodiversity services: Property ownership (public or private), potential habitat (for amphibians, birds, mammals, and reptiles), species richness, vegetation types, and impervious surfaces. Other services were not evaluated for this workshop.

1.2 Data acquisition methodology or process of identifying and sourcing data for your tool, specifically citing public agency data sets used and/or documenting the methodology used in gathering primary data.
Data was downloaded from the Southern Arizona Data Services Program, Arizona Game and Fish Department, and USGS. All data were in ESRI shapefile format. Species maps were first screened for presence in study area.

1.3 Process for uploading data and preparing for tool application including data preparation.
Data were downloaded from source websites and uploaded into ArcGIS software.

1.4 Time implications to source and/or prepare data for inputting into the tool, particularly highlighting staff time implications at what level of staff experience.
Staff spent approximately 25 hours in reviewing, identifying, downloading, converting, and uploading data into EcoAIM. Administrative staff spent 8 hours downloading, and scientist level staff spent the remainder of the time.

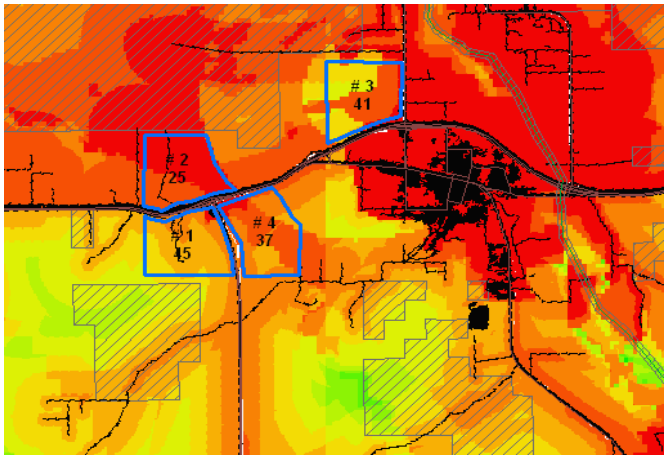
1.5 Challenges encountered in sourcing and/or inputting data, noting whether these challenges were unique to this site or should be planned for in the future.
Challenges included converting older versions of shapefiles into usable formats for ArcGIS and understanding the information displayed on species coverage maps. These challenges are dependent on the study site and the available information for the site.

1.6 Answers to corporate-relevant 'questions' posed to each tool, including:

1.6.1 *New Project Siting / New Project Development*

Where would be the ideal site for a new residential project in order to have the least impact ecosystem services? Why?

Various locations within the evaluation corridor were assessed. Locations were selected based on general proximity to existing roads and development with the assumption that these areas would afford the lowest development costs in terms of existing infrastructure. The ideal site for a residential area is at Site 2 (see map below), north of Highway 10. Based on the ecological habitat score, Site 2 has the lowest score, and therefore, the least impact on ecosystem services.



1.6.2 *Existing Infrastructural/Project Expansion*
Where (and if possible how) would you expand growth of residential units on the US side of the border? Why?

Additional residential units would be expanded into the area north of Highway 10, at Site 3. Site 3 has the second highest ecological habitat but is closest in proximity to the existing residential area, across Highway 10, where developers could have easier access to build connections to existing infrastructure.

1.6.3 *Land Management*
What are the areas where focused ecosystem service-related investments would offer potential benefits?
Focus for restoration areas was on potential wildlife corridors that could support endangered, threatened, or special concern species. Factors such as connections between public land and riparian areas, important vegetation habitats, and the potential to increase the desired habitat area were considered.

What are the recommended investments?
Investments in restoration should focus on improving habitat for special status species while securing wildlife corridors between currently fragmented public lands.

What ROI (quantitative or qualitative) would be realized on what time frame (e.g., payments from environmental market transactions, real estate sales, etc.)?
ROI is highly dependent on the existence of markets for ecosystem services and cost of property acquisition and restoration. Due to lack of definition of these variables in the current scenario postulated, the ROI was not evaluated for this demonstration.

What might be ways to avoid regulatory exposure in light of:
Endangered species habitat sites?
The tool application considers special status species as a major determinant of biodiversity and thus selection of development sites optimizes for minimum possible impact on special status species.
Indigenous peoples / Native American claims sites?
The tool was not developed to assess these services for this demonstration.
Other?

1.7 Reflections on corporate applications of your tool, such as:

1.7.1 Appropriate conditions and contexts in which to apply the tool.
EcoAIM is perhaps best suited as a scalable tool that at a coarse level can be used for screening (as in the present case) using publicly available data and at progressively finer (and more data intensive) levels be used to evaluate specific outcomes of land management or resource management decisions.

1.7.2 Relationship between environmental impact and ecosystem services, particularly in terms of how this tool might 'interface' with pre-existing corporate tools and processes for assessing impact.
Identification of the presence of potentially sensitive species and habitats that could trigger regulatory review. Geographical context parallels standard impact assessment approaches and could directly input to impact assessment frameworks.

1.7.3 Building the business case of how this tool may improve corporate environmental systems and processes for decision-making.
In the context of environmental and social responsibility, there is movement toward accounting for ecosystem services. Markets for ecosystem services are emerging, creating the potential for revenue generation, enhancing good will, and cost avoidance for companies that have reliable accounting mechanisms in place. There is an interest among corporations to integrate ecosystem services accounting with classic impact assessment as a unifying concept. Emerging regulatory drivers will favor companies that employ programs to inventory ecosystem services.

Component #2 – EcoAIM Tool Description

Understanding the Tool	• **What is the objective of the tool / methodology?** *1) To provide managers with a tool to inventory ecological services and help in making decisions regarding development, transactions, and ecological restoration; 2) to provide managers with a tool to develop specific estimates of ecosystem services in a geographically relevant context, and 3) to provide the means for evaluating tradeoffs of ecosystem services resulting from different land or resource management decisions.* • **Who are the intended users?** *Land and resource managers/owners.* • **What is the intended use of the tool?** *Inventory ecological services and scenario analysis to support land management and resource management decisions.* • **What do outputs look like? (Excel spreadsheet? Narrative interpretation? Explicit mapping?)** *Maps, tables, and graphs.*
Considering Analytical Parameters of Tool	• **Which ecosystem services does the tool currently include?** *Habitat supporting potential for the San Pedro site. Other ecosystem services available but not used are flood control, pollution sequestration, carbon sequestration, and recreation/aesthetics.* • **Which ecosystem services does it omit?** *No ecosystem services are selectively omitted. EcoAIM can be customized to incorporate any ecosystem service.* • **Are there any services being used as proxies for others? If so, which?** *Habitat supporting potential is a proxy for biodiversity; volume calculations are a proxy for flood storage capacity, and biomass is a proxy for carbon sequestration.* • **Do you have plans to build out the tool to include other ecosystem services? If so, on what timeline?** *Yes, we plan to build out to other ecosystem services, dependent on clients' preferences.*
Assessing Data Requirements, Quality & Costs of Application	• **What are the data requirements?** **A) Preexisting databases: If the tool runs on databases:** - **What are the database sources?** *Public GIS data supplemented with specific user information as needed.* - **What issues exist with these database sources, if any? (e.g., quality, reliability, verification, replicability, availability)** *Varies by database.* - **What assumptions are embedded within these databases?** *Varies by database.* **B) User provides data: If the tool requires input data, what are the time and costs for acquisition and verification of data?** *Varies depending on availability* • **What is the quality of the data (reliability, verifiability, credibility):** - **On the input side?** *Varies depending on data source.* - **On the output side?** *Dependent on quality of input data.* • **Is sensitivity analysis included? Qualitatively or quantitatively?** *Sensitivity is established through preference weighting by the user and sensitivity analyses are run by the user with varying preference weightings and other assumptions.* • **Does the tool have capability for technologies to feed data into the tool?** *NA.* • **Is the tool designed to interface with GIS, carbon measurement technologies, mesh networks, or other technologies?** *Yes, this is a GIS-based tool.* • **Are you exploring potential technology interface points or partnerships with large database firms (e.g., IBM or Microsoft)?** *Yes, depending on user preference.* • **What are the anticipated resource (human or otherwise) requirements of the tool? (Provide $$ and/or labor hour examples based on pilot projects)** *Can vary from several person hours to several people days/weeks or more depending on user needs.*
Accessing the Tool	• **What is the availability of the tool?** *Not publically available.* • **Specifically:**

	- **Will the tool be broadly available through online materials?** *Not expected, except perhaps via potential work for the U.S. Government.* - **Will companies be required to work with the tool developers directly as the 'delivery mechanism'?** Yes. - **If neither, what are the plans?** • **What are future availability / 'delivery' plans for the tool? On what timeline?** *Currently available to our clients. Immediately available, but customization will depend on specific needs.*
Assigning Values within the Tool Application	• **Does the tool / methodology assign value to ecosystem services?** *Yes. This can be relative based on elicited user preferences or regional ranking. Value is not monetized, thus avoiding many uncertainties/controversies as well as potential fiscal obligations associated with monetization.* - **If so, what type of value is assigned and how is it assigned?** *Ecosystem Service Level is assigned through models specific to the ecosystem service.* o **Biophysical (e.g., pounds of fish, cubic feet of water)** o **Economic: Monetary or non-monetary (e.g., dollar values or other nonmonetary expressions of human economic preferences)** *Non-monetary.* - **If the tool does not assign value in some economic unit, then does the tool assign weight? If so, how?** *The user can assign weights and rankings.* • **How does the tool avoid double-counting (e.g., clean water to produce fish, if also counting fish)?** *NA. User can run sensitivity analyses on effect of double counting on outputs by varying weights, rankings, and other assumptions.*
Exploring Stakeholder Engagement	• **Does the tool include guidance on use within:** *EcoAIM was not intended to be a tool for stakeholder engagement.* - **Internal stakeholder engagement processes?** - **External stakeholder engagement processes?** - **Other facilitated decision-making processes?** • **Specifically, does the tool have a process for including public input into assigning ecosystem service values? If so, is this a process for:** - **General public input?** *Depends on user needs.* - **Local / site-specific public input?** *Depends on user needs.* • **In cases where there are a range of stakeholder values placed on the same ecosystem service flow, how does the tool balance these values?** *User can balance values based on their preferences or interpretation of all stakeholder preferences as a sensitivity analysis.* • **Does the tool rank these different stakeholder viewpoints on ecosystem service values? If so, how?** *No.* • **Is there a default weighting across services? If so, how?** *Yes, but user can change values.*
Applying within Existing Corporate Decision-Making Processes	• **What are the conditions of applicability of this tool in corporate decision-making processes?** *Tool applications are intended for corporations to compare the ecosystem services at their site with the surrounding landscape and determine the intrinsic ecological value. EcoAIM assists in the decisions for development and operations, by evaluating impacts on the provision of ecosystem services.* • **Is the tool being designed to fit within corporate Environmental Management Systems and/or Environmental Impact Assessments? If so, how?** *This would be a customizable option as needs of corporate users can vary widely.* • **Do you know whether this tool matches up with existing corporate data gathering and decision-making processes, whether they be voluntary (e.g., ISO 140001) or regulatory (e.g. Total Maximum Daily Load under the U.S. Clean Water Act)? If so, which?** *Not specifically evaluated to date.* • **Would the tool be useful for evaluating corporate land holdings for their value in terms of ecosystem services not accounted for in real estate accounting?** *Yes.*
Identifying	• **What are the fundamental assumptions underlying your approach and methodology?**

Assumptions within Tools	*Assign ecosystem services with geographic/spatial information and value ecosystem services based on intrinsic current value.* • **Can you provide examples of any assumptions? (include article references, if applicable)** *Can be provided if requested, these vary depending on application.* • **How does the tool—and/or these assumptions—interface with profitability goals? Can you provide examples?** *NA.* • **To what degree have the tool developers undertaken trends analyses of likely policy scenarios related to ecosystem services? If such scenarios have been developed, how have these scenarios been integrated?** *Policy scenarios are highly geographically dependent and we have designed the tool to incorporate trends on a regional or site-specific basis.*
Exploring Broad-Based Application	• **What kind of subject matter expertise would a user need?** *At the screening level, a client would need familiarity with basic interactive decision-making tools, ecological processes for ecosystem services in a regulatory context, and information about the site.* • **What have been the challenges found in tool uptake (e.g., design elements practicality of application, comprehensiveness, flexibility of the tool)?** *NA* • **Would the tool benefit from broader participation, uptake, engagement with other tool developers? If so, how? And where are areas you would benefit from collaboration with other tool developers?** *Tool may benefit from collaboration with other tool developers; however, this would require establishing commercial agreements. The tool would benefit most from increased collaboration with end users.* • **Do you see opportunities for standardization or consistency across tools?** *Depends on the objectives of each tool. Standardization is important for tools that derive monetary value for ecological services.*
Understanding the Value Proposition	• **What value proposition does this product provide?** *The business case for decisions on land portfolios.* • **What is the business case for companies to:** - **Apply this tool?** *Derive value from land management decisions.* - **Apply this tool versus other tools that are emerging?** *Not applicable to EcoAIM.* - **Encourage/support public policy makers or others to apply the tool to private sector activities?** *Not applicable to EcoAIM.*

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EcoMetrix

1.1 Data needed for tool application.

EcoMetrix relies primarily on primary data collected from the site where it is being applied. Data collection focuses on specific landscape attributes associated with vegetation, soil, water, etc. Data from pre-existing databases are utilized where needed and available; database and GIS spatial data sources used vary, depending upon the location of a given site.

1.2 Data acquisition methodology or process of identifying and sourcing data for your tool, specifically citing public agency data sets used and/or documenting the methodology used in gathering primary data.

Field data acquisition: Attribute data are collected separately for areas of relative homogeneity within the project site. These areas of homogeneity are treated as distinct "map units" and are scored based on the specific attribute data collected within the map unit. The data collection process is guided by a data sheet that structures all necessary attribute information into a hierarchical system for ease of collection. We currently use a mix of paper data sheets and hand-held electronic data loggers.

External data acquisition: External data acquisition depends on the specific function needs. When a need for an external dataset is identified during the development of a function, a data search is undertaken to identify potential datasets that match that functions exact requirements. If an exact match cannot be found in the available public data, then the function's requirements are reviewed to determine if one of the available datasets can be used. In the event an external data source cannot be found, the function development must determine a surrogate for that attribute, or identify a new attribute.

1.3 Process for uploading data and preparing for tool application including data preparation.

Field data uploading: The attribute information collected on the data sheets is entered into the system (currently a linked GIS/Excel spreadsheet). When paper data sheets have been used, the data responses are manually entered into the database. When data loggers are used, the data are automatically entered into the database.

External data uploading: If the external dataset is a static database or static spatial dataset, it is downloaded and incorporated into the office data collection methodology. In the case of web-mapping services, the service is added to our map document and the data analysis is incorporated into our office data collection methodology.

External data is incorporated into our office methodology through the development of GIS analysis and data queries needed to retrieve the data from the external data set and enter them into the EcoMetrix application, where new logical queries, lookup equations, and lookup tables are generated.

1.4 Time implications to source and/or prepare data for inputting into the tool, particularly highlighting staff time implications at what level of staff experience.

Field data sourcing and preparation: Data sourcing (collection) can be performed by mid-level staff, although we highly recommend training and QA/QC be performed by an experienced user. Ideally, data entry should be performed by the field crew and QA/QC'd by the field crew supervisor. The following estimates include field data collection, data entry, and data verification.

Site Complexity	Field Data Collection Approx. Minutes/Acre	Field Data Verification Approx. Minutes/Acre
Simple (Relatively Homogeneous)	15-30	<5
Moderate (Mix of Habitat Types)	30-45	<10
High (Diverse with Streams, Mosaics)	45-60	<15

External data sourcing and preparation: Incorporating external data sources needs to be completed by staff with a background in GIS analysis and database design/development. Depending on the complexity of the analysis or queries needed to incorporate external data, this may take several days. However, this is a one-time time constraint. As the tool is applied to different geographies, some adaptation to the lookup tables used for scoring may be needed.

1.5 Challenges encountered in sourcing and/or inputting data, noting whether these challenges were unique to this site or should be planned for in the future.

Field data challenges: There were no challenges encountered in this pilot application. However, it is worth noting that since the system relies on primary data, site access is always a consideration.

External data challenges: No challenges were encountered for this pilot application. However, when using external data sources, there is always the potential for data gaps in the static downloaded data and web-mapping services, for network outages, or even for the service being deleted from the relied upon web-mapping services. To protect against this, secondary attributes that can be used as surrogates are developed, or at least researched for all attributes generated from external data sources.

1.6 Answers to corporate-relevant 'questions' posed to each tool, including:

1.6.1 *New Project Siting / New Project Development*[4]

Where would be the ideal site for a new residential project in order to have the least impact to ecosystem services?[5] Why?

Project Siting: For the San Pedro pilot project, we assumed that the initial step of identifying a selection of sites had already occurred at a landscape level. Working with BSR staff, we identified a cross-section of five specific sites to evaluate as part of the site selection alternative analysis. Although the hypothetical suggests a 500-acre site, we assessed five sites of approximately 20 acres each. We assumed that, for each site, the 20 acres surveyed provided a representative analysis of a 500-acre site.

On each of the 20-acre sites, we placed a *pro rata* number of residential lots at the stated hypothetical density (approximately 40 lots per site), using a standard lot size (based on typical lot sizes gleaned from aerial photos of existing developments in the region). For each site, the units were placed in the lowest value portions of the site first. Any leftover areas were assumed to remain as undeveloped open space.

The results of the alternative analysis were not surprising. The best location identified for development was a site referred to as the St. David site, which had ongoing impacts associated with cattle grazing. The site is also surrounded by properties being impacted by urban and agricultural activities. The second most suitable site, known as the Charleston Bridge site, had existing impacts but was connected to some surrounding functional areas, which increased its ecological scoring. While the outcome was not particularly profound in this instance, the pilot does illustrate how a site-level tool can be used to refine the information available for an alternative site analysis process.

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[4] Tools for analyzing ecosystem services will be compared through an exercise in siting new or expanding existing projects. Any scenarios considered in this exercise are purely hypothetical, and are not intended to contribute to a proposal subject to a current or future land use decision by an agency of the federal government.

[5] The rationale for this hypothetical case is that several large-scale residential development projects were proposed for communities in the San Pedro watershed, including Benson and San Manuel, prior to the collapse of the real estate bubble. These proposed projects would accommodate retirees or long-distance commuters to places such as Tucson or Sierra Vista. Although induced commercial development would likely follow large-scale residential development, the San Pedro valley is likely too sparsely populated to currently support large-scale commercial ventures. In light of this context, the tool developers have been asked to apply tools to the following hypothetical case, in which there would be disturbances to the Chihuahuan desert scrub as the primary existing vegetation type. Specifically, the specifications for consideration are of a proposed 500 acre and 1,000-unit housing development near Benson, Arizona, with specific locations near the intersection of Interstate 10 and Arizona Highway 80 or 90. The assumed water use would be 312 gpcd (gallons per capita day) for 2.56 people per home in unincorporated areas (ADWR 2005, cited in 2007 Section 321 Report), which represents 894.5 acre feet per year in new demand from 1000 new housing units, plus induced commercial demand.

Project Design: Since EcoMetrix measures at a site level, we were also able to use it to provide alternative *design* analysis. To illustrate this concept, a "typical" site design was used that reflects a fairly generic lot layout and design composition. Using the site scoring information, we identified site attributes that could be modified to reduce the impact to the selected ecosystem services (water provisioning, carbon sequestration (climate regulation service), biodiversity, and cultural services) from the development. Some obvious opportunities were to change the roofing color, replace the backyard pool and surrounding concrete with trees and vegetation, and use pervious materials for the driveways. The total change in ecosystem services impact associated with each of these design alternatives was identified so that a cost/benefit determination could be made by site developers.

1.6.2 *Existing Infrastructural / Project Expansion*

Where (and if possible how) would you expand growth of residential units on the US side of the border? Why?

Ultimately, the answer to this question should hinge largely on the cumulative effects issues within the region. Cumulative effects must be understood at two scales. First, it is necessary to understand the regional context of loss of habitats and functions over time. However, cities and communities are not typically built in a single action, but rather in a series of incremental steps over time. Accordingly, it is also necessary to know the incremental effects of these proposed actions. These incremental steps occur at a site level, and EcoMetrix is well suited to informing this aspect of the cumulative effects process.

1.6.3 *Land Management*

What are the areas where focused ecosystem service-related investments would offer potential benefits?

There are opportunities to create benefits from ecosystem services-related investments both within the development site itself and on a potential restoration site. In addition, assuming the developer anticipates implementing future projects in the area, there are some corporate operational benefits created by investing in ecosystem services. The potential ecosystem service-related opportunities for benefits include the following.

Incorporating Ecosystem Services into Site Development

Ecosystem services concepts can be incorporated into site development in a number of ways to reduce ecosystem services impacts and improve the economic efficiency of the project. Ultimately, these strategies are generally intended to result in a cost savings for the project, as opposed to an actual revenue stream.

Addressing supply chain dependence: When an organization relies in some fashion on an ecosystem service or product (e.g., clean water, a particular plant species, or a watershed process such as sustained run-off levels), replacing that service or product can be expensive or even impossible. In this instance, the developer has limited incentive to think about long-term supply chain issues. However, ensuring a long-term supply of potable water should be an important consideration, not just for this development, but also for any future developments being considered by the developer within the basin.

Reducing site management costs: When developments include significant impervious surfaces, it drives the need for expensive stormwater management solutions. While impervious surfaces are needed for some facilities, the amount of impervious surfaces can be reduced in many cases. For such sites, treatment costs can be significantly reduced. For the developer in this pilot study, using open space areas to aid in dealing with site stormwater could be a cost benefit added to the overall mix of considerations for the potential use of these open space areas.

Beyond stormwater (for which a permit is usually required), a typical developer has few concerns over long-term site maintenance. However, some investments would reduce long-term maintenance costs for the residents, including: 1) restoration of floodplain functions, 2) actions that ensure adequate soil

retention (this would likely be required by local ordinances, anyway), and development approaches that reduce energy consumption. Some recommended design options include:

- Using pervious surfaces where possible (e.g., pervious pavers);
- Using curb extensions for stormwater;
- Avoiding bare ground through use of native plantings or rock cover;
- Providing adequate site shading; and
- Making suitable color choices to affect site albedo values.

Payment for Ecosystem Service (PES): A PES exchange is still a relatively uncommon eco-asset source, although there are a few good examples that can be cited. Essentially, this approach identifies where an ecosystem service is being produced by one part of the landscape but is being used in another. Economic efficiencies can sometimes be created by having the recipient of the service pay the producer of the ecosystem service to forego disrupting the production of that service. There are obviously a number of criteria that need to be met before a PES transaction becomes viable. However, where a PES transaction is appropriate, the benefits from the transaction are felt by both parties to the transaction. Accordingly, this opportunity can flow either direction—a facility manager could either be a buyer or a seller of a service. Thus, a site may provide benefits that are needed elsewhere, or others may have the ability to produce benefits needed by the development more cost effectively than if the services are provided on the development site itself. A potential opportunity in the pilot context would be paying area farmers to reduce water consumption (through increased system efficiency, for example) to obtain necessary water to support the development. However, because local jurisdictions have historically subsidized water provisioning by not charging actual costs of providing the water, the opportunity for savings may be minimal.

In addition, there can be a significant educational component necessary for implementing a PES approach and since there are few PES template projects to build from, the costs associated with developing PES transactional documents may be relatively high. For these reasons, we would only recommend this investment where there is a clear and obvious benefit.

Ecosystem Services Investments – Offsite Restoration

Through use of EcoMetrix, we identified the Charleston Bridge site as having the greatest potential to provide meaningful uplift from restoration opportunities. The site contains a mixture of high quality habitat with anthropogenic disturbances, and is located in an area that has good connectivity with surrounding natural habitat. There are a number of uplift opportunities, related to the ecosystem services studied in this pilot, which can provide ecological and economic benefits.

Future Mitigation Needs: Based on the site density provided within the hypothetical, there may be enough available open space to off-set impacts associated with the project. However, an obvious consideration for any large developer is the potential need for mitigation associated with a current project or program. There are many examples of organizations selling off property with good mitigation potential and then having to purchase other property for mitigation at a much higher cost. Our experience with eco-asset management suggests that when this approach is most important, it can be the hardest to justify. As growth in an area increases, there will be more opportunities and incentives for the developer to “productively” use as much of the site as possible. However, where there is growth in a region, there is often a disproportionate increase in the cost of suitable restoration property (since prime restoration sites can have much in common with prime large-scale development sites). Accordingly, any future mitigation sites in that region may need to be purchased at a premium. Given this scenario, if the developer in this hypothetical is planning any future developments, then they should consider the benefit of maintaining ownership of any high-uplift opportunity portions of the site.

However, we would ultimately have a hard time recommending this investment unless there was an expectation of considerable future growth, which is not currently apparent.

Ecosystem Markets: Even if there is no internal need for mitigation, it is not uncommon for ecosystem market credits to provide a good alternative revenue source from certain properties. This is particularly

true where there will be high social or regulatory costs associated with consumptive development of the property. For instance, where the property is part of or proximate to a culturally or ecologically valued area, it will be very expensive to get the property even to the point of revenue return. Whether an ecosystem market provides an alternative outlet depends on a number of factors, including:

- Existence of viable market drivers,
- Probable service area limitations on credit sales,
- Market demand within the anticipated service area,
- Uplift potential for resources with market drivers, and
- Anticipated credit release schedules.

In truth, ecosystem markets provide a promise of future investment opportunity more often than they provide a realistic source of current revenue potential. However, some of the basic market drivers to consider in making this decision are Natural Resource Damage Assessments, CWA §404 (potential wetland impacts), CWA §402 (primarily TMDL-driven water quality trades), ESA-listed species, relevant state regulations and local land use obligations (generally tied to a designated important resource type such as floodplains, aquifer recharge zones, or declining habitat types). In addition, CEQ's proposed NEPA guidance for mitigation and monitoring would add specific implementation obligations to mitigation identified within a NEPA document, including mitigation to reach a Mitigated EA status. The increased rigor suggested by this guidance could potentially make NEPA a potential market driver as well.

In our evaluation of the project area, we identified the following potential market drivers:

- Fort Huachuca is a Department of Defense facility adjacent to Sierra Vista that is listed as active on the Superfund watch list. In our quick review, we did not see an indication of any current NRDA claims discussions. Accordingly, unless DOD is looking for proactive settlement, this is likely a long-term opportunity.
- There are 29 listed species in Cochise County, and several of the surveyed sites are in "designated critical habitat" areas for Mexican spotted owl and willow flycatcher. The US Fish and Wildlife Service in Arizona is receptive to conservation banking where it can be shown to provide clear species benefits. We see the best banking opportunity to be associated with the Charleston Bridge site, which we selected as the preferred off-site restoration opportunity as well. The Charleston Bridge site provides opportunities to restore and enhance habitat features by removing the pilings and bridge and by planting riparian vegetation. These actions would improve and create aquatic habitat for the endangered gila chub and riparian habitat used by the endangered Southwestern willow flycatcher.
- Because of the structure of western water law, water quantity markets are difficult to create and make viable. However, it is possible to do this, and there are good examples where these markets have been successful. As a scarce resource, water is obviously a potential market driver, but not a casual investment pursuit.
- There are a few local ordinances that could potentially serve as market drivers, including a land clearing and a water conservation ordinance for Cochise County. Evaluating the potential for these markets would require additional coordination with the County land use planning staff.

Although wetland mitigation banking pursuant to §404 is the most abundant and ubiquitous ecosystem market opportunity, there is little if any opportunity for this in Arizona. The primary reason is that the subsidized nature of the fee-in-lieu program managed by the Corps District makes it virtually impossible for banks to be competitive. There are also no TMDLs to drive water quality trading, and little apparent opportunity.

Corporate Sustainability and Social License Benefits

As stated above, we also consider non-monetary or indirect monetary benefits that are provided by ecosystem services-related investments. We typically track the following types of benefits under this category.

Meeting Internal Sustainability Objectives: Having a legitimate sustainability program and taking clear measures to meet program objectives can result in a variety of indirect monetary benefits. For instance, a legitimate sustainability program can make a company eligible for socially responsible investment funds and can increase product appeal by appealing to consumer preferences. For the pilot we used EcoMetrix help identify a number of easy project design steps that could be used to help meet internal sustainability program objectives, including those listed above under the site management discussion.

Social License: Social license has clear linkages to monetary benefits. First, a corporation without adequate social license will typically incur higher costs for permitting and approval processes. This is particularly true where a corporation's activities involve NEPA or EIA processes, a land use variance, or specific approval requirements (such as an activity within an overlay zone). Second, a corporation without adequate social license will have a harder time obtaining necessary resources. In the case of our developer, failure to adequately consider cultural and community concerns could adversely affect the ability to obtain adequate water for the development.

What are the recommended investments?

Of the identified potential ecosystem services-related investments, would prioritize the following for consideration:

- Addressing supply chain dependence for future ongoing water availability,
- Incorporating design options to reduce site maintenance costs, and
- Taking necessary steps to obtain necessary social license.

Whether the developer should consider conservation investment for non-monetary reasons is difficult for us to determine. To ascertain the need for this type of investment, we would need to better understand the developer's internal processes and past permitting/community and stakeholder interactions.

If the developer is interested in a more aggressive eco-asset strategy, then we would recommend further evaluation of the Charleston Bridge site for possible development as a conservation bank for either the Gila chub or Southwestern willow flycatcher, or both. The additional evaluation should focus in particular on a credit demand study that would include surveys of the Arizona DOT and other infrastructure agencies. The demand study should also include discussions with USFWS about who submits the most section 7 consultation documents, what they currently use for conservation measures, and whether there are any HCP discussions occurring or options for low impact HCPs tied to conservation measures.

What ROI (quantitative or qualitative) would be realized on what time frame (e.g., payments from environmental market transactions, real estate sales, etc.)?

The anticipated return on investment associated with the recommendations above would include the following:

Addressing supply chain dependence for future water availability: The cost of this investment could be relatively low (at least, the cost of steps necessary to maintain ecosystem processes will be low). The return on the investment will depend on whether the developer's actions are isolated or part of a comprehensive effort to address the issue (since groundwater is a resource that is susceptible to a tragedy of the commons scenario).

Reducing site maintenance needs: The ROI for these activities can be quite high. This is due to the low cost associated with implementing most of the recommended activities for reducing site maintenance needs. In addition, many of the recommended steps provide considerable long-term benefit.

Obtaining social license: Because many of the steps necessary for reducing site maintenance needs will also contribute to obtaining social license, the additional investment costs are not high. The one area of additional investment would be to pay particular attention to aesthetic, recreational, and cultural heritage issues. Given the degraded baseline condition of the site, it would be relatively easy to avoid impacts, or even improve conditions by adding a path through the greenway established for the site (recognizing that the social benefits of the path would need to be balanced with potential ecological impacts). Quantification of the ROI, in this case, relies primarily on capturing the avoided costs of prolonged permitting and resource acquisition. Since schedule delays are generally very expensive propositions for most developers, the ROI for this investment is potentially considerable.

Developing a conservation bank: The return on investment associated with developing ecosystem credits depends on the rate of growth in the region and the anticipated credit demand. However, mitigation/conservation banks generally require considerable up-front investment (associated with restoration, funding site endowments, permitting and certification processes, etc.) and can take several years to begin generating revenue. The return depends on the credit demand in the region, but we would anticipate relatively low return unless economic conditions and development demands increase considerably.

What might be ways to avoid regulatory exposure in light of:

Endangered species habitat sites?

The investments indicated above all have the benefit of also addressing potential regulatory concerns. In particular, the development site was selected, in part, because it has relatively low species support values, which lessens the likelihood of ESA issues. In addition, the identified restoration site has good opportunities to provide uplift for listed species habitat.

Indigenous peoples / Native American claims sites?

With regard to cultural values, we would normally base our service scoring on collaboration with the relevant indigenous peoples or cultural group. This collaborative process is a critical part of gaining the trust of the relevant populations and establishing the legitimacy of the scoring process. In this instance, we had to presume cultural significance from SHPO database and local knowledge, but we were able to use the scoring outputs to show how we would avoid cultural impacts.

1.7 Reflections on corporate applications of your tool, such as:

Appropriate conditions and contexts in which to apply the tool[6]

Streamlining Capital Project Delivery: EcoMetrix is generally well suited for a multitude of project level applications, including alternatives analyses, stakeholder processes, impact analyses, mitigation design, etc. Within this application context, EcoMetrix can also be used creatively to streamline project approval processes.

In the streamlining context, EcoMetrix bridges the gap between early project planning processes and actual project implementation. One form of streamlining occurs when an organization pre-negotiates a program-wide permit with an agency by agreeing upon the total allowable level of resource impact its activities can have. Typically, these permits are accompanied by pre-negotiated performance standards (terms and conditions) that apply to all projects covered by the permit. EcoMetrix can be used to help define the performance standards, as well as to measure post-construction compliance at the site and overall program levels.

[6] Such as within corporate Life Cycle Assessment models, product development, capital projects, measuring performance against baseline in terms of moving towards environmental goals, cumulative impacts, incremental effects, conducting asset portfolio review for surplus / idle properties, clarifying both stakeholders' interests, identifying corporate license to operate issues, or other applications.

Measuring Cumulative Effects: EcoMetrix can provide a key aspect of understanding cumulative effects. Ultimately, cumulative effects must be understood at two scales. First, it is necessary to understand the regional context of loss of habitats and functions over time. Cities and communities are not typically built in a single action, but rather in a series of incremental steps. Accordingly, it is necessary to be able to measure the incremental effects associated with a specific project and to relate that incremental impact to the regional context provided by landscape oriented tool (such as those tested in this pilot).

Addressing Supply Chain Dependencies: When supply chain assessments identify specific ecosystem services dependencies, EcoMetrix can be used to measure and track impacts to those dependencies.

Improving Stakeholder Relationships and Public Perception: EcoMetrix quantifies impacts and benefits to the natural environment, the human environment, and the economy. The tool provides information that can be used to develop a shared understanding of effects, opportunities, and tradeoffs, thereby enabling organizations and stakeholders to have productive conversations that help move a project forward. The improved communication can also provide a programmatic benefit by increasing the ability to obtain social license to operate in a community.

Meeting Sustainability and Stewardship Goals: EcoMetrix quantifies impacts at a function level, using the same unit of measure for all functions (percent of optimal performance). This approach provides considerable flexibility in measuring and tracking progress toward sustainability and stewardship goals – however they have been defined. Further, EcoMetrix is designed to facilitate decisions that maximize the ecological return on restoration and conservation investments, resulting in high quality ecological results and the investment of resources in projects with the greatest likelihood of success.

Controlling Costs and Generating Revenue:

- *Avoided Costs:* EcoMetrix can be used to inform project design decisions and to help identify the often excessive costs associated with the capital development and long-term maintenance of proposed "hard" infrastructure projects. These proposed projects would sometimes replace functions that could otherwise be performed by the ecosystem (e.g., stormwater management facilities).
- *Asset Management and Revenue Generation:* EcoMetrix can be used to establish a baseline functional value for natural assets. This baseline measure can inform pricing decisions for conservation easements, as well as provide a measurable unit of trade that serves as a basis for environmental market transactions.
- *Sustainability and Organizational Performance:* EcoMetrix enables the organization to establish environmental performance goals, measures how specific actions affect the organization's progress toward those goals, and provides quantitative information for sustainability reporting.

Relationship between environmental impact and ecosystem services, particularly in terms of how this tool might 'interface' with pre-existing corporate tools and processes for assessing impact

EcoMetrix can build upon existing corporate tools and processes, including EMS and environmental impact analyses.

Environmental Management Systems: EcoMetrix can either complement an existing EMS (or EMAS) or be used as the framework for constructing an EMS. It provides the ability to quantify an organization's effect within, and across, various environmental media in a common language (percent of optimal functional performance). EcoMetrix has been designed to accommodate a wide array of inputs – an important cost control issue when supplementing existing systems with new tools. It can be adapted to accommodate the specific attributes relevant to an organization's operations, products, activities, and services that affect the environment

Environmental Impact Assessments: EcoMetrix is well suited to helping decision makers consider potential environmental impacts in an objective, transparent, and repeatable manner. Because they are quantified, the outputs from EcoMetrix-assisted environmental assessments and alternatives analyses can also be used to structure constructive stakeholder conversations about impacts, opportunities, and

tradeoffs in a manner that is consistent with the intent of International Association for Impact Assessment (IAIA) guidance.

Regulatory Compliance: In terms of data gathering and decision-making processes in a regulatory context, the application of EcoMetrix meshes nicely with a number of existing regulatory processes and can be adapted to accommodate others as needed. EcoMetrix can accommodate aggregating any suite of functions to address a particular regulatory concern. In fact, it has been used that way in the Northwest for measuring debits and credits for conservation banking of listed salmon. During the design of EcoMetrix, a wide variety of existing regulatory compliance data needs were reviewed to inform our attribute selection process. EcoMetrix aligns well with Environmental Impact Assessments, whether applied in a NEPA context or elsewhere.

Building the business case of how this tool may improve corporate environmental systems and processes for decision-making

- EcoMetrix increases certainty, enables flexible solutions (e.g., out-of-kind mitigation), and reduces risks associated with regulatory compliance and public perception.
- EcoMetrix provides corporations with access to new markets and revenue streams, and helps establish additional value for land assets.
- EcoMetrix identifies the ecosystem services that a corporation depends upon, and enables it to take a more active role in the protection and beneficial management of those resources.
- EcoMetrix provides a means to quantify corporate environmental performance in a manner that can be used to develop, or supplement, corporate sustainability programs.
- EcoMetrix quantifies the ecosystem services and co-benefits associated with “above and beyond” compliance requirements. Without an ability to quantify these benefits, they go unrecognized—a missed opportunity for strengthening stakeholder relationships, establishing and maintaining corporate license to operate, and changing consumer preferences.

COMPONENT #2: ECOMETRIX TOOL DESCRIPTION

Understanding the Tool

- What is the objective of the tool / methodology?

  EcoMetrix is an environmental measurement and modeling tool that supports sustainable infrastructure, restoration projects, and enterprise-level program decision-making. EcoMetrix models and quantifies changes within an ecosystem, enabling users to evaluate the positive or negative effects of different scenarios and alternative designs on ecosystem services.

- Who are the intended users?

  EcoMetrix is intended for use by anyone who needs to quantify impacts and/or benefits associated with a given project, program, or change in type or intensity of land use. It enables the user to understand the effects of their decisions upon the environment, the community, and the economy. Users may include, but are not limited to:

  - Corporations
  - Landowners
  - Sustainability Professionals
  - Ecologists
  - Students
  - Agencies (Federal, State, Local)
  - Planners
  - Permit Specialists
  - NGOs
  - Mitigation Bankers/Credit Traders

- What is the intended use of the tool?

  EcoMetrix is a decision support tool for quantifying and evaluating impacts and/or benefits to ecosystems services resulting from individual infrastructure or environmental restoration projects or from a group of related such projects. EcoMetrix has been constructed for use in multiple contexts, including:

  - *Project Delivery:* EcoMetrix helps reduce risk and improve project delivery for infrastructure and restoration projects. Specifically, it facilitates communication with the public, informs project siting decisions and analyses of project design alternatives, helps streamline regulatory compliance processes, helps prioritize mitigation needs and opportunities by greatest environmental benefits, and provides a tool to monitor short and long-term project performance.
  - *Stakeholder Relationships and Public Perception:* EcoMetrix quantifies project impacts and benefits to the natural environment, the human environment, and the economy in terms of ecosystem services. It provides information to help develop a shared understanding of effects, opportunities, and tradeoffs, thereby enabling organizations and stakeholders to have productive conversations that move projects forward.
  - *Stewardship:* EcoMetrix facilitates decisions that maximize the ecological return on restoration and conservation investments, promoting investments in projects that yield high quality ecological results and that have the greatest likelihood of long-term success.
  - *Avoided Costs*: Hard infrastructure projects are sometimes proposed that would replace ecological functions currently or potentially performed by the ecosystem (e.g., stormwater management facilities). EcoMetrix helps identify the costs associated with the capital development and long-term maintenance of these “hard” projects, thus helping to identify cases where an ecosystem-based solution can provide equal functional value at less cost.
  - *Asset Management and Revenue Generation:* EcoMetrix establishes a baseline functional value for natural assets. This baseline measure can inform pricing decisions for conservation easements, as well as provide a measurable unit of trade that serves as a basis for environmental market transactions.
  - *Sustainability and Organizational Performance:* EcoMetrix enables the organization to establish environmental performance goals, monitor its progress toward those goals, and provides quantitative information for sustainability reporting.

- What do the outputs look like?

  EcoMetrix partitions each project site into smaller areas called map units, and assigns

scores to ecological functions and ecosystem services provided by each map unit and for the site as a whole. The outputs of the tool include a set of GIS shapefiles that depict the baseline and potential future design (alternative) map unit characteristics, and a spreadsheet that contains the data and scores for each map unit and for the overall site. This spreadsheet can be dynamically joined to the spatial data to create an explicit mapping of everything from the characteristics of individual attributes to the ecosystem services scores. Interpretation of the results in a narrative format must be developed by the user, based on the project context.

- Excel spreadsheet? Yes
- Narrative interpretation? No, but the tool provides all the information necessary to develop a narrative interpretation.
- Explicit mapping? Yes

Considering Analytical Parameters of Tool

- Which ecosystem services does the tool currently include?

  The tool includes all of the ecosystem services identified in the Millennium Ecosystem Assessment (MEA). However there are four stages of development. Stage 1 status means that a service is in EcoMetrix but its relationships to specific functions are currently still being defined. Stage 2 means that we have identified the relationships between specific functions and the service, but the calculations are not yet automated. Stage 3 services have been programmed into the EcoMetrix database. Ultimately, all functions will reside in Stage 4, meaning they are fully programmed into the model, but will be updated and refined as project monitoring results indicate that a revision is appropriate.

Stage 1 **Function-to-Service Relationships Under Development**	**Stage 2** **Function-to-Service Relationships Defined; Calculations Not Yet Programmed**	**Stage 3** **Calculations Programmed**
• Genetic Resources • Water Purification and Waste Treatment • Regulation of Human Diseases • Biological Control • Cultural Diversity • Sense of Place • Social Relations • Spiritual and Religious • Educational Values • Inspiration • Knowledge Systems	• Biochemicals, Natural Medicines, and Pharmaceuticals • Food and Fiber • Fresh Water • Fuel • Air Quality Regulation • Erosion Control • Pollination • Storm Protection	• Biodiversity (Note: not an official MEA-listed service) • Climate Regulation • Water Regulation • Aesthetic Values • Cultural Heritage • Recreation and Ecotourism

- Which ecosystem services does it omit?

  Based on our progress over the last year, we do not anticipate that the tool will omit any of the currently identified services.

- Are there any services being used as proxies for others? If so, which?

  None, currently. There are, however, services that affect other services, and we have yet to decide how we will address that issue.

- Do you have plans to build out the tool to include other ecosystem services? If so, on what timeline?

  As previously mentioned, we intend to finish development of each service listed above. Our timeline will be dictated by our clients' specific project needs and priorities.

Assessing Data Requirements, Quality & Costs of Application

- What are the data requirements?

  Data from pre-existing databases are utilized where needed; however, the real strength of our tool is that, as discussed below, the majority of our data is collected in the field.

A) Pre-existing databases: If the tool runs on databases:

- What are the database sources?

  Database and GIS spatial data sources will vary depending upon the location of a given site. Wherever possible, when incorporating spatial data to create attribute information, we look for data sources that provide national or state/province coverage. Also when considering using spatial data as an attribute, specific attention is paid to the availability of this information at an international scale. The tool currently uses several geodatabases, shapefiles, and web-based map services for some of its data input needs. Geodatabases and shapefiles from the following sources have been downloaded to date and are used to obtain attributes for EcoMetrix:

  - NRCS – Soil Data Mart (SSURGO database)
  - StreamNet – Anadromous and resident fish distribution geodatabase
  - National Climatic Data Center – Precipitation, solar radiation, temperature, and wind power shapefiles
  - National Land Cover Gap Analysis Project – National landcover shapefiles
  - Landscape Fire and Resource Management Planning Tool Project – Fire regime condition class departure index shapefiles
  - Arizona Cultural Resource Inventory from Arizona State University
  - Arizona Geographic Information Council Portal – Spatial Data for State Agencies
  - Bureau of Land Management Arizona Office – GIS Data

  The following GIS web-mapping services are also used in EcoMetrix:

  - FEMA – National Flood Hazard Layer
  - ESRI – Aerial image service
  - Arizona DEQ Web Mapping Service

- What issues exist with these database sources, if any? (e.g., quality, reliability, verification, replicability, availability)

  There are a variety of issues inherent in using static databases and web-mapping services. The primary concern with a static, downloadable database is ensuring that it is accurate and up to date. Web services can have availability issues. As an example, we have had instances where we could not access the FEMA database service. However, we have identified alternative sources of the data inputs, in case the dataset isn't available in the future. Using the aerial image service can be more challenging because high quality, current imagery isn't always available and occasionally, the data may be unavailable. To avoid this problem, current aerial imagery can be purchased, if available.

- What assumptions are embedded within these databases?

  The main assumption for all third-party data used in EcoMetrix is that the data have been verified for accuracy. When screening data, we adhere to the following criteria:

  - Data inputs must have a geographic or spatial component.
  - The spatial units must be of resolution and scale compatible with the intended analysis.
  - The data must be documented, public, and trusted.

B) User provides data: If the tool requires input data, what are the time and costs for acquisition and verification of data?

Field data: The time required for data collection depends on field crew experience and proficiency, and site complexity, size, and access. Typically, an experienced Parametrix field crew and an experienced data reviewer can complete their tasks at the approximate rates shown below:

Site Complexity	Field Data Collection Approx.	Field Data Verification

	Minutes/Acre	Approx. Minutes/Acre
Simple (Relatively Homogeneous)	15-30	<5
Moderate (Mix of Habitat Types)	30-45	<10
High (Diverse with Streams, Mosaics)	45-60	<15

Costs associated with data collection and verification depend on the rates charged by the entities doing the work and are context-specific. Our experienced field crews bill out in the range of $100–120/hr, and our field crew supervisors performing data verification generally bill out in the range of $120–140/hr. Our preferred approach for helping clients minimize costs is to have our field crew supervisors train our client's junior staff to do the field work. This can dramatically cut user costs for all subsequent data collection efforts.

Office data: Additional attribute data is generated in the office using GIS. This process generally takes a base level of 8 hours to gather and process for a simple site; 16 hours for a moderately complex site; and 24 hours for a complex site. This data collection effort is very context-sensitive because data availability is situation-dependent.

- What is the quality of the data (reliability, verifiability, credibility):

  - On the input side?

    Because the data are based on field work, the quality of the data is determined by the skill of the field crew. In order to ensure data quality, our experienced staff perform the initial data collection and provide training to our client's staff, enabling them to independently perform future data collection for monitoring or for other projects. When data are collected by our clients, we typically perform data verification to improve data accuracy and to increase associated confidence levels.

    We are currently engaged in data collection repeatability testing, which has been organized by a third party. The results of this process have helped us identify potential opportunities for error, and we have used this information to make continued improvements to our training. We are also in the process of updating our Field Guide, which facilitates training and provides a quick reference for field crews.

  - On the output side?

    The quality of EcoMetrix outputs is dependent on the quality of data on the input side. The results can be verified by examining the algorithm to ensure that it has been constructed accurately.

- Is sensitivity analysis included? Qualitatively or quantitatively?

  For our system, the sensitivity analysis actually occurs every time we develop a new function and/or use the system. The need for sensitivity analysis is perpetual and its relevance comes into play at the function scoring level. When we develop a function, we identify a list of relevant attributes that must be collected in the field in order to evaluate how well the function is being performed. We also establish the units of measurement (often, these are ranges such as 10–20%) that field crews will use to collect information about the site's attributes. The ranges are specific, but broad enough to avoid producing an inappropriately precise measurement (e.g., a response of "12.3%"). We then establish curves that show the relationship of a given attribute to the function under development, and these curves are ultimately used to derive the function's score. The key issue for sensitivity analysis is whether or not we have adequately defined the relationship between the attribute and the function. In our development process, the relationship between the two is scenario-tested during development, and every time the system is used, the function output is reviewed to determine whether or not the output is giving the anticipated result. If it is not, we re-examine the scoring relationship and determine if revisions are necessary. This provides an opportunity for continuous improvement based on monitoring results—a feature that the regulatory agencies have actually identified as a great strength of the system.

- Does the tool have capability for technologies to feed data into the tool?

  Yes. Currently, EcoMetrix accepts relevant inputs from a variety of outside data sources. It

also relies on GIS analysis to generate several attributes.

- Is the tool designed to interface with GIS, carbon measurement technologies, mesh networks or other technologies?

  Yes. The ability of EcoMetrix to interface with other tools is critical to its success. Our system relies heavily on GIS, and will ultimately be able to interface with other systems. EcoMetrix has been carefully designed to have the flexibility needed to accommodate inputs from a very wide array of sources, and to provide outputs in a variety of formats. Currently, we must manually transfer data between systems. To date, we have manually tested our ability to interact with water temperature regulation and nutrient management tools developed by the Oregon Department of Environmental Quality and NRCS, respectively. In addition, over the past year, we have been partnering with TNC on a pilot project to test our ability to receive inputs from InVEST, allowing us to provide site-level results that are informed by landscape-scale issues.

- Are you exploring potential technology interface points or partnerships with large database firms (e.g., IBM or Microsoft)?

  Parametrix is currently exploring partnerships with database firms, software firms and other organizations, to develop the desired software product.

- What are the anticipated resource (human or otherwise) requirements of the tool? (Provide $$ and/or labor hour examples based on pilot projects)

  Costs vary, depending on the site and the proposed project. Human resource requirements for generating outputs from EcoMetrix (including field preparation, data collection, and data entry) for both the baseline condition and one hypothetical design alternative are provided below for two recent pilot projects. Note that the times given are for using EcoMetrix to calculate scores; the table does not include the time required for customization, context-based interpretation, development of narrative reports, etc. Rather, once trained and proficient with the data collection and entry process, this is the approximate amount time required for a user to generate baseline and future scores for one alternative. If only baseline scores are calculated, the amount of time spent on mapping and data entry would likely be reduced by approximately one-third.

BSR Pilot, San Pedro (5 Non-contiguous Sites)

Acres examined	90 acres (130 map units)
Site complexity (H, M, L)	Moderate
Mapping time*	10 hours
Field time**	26 hours/person; 68 man hours
Data entry time***	4 hours
Verification of outputs time	1 hour
Total hours	83

Confidential Pilot, Eastern U.S.

Acres examined	150 acres (62 map units)
Site complexity (H, M, L)	Moderate
Mapping time*	8 hours
Field time**	28 hours/person; 70 man hours
Data entry time***	6 hours
Verification of outputs time	1 hour
Total hours	85

* Includes baseline and alternatives mapping.
** Does not include travel to and from sites.
*** Includes baseline and alternatives data entry.

These results are generally consistent with the amount of time spent on other recent projects and pilot studies. Costs depend on the user's billing rates or staff salaries. Non-human resources include access to Excel and GIS.

Accessing the Tool	• What is the availability of the tool? While not yet an "off the shelf" product, EcoMetrix is ready for immediate use. Parametrix is committed to partnering with clients to build out additional functions, if needed, as quickly as possible. We are also willing to work with clients to develop an interim desktop application, if desired. A previous version of EcoMetrix can be found at http://ecometrix.parametrix.com. However, that version was designed early in our process and it is limited to four functions relevant only in a stream context. • Specifically: - Will the tool be broadly available through online materials? Yes. Our intent is to have an online version of EcoMetrix that will allow users to enter project data, evaluate alternatives, and generate outputs that quantify changes in functional performance, as well as associated effects on ecosystem services scores. - Will companies be required to work with the tool developers directly as the 'delivery mechanism'? This is highly dependent on how each company wants to use the tool and whether or not the available on-line version will require customization for their use. A company's dependence on Parametrix in this regard is thus strongly influenced by the uniqueness of its specific needs. If the system has been used for similar purposes in a similar geography, the attributes and functions already included may preclude the need to engage us. An example where customization was needed is provided by the BSR pilot study. For this project, we needed to build out the temperature regulation function to extend beyond the ability to provide shade. We added the capacity to factor in the albedo effect, which is critical to making sustainable design decisions in the Southwest. This type of customization is also likely to be needed to reflect local priorities for social functions and services. Because of Parametrix's expertise in quantifying functional performance and impacts to ecosystem services, companies would benefit from our consulting services when applying EcoMetrix to the strategy, planning, data analysis, and monitoring phases of complex projects, as well as when performing eco-asset inventories and engaging in enterprise-level corporate sustainability program development. - If neither, what are the plans? NA • What are future availability / 'delivery' plans for the tool? On what timeline? To be perfectly honest, we have struggled – and continue to struggle – with the issue of how to make EcoMetrix readily accessible. We are committed to maintaining the transparency of the methodology, and we intend to make a no-cost version of the tool available. Currently, unless we develop a desktop application at the request of a client, we do not have the means to provide access to the EcoMetrix database in a manner that allows us to ensure its continued integrity or correct application. In its current state, a user could – intentionally or unintentionally – make changes to the database that could significantly skew the outputs. Not only would this be problematic for the user, but it could also compromise the credibility of the methodology. Our timeline for making the system more readily available will be dictated by our client's specific project needs and priorities.
Assigning Values within the Tool Application	• Does the tool / methodology assign value to ecosystem services? - *If so*, what type of value is assigned and how is it assigned? o Biophysical (e.g., pounds of fish, cubic feet of water) EcoMetrix measures how changes in a site's ability to perform ecological functions affects its ability to provide ecosystem services. When we score functional performance and ecosystem services production, we measure a relative percent of optimal performance. This percent of optimal performance is

calculated for a specific study area as a "functional acre" or "ecosystem services acre." By way of example, this output can be expressed in the context of multiple services performed on a given site, such as the ability of the site to support resident fish production as well as the extent to which a proposed action could impair climate regulation services.

- o Economic: Monetary or non-monetary (e.g., dollar values or other nonmonetary expressions of human economic preferences)?

  EcoMetrix does not directly calculate a monetary value for a site. However, the use of EcoMetrix is an instrumental step in realizing new revenue streams and determining eco-asset monetary values. For instance, EcoMetrix is used in some locations for calculating debit/credit amounts for market transactions where the cost per credit is already known. In addition, we have used EcoMetrix outputs as the basis for calculating the monetary consequences associated with having to replace ecosystem functions lost due to development.

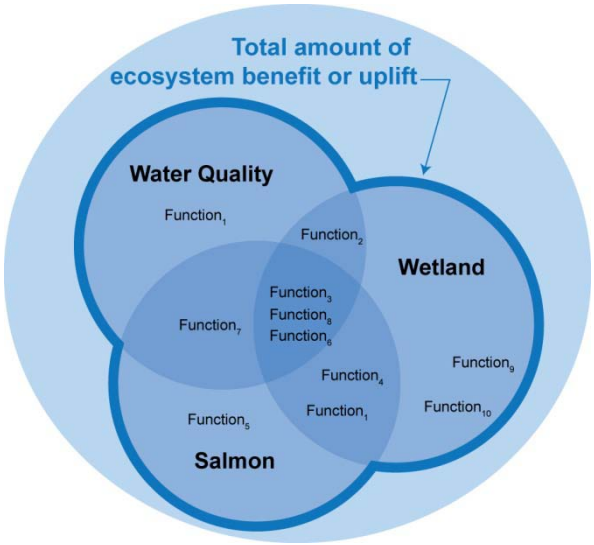
- If the tool does <u>not</u> assign value in some economic unit, then does the tool assign weight? If so, how?

  EcoMetrix accommodates, generally established by stakeholders and landscape-level priorities, for functions and services. These weighted scores can be converted into "credits" whose price is determined by market demand.

- How does the tool avoid double-counting (e.g., clean water to produce fish, if also counting fish)?

  The ability to measure multiple resources and services at once is a critical function in EcoMetrix, particularly when used to generate credits that will be bought or sold in a mitigation or ecosystem marketplace context. By working at the most basic level of environmental measurements, EcoMetrix provides a system that can "stack" or combine multiple credit types or resources and, at the same time, assures that credits are used only as approved and allowed. This stacking function allows for the interactions of the natural elements to be more fully measured.

  Stacking requires strict accounting to prevent the use of a single credit to offset impacts of multiple projects. In a regulatory context, this is critically important. An EcoMetrix-based credit is created by identifying the relevant functions that support or are performed by the regulated resource being tracked. Often, a specific function is relevant to more than one credit type. Since EcoMetrix tracks uplift for all functions separately, it provides a transparent means to ensure that the relevant functions within the various credit types are not used repeatedly in different transactions (double-dipping).



A Venn Diagram can be used to illustrate this concept. The figure shows several overlapping circles, each of which represents an amount of restoration benefit (uplift)

	expected to result from restoration actions on a hypothetical mitigation site. Each type of uplift reflects improvements to resources (water quality, wetlands, salmon) regulated within a specific regulatory context. For each one, ecosystem markets exist, thus enabling the buying and selling of credits generated from the uplift activities. In order to allow for multiple types of credits to be generated from the same site, controls need to be in place to keep a given credit from being sold more than one time. EcoMetrix's ability to provide these controls is based on the way uplift is calculated—by using functional performance measurements. If all of the circles of the Venn Diagram are looked at together, the outside edge (traced without moving into any one circle) defines the total amount of ecosystem benefit or uplift that has been provided. However, this may not be equal to the actual total amount of ecosystem benefit provided by the site, because there are overlaps that may provide even greater benefit as a sum than do any of the parts. Within the wetland circle, for example, a subset of functions also contributes to water quality. However, in current regulatory schemes, these benefits are recognized in only one context: water quality or wetlands, but not both. In order to allow for this recognition, while preventing a given credit from being sold for two different projects, EcoMetrix is designed to structure accounting for the debit-credit sales such that, for every transaction, it tracks both the total ecosystem debit and credit and the debits and credits relevant in a specific regulatory context. Functionally, EcoMetrix makes this tracking simple because, since only one set of attribute data is collected and used to calculate the performance of those functions, it is easy to obtain from the database any subset of function scores as well as a total function score. Based on this quantification, the total ecosystem uplift score can be calculated for the site, and this number represents the limit of credits available for sale at a site level. Credits can then be sold from within each circle. Within the wetland context, for example, a landowner cannot sell more than the circle of wetland benefit that was calculated. As long as these restrictions are put in place for each of the markets and overall ecosystem uplift is tracked, the system knows know when credits can no longer be sold.
Exploring Stakeholder Engagement	• Does the tool include guidance on use within: - Internal stakeholder engagement processes? Not currently, but we anticipate developing such guidance in the future. So far, Parametrix has provided stakeholder engagement support as a service. However, we anticipate that once a user becomes sufficiently familiar with the tool to be able to answer the questions raised by stakeholders, the user should be able to incorporate EcoMetrix into their existing stakeholder processes. - External stakeholder engagement processes? Same as above. - Other facilitated decision-making processes? Same as above. • Specifically, does the tool have a process for including public input into assigning ecosystem service values? If so, is this a process for: - General public input? Yes. The tool has been developed so that weights can be assigned, when scoring any of the services, to reflect stakeholders' priorities. Depending on the circumstances of use (e.g., regulatory context), we anticipate that the ability to adjust weights may need to be limited to administrators in certain cases. - Local / site-specific public input? Same as above. • In cases where there are a range of stakeholder values placed on the same ecosystem service flow, how does the tool balance these values? The basic tool is structured to treat all functions and services with equal weights. Based on stakeholder values or agency priorities, these functions and services can be weighted differently. This allows users to clearly see how different weighting (i.e., placing different

values on the same service or different services) affects the scoring outcomes. These adjustments have been made for several clients to date, based on priorities set by their stakeholders. It is important to note that the outputs provide information that can be used in conversations about tradeoffs, and that EcoMetrix supports decisions, but does not make them.

- Does the tool rank these different stakeholder viewpoints on ecosystem service values? If so, how?

  No, EcoMetrix does not rank stakeholder viewpoints or ecosystem service values. However, the tool's weighting capability allows users to explore how different viewpoints can affect outcomes and how those outcomes positively or negatively affect priorities (see above).

- Is there a default weighting across services? If so, how?

  Yes. The default weighting value for all indicators, functions, and services is 1. Defaults are sometimes set on a watershed or "service area" basis in order to prioritize measures that directly address limiting factors and/or are being implemented in sensitive areas.

Applying within Existing Corporate Decision-Making Processes

- What are the conditions of applicability of this tool in corporate decision-making processes?

  The tool is relevant in any situation in which an organization desires to evaluate its enterprise-level or project-specific impacts on the functional performance of an ecosystem and/or its impacts on ecosystem services. There are, however, two considerations to bear in mind:

  - The tool may require customization, depending on desired use and project location.
  - Because the tool has been designed to utilize many of the same inputs as those currently gathered for typical permitting processes, it generally does not generate results in the types of units currently used in typical command- and control-based markets (e.g., water quality trading under §402 of the Clean Water Act). The outputs are more typical of those found in wetland or endangered species-based markets under §404 and the Endangered Species Act, respectively. The results can, however, be correlated (though not necessarily converted) to these other types of units, so that the effects of modifying functional performance can provide an understanding of how regulated resources may be affected and what that may mean in terms of permitting challenges (see below).

- Is the tool being designed to fit within corporate Environmental Management Systems and/or Environmental Impact Assessments? If so, how?

  EMS: Yes. EcoMetrix can be used either to complement an existing EMS or as the framework for constructing an EMS. It provides the ability to quantify an organization's effect within, and across, various environmental media using a common language (percent of optimal functional performance). This enables organizations to bring diverse reporting streams together for overall-effect analyses, footprinting, certification and registration programs (e.g., EMAS), and corporate sustainability planning.

  EcoMetrix has been designed to accommodate a wide array of inputs – which is an important cost control issue when supplementing existing systems with new tools. It can be adapted to accommodate the specific attributes relevant to an organization's operations, products, activities, and services that affect the environment. It can be used to support the iterative EMS "Plan-Do-Check-Act" cycle for developing policy statements, identifying aspects and impacts, developing objectives and targets, measuring performance, identifying opportunities for improvement, developing risk management strategies, improving reporting, and facilitating program reviews, adaptive management, and communication with the public.

EMS Application for a Construction Company

Existing Corporate Policy: Develop sustainable communities that improve ecosystem services performance.

PLAN
- **Set Objective:** Achieve a Net Improvement in Biodiversity
- **Set Target:** Increase biodiversity ecosystem service performance by 10% over baseline (or by an additional 10% over a 1:1 offset)
- **Identify Aspects:** Grading, vegetation removal
- **Identify Impacts:** Small mammal support functions, reptile support functions, songbird support functions

DO
- Measure baseline functional performance
- Plan "uplift"
- Construct project

CHECK
- Monitor "uplift" performance
- Implement corrective actions

ACT
- Review progress
- Manage adaptively

	EIAs: Yes. EcoMetrix provides a tool well suited to helping decision-makers consider potential environmental impacts in an objective, transparent, and repeatable manner. Because they are quantified, the outputs from environmental assessments and alternatives analyses can also be used to structure constructive stakeholder conversations about impacts, opportunities, and tradeoffs in a manner that is consistent with the intent of International Association for Impact Assessment (IAIA) guidance. Particularly when integrated with a landscape-level tool, EcoMetrix provides a means to address the current criticisms that the spatial and temporal scales considered in many EIAs are too narrow. EcoMetrix can also be used to perform EIA audits and monitor project performance over time. • Do you know whether this tool matches up with existing corporate data gathering and decision-making processes, whether they be voluntary (e.g., ISO 140001) or regulatory (e.g., Total Maximum Daily Load under the U.S. Clean Water Act)? If so, which? The current draft of the ISO's Corporate Social Responsibility standard (ISO 26000), Environmental Issue 4, states that organizations can become more socially responsible by "valuing, protecting and restoring ecosystem services" and "valuing and protecting biodiversity." Although development of the EcoMetrix methodology pre-dates inclusion of ecosystem services in the standards language, it was designed explicitly to provide the type of evaluation ISO now references. In terms of data-gathering and decision-making processes in a regulatory context, the application of EcoMetrix meshes nicely with a number of existing regulatory processes, and it can be adapted to accommodate others as needed. During the design of EcoMetrix, a wide variety of regulatory compliance data needs were reviewed to inform the attribute selection process. For example, EcoMetrix was adapted in 2008 to ensure that data collection performed as part of a municipal utility's TMDL reporting program would be consistent with the attributes used in EcoMetrix. As a result, the data from EcoMetrix can be readily exported for use by the Oregon Department of Environmental Quality's Shadealator water temperature modeling program. In addition, EcoMetrix outputs have been used in permitting processes to inform the evaluation of impacts and the negotiation of mitigation ratios that more accurately reflect the impact a given project has on a site's functional performance (e.g., including Clean Water Service's water temperature trading program and the WSDOT 520 bridge project). As mentioned above, EcoMetrix aligns well with Environmental Impact Assessments, whether applied in the NEPA context or elsewhere. • Would the tool be useful for evaluating corporate land holdings for their value in terms of ecosystem services not accounted for in real estate accounting? Yes, in several ways: - EcoMetrix is designed not only to capture baseline ecosystem services scores, but also to calculate the potential uplift that restoration actions may create. Both of these outputs can be used to increase the financial value of a property, as they can become the basis for environmental credit trading, setting prices for the sale of conservation easements, etc. Companies can also use EcoMetrix to make better decisions regarding the disposal of surplus properties. Often, organizations do not realize the mitigation potential of a site; consequently, it is sold below its true value because the organization thinks of the site as encumbered by environmental liabilities, rather than endowed with eco-asset potential. - EcoMetrix also enables an organization to establish values associated with a number of benefits provided by a property, enabling the organization to articulate the costs the public avoids because of the organization's contribution to ecosystem health. This can, in fact, serve as a foundation for establishing Payments for Ecosystem Services (PES), whereby private landowners are compensated for the public benefit their property provides as the result of stewardship-oriented management.
Identifying Assumptions within Tools	• What are the fundamental assumptions underlying your approach and methodology? - Assumption A: Application in Development Context The post-construction development accurately reflects site designs used when generating anticipated future scores. The collection of as-built monitoring data is required to determine whether project implementation resulted in more – or less – impact than originally expected.

- Assumption B: Application in Restoration Context

  The anticipated future condition for restoration sites reflects a 20-year condition projection. It assumes that restoration plans will be implemented as designed and that restoration actions will be successful. The collection of monitoring data is required to determine that success is achieved as anticipated. Analyzing such data using EcoMetrix provides the ability to measure progress, as new scores will be generated for comparison to original results.

- Can you provide examples of any assumptions? (include article references, if applicable)

  NA

- How does the tool—and/or these assumptions—interface with profitability goals? Can you provide examples?
  - Time is money. EcoMetrix increases certainty, enables flexible solutions (e.g., out-of-kind mitigation), and reduces delay risks associated with regulatory compliance and public perception.
  - Using EcoMetrix to monitor development projects and restoration sites can help minimize costly regulatory non-compliance issues.
  - EcoMetrix identifies the ecosystem services a corporation depends upon—that it needs to lobby for protection of—in order to protect its supply chain and operations.
  - EcoMetrix can be used to reduce costs associated with capital development by identifying when/where the protection of natural assets can complement or provide a low-cost alternative to hard infrastructure solutions.
  - Corporations can use EcoMetrix as the foundation for calculating the type and number of environmental credits a property may be able to generate for sale in environmental markets.
    - It generates outputs that can be converted to multiple credit types for sale in one-off or environmental market transactions.
    - It facilitates credit stacking, enabling corporations to derive maximum credit value from a given site.
  - EcoMetrix quantifies eco-assets in support of property management decisions.
    - It identifies existing corporate land holdings that can be used to mitigate the corporation's own environmental impacts, thus reducing the need to purchase mitigation.
    - It can also inform surplus property pricing decisions for sites that have restoration-based revenue generation potential, and it can inform conservation easement price setting, based on the benefits a site provides.

- To what degree have the tool developers undertaken trends analyses of likely policy scenarios related to ecosystem services? If such scenarios have been developed, how have these scenarios been integrated?

  Since the relevance of our tool in both the regulatory and environmental market contexts is highly affected by policy developments and trends, we pay very close attention to anticipated developments. For example:
  - Regulatory Context

    In the US, we have witnessed the development of federal, state, and local policies encouraging, and indeed sometimes requiring, the evaluation of ecosystem services in association with restoration and development projects. In each of these cases, we have found that standardized metrics do not exist and that many of the analyses are highly qualitative, which introduces significant regulatory risk. In anticipation of the need for quantification, we have specifically designed EcoMetrix to provide repeatable, quantified results that can measure impacts at a project level. EcoMetrix can provide agencies with a mechanism to set performance standards during the permitting process, which provides greater certainty for project sponsors and more defensible decisions by regulators.
  - Market Context

    EcoMetrix has been designed to provide an objective, verifiable mechanism for

	generating credits and ensuring their validity. Previous uncertainty about environmental market credit integrity, and the resulting trends toward ensuring the avoidance of duplicative sales of the same credit, has significantly influenced our accounting approach. We have the ability to break site credits into their component parts so that they can be accurately tracked in a registry, thus avoiding double-dipping and ensuring credit retirement after sale.
Exploring Broad-Based Application	• What kind of subject matter expertise would a user need? Expertise needed to complete the four basic steps in an EcoMetrix analysis includes: - Field data collection – basic biology background, including field data collection experience. - Designing project alternatives – biology and/or engineering, depending upon anticipated land use. - Developing map units and calculating baseline conditions – GIS. - Analyzing and presenting results – biology or planning. • What have been the challenges found in tool uptake (e.g., design elements practicality of application, comprehensiveness, flexibility of the tool)? - Originally, streamlining field data collection efforts was a concern. However, with continued improvements to the data collection process, datasheets, and a field guide, we are finding efficiencies that have reduced our concerns in this area provided that field crews receive adequate training. - The comprehensiveness and flexibility of the tool are so great, and its applications so varied, that we anticipate EcoMetrix will never be "complete"— we view this as a great strength, but it is unlikely that it will ever reach the point where it meets the needs of every specific situation without requiring some customization. - When presenting results, it can be challenging to get users to put aside personal biases and assumptions and look at the outputs from a function-based perspective. For example, in one pilot test, a forested wetland received a lower functional score than an emergent wetland, which was counter-intuitive to wetland biologists involved in the project until they looked at the specific functions performed by each habitat and realized their perception was based on personal preference rather than functional performance. • Would the tool benefit from broader participation, uptake, engagement with other tool developers? If so, how? And where are areas you would benefit from collaboration with other tool developers? Yes, EcoMetrix would benefit from continued coordination with systems that value entire watersheds in order to automatically incorporate the contextual value of a site—i.e., the relative importance of a site and how a property contributes to the overall delivery of ecosystem services. In addition, EcoMetrix can also provide valuable front-end information to a tool that focuses specifically on the monetary aspect of ecosystem services. Because EcoMetrix focuses on providing a rigorous evaluation of the change in functional performance and how that relates to the performance of an ecosystem service, EcoMetrix can provide a robust basis for calculating the monetary consequences of decision-making. • Do you see opportunities for standardization or consistency across tools? Yes. However, it is likely that an organizing body will be needed if standardization is to occur. In addition, serious thought needs to be given to how individual tools are updated and how those updates will have ripple effects upon other tools in various stages of completion. This is particularly important if tools that interface with other tools are redesigned or modified in such a way as to compromise their compatibility. This infrastructure maintenance will need to be coordinated, and it will have costs associated with it.
Understanding the Value Proposition	• What value proposition does this product provide? By allowing an organization to chart performance and anticipate future needs, EcoMetrix helps **reduce risks** associated with supply chain resilience, environmental performance, changing regulatory environments, and maintaining stakeholder and customer support. Additional benefits a corporation can derive from the use of EcoMetrix can be captured under the umbrella of corporate sustainability and organizational performance: EcoMetrix can benefit corporations by **reducing the uncertainty** associated with planning for, measuring, and reporting on an organization's environmental performance, whether at a

project, program, or enterprise level. Because the system quantifies environmental impacts and benefits, it can be used to help corporations set appropriate, attainable goals, budget for measures needed to improve performance, evaluate costs/benefits associated with implementation of sustainability measures, and produce credible, user-friendly monitoring results. The value proposition for corporations includes the provision of:

- Economic Benefits
  - *Project Delivery:* EcoMetrix benefits corporations in the project delivery process by providing quantitative impact/benefit information that helps to **streamline regulatory compliance, efficiently obtain public support, and achieve better environmental outcomes**. EcoMetrix's foundational principles, and performance standards developed by Parametrix, were used as part of a recent statewide transportation infrastructure replacement program in Oregon. The use of these tools contributed to a **documented cost savings of $73M** over conventional delivery.
  - *Avoided Costs*: EcoMetrix can be used to **reduce costs** associated with capital development by identifying when/where the protection of natural assets can provide a **low-cost alternative** to, or complement for, hard infrastructure solutions.
  - *Asset Management and Revenue Generation:* EcoMetrix benefits corporations by identifying existing corporate land holdings that can be used to **mitigate a corporation's own environmental impacts**, thus reducing the need to purchase mitigation. It can also **inform surplus property pricing decisions** for sites that have restoration-based revenue generation potential, and it can **inform conservation easement price setting**, based on the benefits a site provides. Corporations can use EcoMetrix as the foundation for calculating the type and number of **environmental credits** a property may be able to generate for sale in environmental markets.
- Ecological Benefits
  - *Stewardship:* EcoMetrix benefits corporations by identifying ecologically meaningful restoration and mitigation sites that have the greatest likelihood for success. This facilitates decision-making regarding the need to **balance construction costs, maintenance expenses, and monitoring obligations with the ecological benefit received**. EcoMetrix is routinely used to screen out restoration investments that will result in a substantial cost but only minimal benefits. The Freshwater Trust is currently using EcoMetrix for its Streambank program to evaluate the appropriateness and effectiveness of proposed restoration projects. Evaluating projects with EcoMetrix is helping Streambank **document how funds are spent and what specific environmental benefits are achieved**.
- Social Benefits
  - *Stakeholder Relationships and Public Perception:* EcoMetrix improves a corporation's standing with public and private stakeholders by providing a credible means of responding to the paradigm shift in how businesses and society view sustainability and corporate responsibility. EcoMetrix benefits corporations by providing a framework for identifying local stakeholder priorities, in advance of developing specific project development and operational plans. This allows corporations to develop preliminary project concepts, or evaluate operational activities, with an understanding of potential impacts/benefits to priority resources.

    Communicating this awareness to the public encourages **productive stakeholder conversations** about how to move a project forward and about what is needed to maintain a corporate license to operate in a specific community. EcoMetrix was recently used to help the Washington State Department of Transportation, the regulatory agencies, local tribes, and NGOs discuss mitigation needs for replacement of the world's longest floating bridge (State Route 520). The EcoMetrix analysis provided information that improved the conversation between the project sponsor and the stakeholders and which is helping to remove the issue of mitigation from the project delivery critical path. The use of EcoMetrix in this manner has helped protect the project sponsor's relationship with stakeholders, while also helping to minimize the potential for incurring **an estimated $10M loss** for every month of potential project delay.

- What is the business case for companies to:

- Apply this tool?
  - EcoMetrix increases certainty, enables flexible solutions (e.g., out-of-kind mitigation), and reduces risks associated with regulatory compliance and public perception.
  - EcoMetrix provides corporations with access to new markets and revenue streams and helps establish additional value for land assets.
  - EcoMetrix identifies the ecosystem services a corporation depends upon and enables it to take a more active role in the protection and beneficial management of those resources.
  - EcoMetrix provides a means to quantify corporate environmental performance in a manner that can be used to develop, or supplement, corporate sustainability programs.
  - EcoMetrix quantifies the ecosystem services and co-benefits associated with "above and beyond" compliance requirements. Without an ability to quantify these benefits, they go unrecognized— a missed opportunity for strengthening stakeholder relationships, establishing and maintaining corporate license to operate, and changing consumer preferences.
- Apply this tool versus other tools that are emerging?

  EcoMetrix is unique in several ways:
  - EcoMetrix quantifies ecosystem services based on specific functions performed on the landscape.
  - As a decision support tool, EcoMetrix provides quantified site-level project impact and benefit data in a manner that improves project delivery, regulatory negotiations, and public engagement processes.
  - EcoMetrix generates outputs that can be converted to multiple credit types for sale in one-off or environmental market transactions.
  - It facilitates credit stacking, enabling corporations to derive maximum credit value from a given site.
  - EcoMetrix quantifies eco-assets in support of property management decisions.
  - EcoMetrix is well suited to diverse applications, and its flexibility enables it to be applied to existing corporate environmental management processes and programs without requiring wholesale redesign of established practices.
  - EcoMetrix can be used to construct or support sustainability programs in a manner that provides defensible environmental performance results that can be easily communicated internally and to the public.
- Encourage/support public policy makers or others to apply the tool to private sector activities?

  EcoMetrix provides corporations with flexibility in developing compliance solutions, and it creates opportunities for organizations to derive maximum value for eco-assets in a market context. It provides the opportunity to incentivize ecologically significant restoration projects that can help move organizations, and society, toward sustainability.

ESValue

1.1 Data needed for tool application.
ESValue^{SM} is a strategic decision support tool that helps managers and stakeholders systematically, transparently, and cooperatively assess and value the key ecosystem services that are affected by alternate natural resource management strategies such as a residential development. The tool is very flexible in data needs; it is designed to be able to provide meaningful output based solely on stakeholder input, expert elicitation, and commonly available GIS data.

There are four data requirements for ESValue^{SM}application:

1) A list of key ecosystem services valued by stakeholders or decision-makers,

2) Input from scientists on the key determinants of ecosystem service quality (to be used in ecological production functions that specify, for example, the impact of development on riparian habitat quality as a function of groundwater levels, proximate population density, and habitat fragmentation)

Ecological Production Function

Purpose: To define the ecological effect of a management action or policy in terms of changes in the flow of key ecosystem services. Specifically, this step is to measure the change in physical or biological attributes of the ecosystem with social value.
Data Needs: Utilizes available data – including GIS layers and general scientific knowledge about key cause and effect relationships in ecosystem. Relationships defined based on input by Cardno ENTRIX scientists and/or local experts.

Social Value Function

Purpose: To identify preferences and relative value/importance of affected physical or biological attributes to stakeholder populations.
Data Needs: Input by stakeholder populations during structured facilitation sessions and follow up.

3) Input from stakeholders and decision-makers on their preferences for different ecosystem services, and

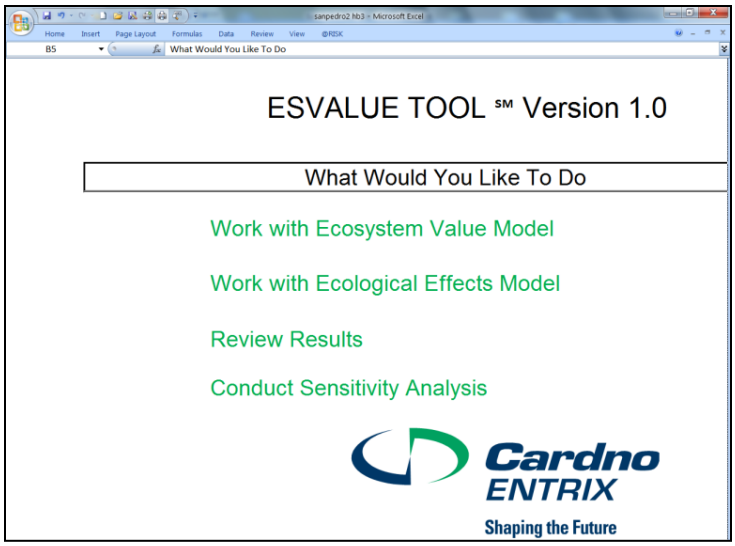
4) Commonly available GIS layers to conduct a spatial analysis with a minimal amount of processing.

Based on these inputs, ESValue^{SM} estimates the effect of different management options on ecosystem services and the resulting effect on ecosystem service value.

1.2 Data acquisition methodology or process of identifying and sourcing data for your tool, specifically citing public agency data sets used and/or documenting the methodology used in gathering primary data.
The tool has two primary components:

- Ecological effects model – shows the effect of development on ecosystem services based on science
- Ecosystem service valuation model – shows the relative value of ecosystem services to stakeholders

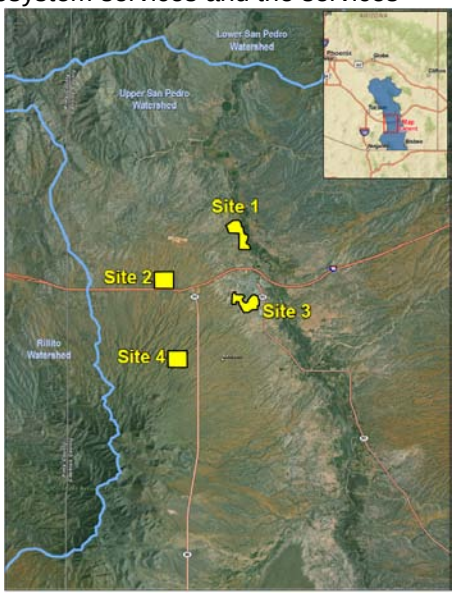
Results from these two components are integrated within a spreadsheet model to estimate the effect of development on value of ecosystem services. The results of the analysis provide an overall relative 'score' for each option, which can be mapped to display spatial distribution of results. Furthermore, a sensitivity analysis shows the key ecological effects and values that are affecting the decisions and/or are have



uncertain impacts based on current information.
In parallel with the four data requirements outlined above, there were four steps to identifying and sourcing data for the application in the San Pedro watershed.

Step 1: Define Options & Identify Key Ecological Effects and Ecosystem Values

Cardno ENTRIX social and natural scientists developed an influence diagram that describes the relationships between location of the development, the impact on ecosystem services and the services that stakeholders might value. In the case of the San Pedro residential development, the key project variables determining the effect of the project on ecosystem services include: location, size, water use, quality/quantity of water runoff, and air and light emissions. ESValue^{SM} focuses the analysis on the differences between the alternatives (rather than conducting an exhaustive inventory of all ecosystem services), to ensure that time and money are optimally dedicated to identifying the best possible alternative. The map below highlights the four potential development sites evaluated.

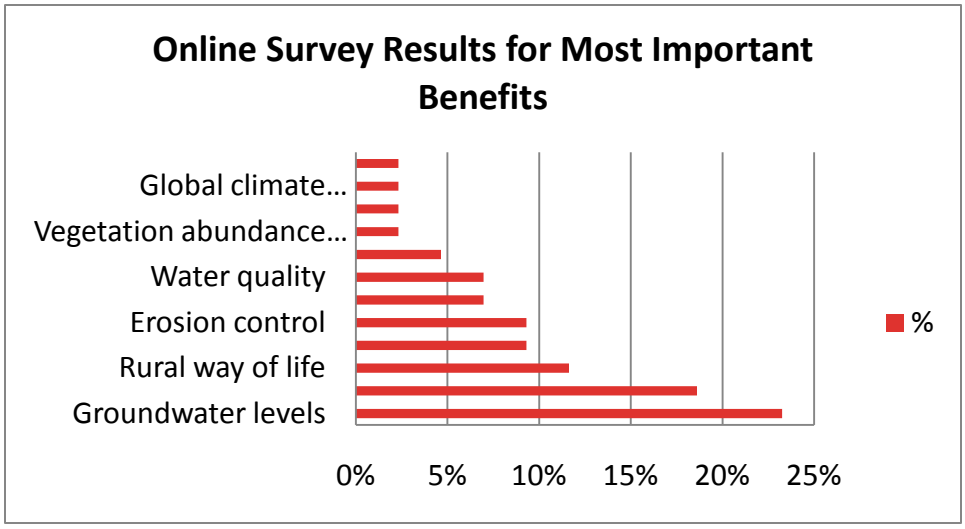


Step 2: Identify Key Ecosystem Services to Value

Ecosystem Service valuation is an iterative process between natural and social science. Using the results of Step 1, we developed an on-line survey to solicit feedback from stakeholders in the Basin (members of the CWA) to identify which of these potentially affected services are important to them. Based on the feedback from the CWA, we developed a condensed list of 16 potential ecosystem services to value. As highlighted in Figure 2, the most important ecosystem services to the CWA included streamflow, groundwater levels, preservation of the rural way of life, erosion control, and species diversity. Finally, the Cardno ENTRIX team reviewed the available data and assessed which biological and physical attributes could feasibly be measured and valued by stakeholders. Through this process, we identified potential ecosystem service metrics to measure the change from the project.

Step 3: Ecosystem Value Model

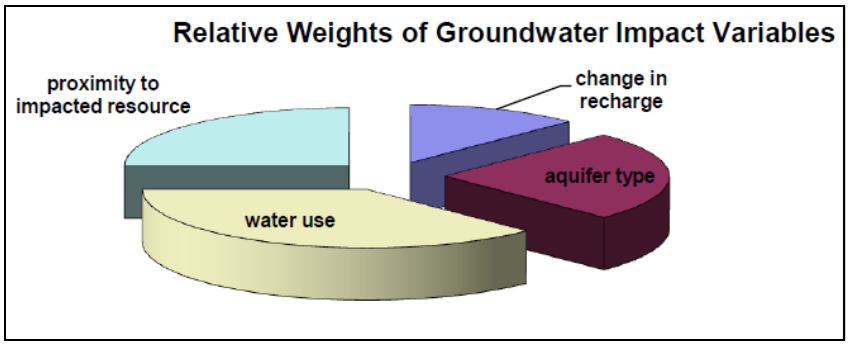
Valuing ecosystem services requires an understanding the importance of these services to stakeholders. ESValue^{SM} measures the *relative* value of each key ecosystem service rather than the *absolute* monetary value (which can be controversial or inaccurate, and difficult or costly to develop). Cardno ENTRIX met with the CWA and facilitated a valuation session to estimate the relative importance to each member of the CWA of each of the key ecosystem services potentially affected by a residential development. After categorizing the key ecosystem services into four groups, the CWA ranked a series of scenarios based on their preferences. This ranking was statistically analyzed to estimate the relative value (and associated certainty) of each key ecosystem service. Results from this session indicated that water (particularly stream flow and water quality) and air quality (particularly



light pollution) were very important to the CWA (see model results below). In other words, it is important to local stakeholders to select development alternatives that protect water and air quality.

An important consideration in valuing ecosystem services is carefully distinguishing between intermediate (or indirect) services and final (or direct) services. Final services are those that can be valued by people, such as recreational bird watching opportunities. Intermediate services are those that are evaluated by scientists, such as the impact of stream flow on bird populations. It is often difficult for scientists and stakeholders to reach final consensus on this distinction. It requires learning by both sides and is it an iterative process. Because this was a demonstration project, we did not have the opportunity to implement the iterative approach.

Step 4: Ecological Effects Model



ESValue^{SM} develops relative ecological value in a parallel manner to relative social value. We worked with local experts and used available scientific data to define the ecological effects relationships for the 16 ecosystem services valued by stakeholders. The ecological effects model specifies the relationship between the provision of each ecosystem service and key ecological parameters that may be modified by the project. ESValue^{SM} is flexible and can use data on ecological relationships as specified in other models, direct data of key parameters (e.g. footprint of the development), or expert judgment models. For example, one of the ecosystem services valued was maintenance of groundwater levels. We used the expert elicitation module of ESValue^{SM} to identify the following variables that determine impact on groundwater: proximity of a site to the proposed project, water use of the project, aquifer type, and change in recharge. Figure 4 shows the relative importance of each in affecting groundwater levels.

GoHome Go Results

Summary of Value Weights - Per Unit

Service	Criteria	Relative, Within Service	Service Percent of Total	Service	Criteria	Relative, Within Service	Service Percent of Total
Group A - Air Quality			27%	Group C - Human Land Use	-		16%
	Air Pollutants	32.5%			Sustainable Communities	23.3%	
	Carbon Emissions	0.0%			Recreation Access	40.6%	
	Carbon Sequestration	0.1%			Agricultural Land	0.1%	
	Light Pollution	67.4%			Views/Open Space	36.0%	
		0.0%					
Group B - Water			38%	Group D - Ecosystem Function	-		19%
	Groundwater levels	5.3%			Riparian Habitat	0.2%	
	Streamflow	53.1%			Upland habitat	0.0%	
	Water Quality	36.0%			Aquatic Habitat	79.8%	
	Recharge Quality	5.6%			Soil Conservation	20.0%	

1.3 Process for uploading data and preparing for tool application including data preparation.
The GIS based site information was converted to table format and entered directly into ESValue^{SM}. Information from stakeholders and experts was also directly entered into the tool during the framing session and webinar.

1.4 Time implications to source and/or prepare data for inputting into the tool, particularly highlighting staff time implications at what level of staff experience.
As nearly all data used in ESValue^{SM} is based on stakeholder preferences and expert opinion, data can be collected quite rapidly (subject to scheduling constraints for stakeholder and science expert input sessions).The major steps for setting up the San Pedro application included the logistics for setting up the focus groups and webinar of stakeholders. We estimate that Cardno ENTRIX staff spent about 60 hours on gathering input from stakeholders and that each stakeholder committed about 10 hours to participate. Preparing the GIS data, meeting with scientists and collecting expert opinion, as well as setting up the ecological production functions required an additional 100 hours of Cardno ENTRIX staff time. Finally about 40 hours were spent on running the tool and analyzing the results. Based on what we've seen with similar projects in the past, we would estimate that a typical project, run completely by a company's or agency's staff, would require about 200 hours of staff time.

1.5 Challenges encountered in sourcing and/or inputting data, noting whether these challenges were unique to this site or should be planned for in the future.
The challenges that we encountered here are similar to those we have encountered in other applications. They include: 1) scheduling meetings with stakeholders and educating them about how ESValue^{SM} works and provides value (our first contact with CWA was in early May, the focus group was held on September 21st); and 2) identifying the best approach to collaborate with scientists (each discipline has its own approach to understanding and specifying ecological relationships, and showing them that the ESValue^{SM} process can capture the unique aspects of their discipline is always a challenge).

1.6 Answers to corporate-relevant 'questions' posed to each tool, including:

1.6.1 *New Project Siting / New Project Developme*nt

Where would be the ideal site for a new residential project in order to have the least impact ecosystem services? Why?

1.6.2 *Existing Infrastructural / Project Expansion*
Where (and if possible how) would you expand growth of residential units on the US side of the border? Why?
See above – answers to this question would be nearly identical to the development of new projects. Although not explicitly considered in the ARIES models, existing expansion that is near currently developed areas would reduce the landscape and habitat fragmentation resulting from highly dispersed development.

1.6.3 *Land Management*
What are the areas where focused ecosystem service-related investments would offer potential benefits?
What are the recommended investments?
What ROI (quantitative or qualitative) would be realized on what time frame (e.g., payments from environmental market transactions, real estate sales, etc.)?
What might be ways to avoid regulatory exposure in light of:
Endangered species habitat sites?
Indigenous peoples / Native American claims sites?
Other?

Once the effects and value functions are complete, ESValue^{SM} shows the type and location of residential developments that will provide the least impact on ecosystem service values. ESValue^{SM} uses @Risk to estimate a 'score' for each development alternative based on the effects and values and the uncertainty associated with the information. This score reflects the relative value of ecosystem services for each development alternative.

For the four project sites evaluated in the San Pedro, the analysis shows that Site 4 has the highest overall score, and is the best choice from the standpoint of ecosystem service values. A sensitively analysis also shows for each site what the range of certainty is for the relative score finding, and how likely it is that Site 4 is the best choice. As discussed above, ecosystem services in the air quality and water groups are most important to stakeholders. Site 4 preserved the most value in these ecosystem services by minimizing impact on the key ecological parameters affecting air quality and water.

Summary of Score Results

Strategy	Site 1	Site 2	Site 3	Site 4
Group A - Air Quality	(1.61)	(1.56)	(3.71)	(1.57)
Group B - Water	(1.03)	(0.46)	(1.05)	3.59
Group C - Human Land Use	4.20	3.20	2.58	1.89
Group D - Ecosystem Function	(7.55)	(1.39)	0.93	(1.68)
Total	(6.00)	(0.21)	(1.25)	2.24
Percent Ranked # 1	9%	12%	27%	52%

1.7 Reflections on corporate applications of your tool, such as:

1.7.1 Appropriate conditions and contexts in which to apply the tool.

1.7.2 Relationship between environmental impact and ecosystem services, particularly in terms of how this tool might 'interface' with pre-existing corporate tools and processes for assessing impact.
1.7.3 Building the business case of how this tool may improve corporate environmental systems and processes for decision-making.

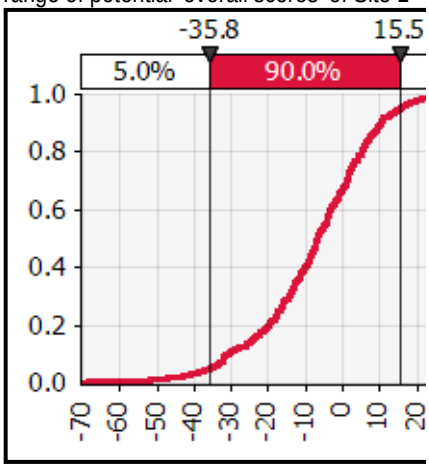
ESValue^{SM} is an integrated model of ecological effects and stakeholder values that is used at the strategic level to indentify how proposed projects will affect the value of ecosystem services. The results of the model identify the drivers of ecosystem effect, priorities to stakeholders, and data gaps such as where additional scientific research and work with stakeholders are needed. The model identifies where the largest sources of uncertainty are, and helps to prioritize next steps so that additional research will have the biggest payoff. Although used in just initial phases in the San Pedro application to identify development locations that would minimize impact on ecosystem services important to stakeholders, the model has much broader applications, including:

1. Evaluating alternatives of project variables such as size, siting, and resource use;
2. Identifying mitigation priorities; and
3. Determining additional ecological data and community outreach needs.

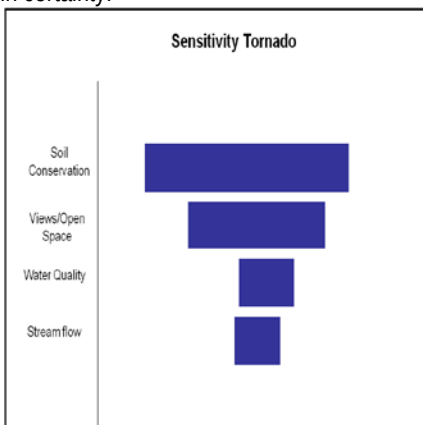
Sensitivity Analysis

ESValue^{SM} conducts sensitivity analysis of the inputs and the results to indicate:

- *Certainty of results*, or the probability that a particular alternative will best meet objectives. The diagram below shows the range of potential 'overall scores' of Site 1



- *Drivers of Uncertainty*, or which inputs are the primary sources of uncertainty. This analysis identifies where data gaps exist, where experts and stakeholders disagree, and where additional research or outreach will provide the greatest increase in certainty.



In summary, ESValue^{SM} brings together ecological data with social and economic values to more comprehensively and holistically support decision-making on projects with environmental consequences.

Component #2: Cardno ENTRIX ESValue Tool

Understanding the Tool	• What is the objective of the tool / methodology? • Who are the intended users? • What is the intended use of the tool? • What do outputs look like? o Excel spreadsheet? Narrative interpretation? Explicit mapping?	• This is a strategic decision support tool that integrates scientific and economic information to show the impact and value of alternative environmental management strategies on ecosystem services • The objective of ESValue^{SM} is to integrate existing information and expert opinion with stakeholder values to efficiently and effectively identify the key site-specific ecological effects and resulting change in economic value for different management strategies • The users can include private corporations, non-profit organizations, and public agencies • The intended use is to provide a systematic and transparent framework for estimating ecosystem service impacts and an initial high-level performance assessment of alternative management strategies • The output is in Excel Spreadsheets (identifying the economic value and ecological relationships). The output can also be represented spatially in landscape mapping
Considering Analytical Parameters of Tool	• Which ecosystem services does the tool currently include? • Which ecosystem services does it omit? • Are there any services being used as proxies for others? If so, which? • Do you have plans to build out the tool to include other ecosystem services? If so, on what timeline?	• ESValue^{SM} is flexible. It can include any ecosystem services that the users feel are affected by the management strategies or are important to value • The users define which ecosystem services are to be evaluated and the extent to which they are proxies for other services. ESValue^{SM} can incorporate additional ecosystem services that are identified by the users.
Assessing Data Requirements, Quality & Costs of Application	• What are the data requirements? **A) Preexisting databases: If the tool runs on databases:** - What are the database sources? - What issues exist with these database sources, if any? (e.g., quality, reliability, verification, replicability, availability) - What assumptions are embedded within these databases? **B) User provides data: If the tool requires input data**, what are the time and costs for acquisition and verification of data? • What is the quality of the data (reliability, verifiability, credibility): - on the input side? - on the output side? • Is sensitivity analysis included? Qualitatively or quantitatively? • Does the tool have capability for technologies to feed data into the tool? • Is the tool designed to interface with GIS, carbon measurement technologies, mesh networks or other technologies?	• ESValue^{SM} does not have preset data requirements. The tool is adaptable to different levels of existing data and is designed such that it can be used with minimal amounts of data or data that can be easily generated. In fact, a primary value of ESValue^{SM} is to help determine the additional research that will provide high-value data for the decision at hand. ESValue^{SM} relies upon expert judgment of scientists and stakeholders (broadly defined), supplemented where desirable with existing scientific or valuation data. The quality and reliability of data inputs thus depends on the participation of a diverse group of stakeholders and experts • The reliability and credibility of ESValue^{SM} outputs for decision-makers is high as the ESValue^{SM} process is very transparent and decision-makers participate in customizing and providing key tool inputs • Quantitative sensitivity analysis is

	• Are you exploring potential technology interface points or partnerships with large database firms (e.g., IBM or Microsoft)? • What are the anticipated resource (human or otherwise) requirements of the tool? (Provide $$ and/or labor hour examples based on pilot projects)	included to illustrate which key elements of the management decision drive effects, as well as to identify the level of certainty associated with which is the preferred management decision • It does not have the capability for technologies to be directly linked to feed data into ESValue^{SM}, but information from other sources can be used as inputs to specify ecological relationships. • The results of ESValue^{SM} can be used with GIS to spatially analyze and display the impact of decisions on ecosystem services. • We are exploring relationships with software developers to more fully automate ESValue^{SM} and provide for rigorous probabilistic modeling • Resource requirements for ESValue^{SM} (to organize and facilitate stakeholder and expert input, as well as analyze and display data) can vary significantly, but are approximately 160 hours
Accessing the Tool	• What is the availability of the tool? • Specifically: - Will the tool be broadly available through online materials? - Will companies be required to work with the tool developers directly as the 'delivery mechanism'? - If neither, what are the plans? • What are future availability / 'delivery' plans for the tool? On what timeline?	• Future delivery of an enhanced stand-alone version of ESValue^{SM} will depend on user demand
Assigning Values within the Tool Application	• Does the tool / methodology assign value to ecosystem services? - *If so*, what type of value is assigned and how is it assigned? o Economic (e.g., pounds of fish, cubic feet of water): Monetary or non-monetary? - *If the tool does <u>not</u> assign value in some economic unit,* then does the tool assign weight? If so, how? • How does the tool avoid double-counting (e.g., clean water to produce fish, if also counting fish)?	• ESValue^{SM} specializes in estimating or assigning ecological and economic value to ecosystem services • ESValue^{SM} can incorporate and compare both monetary and non-monetary values based on stakeholder preferences. • All economic values can be converted to dollar denominated values so long as users supply a range of values for a few key ecosystem services. • ESValue^{SM} uses conjoint analysis (choices between alternatives) to assist the user and stakeholders (broadly defined) to determine the weight that should be given to each ecosystem service. The conjoint analysis is the primary exercise of the valuation tool. • Facilitators work with users to ensure the benefits are not double counted. It has been our experience that that eliminating double-counting is an iterative process that requires reviewing tool output and sensitivity analysis and gaining knowledge about the specific application.

ESR

Component #1 – Overview of ESR's Application to the San Pedro Watershed

1.1 Data needed for tool application.
A method, or process, ESR requires minimal data to "run." Data on the size of the project impact, magnitude of other impacts (i.e., water use for the San Pedro), are helpful for comparing relative impacts but not strictly necessary. What is essential is a good understanding of the project site, potential impacts, and ecosystem sensitivity to a particular change (e.g., groundwater pumping), as well as alternatives to minimize impacts and a consensus on system boundaries of the projects impacts (i.e., direct site impacts, impacts from other resources used during the project, life cycle impacts, etc.).

1.2 Data acquisition methodology or process of identifying and sourcing data for your tool, specifically citing public agency data sets used and/or documenting the methodology used in gathering primary data.
The only primary data needed for the ESR were to obtain per capita water use (from ADWR) and an estimate of the initial project size. These data were needed to define the scope of the analysis, but are not strictly used for any quantitative analysis.

1.3 Process for uploading data and preparing for tool application including data preparation.
n/a

1.4 Time implications to source and/or prepare data for inputting into the tool, particularly highlighting staff time implications at what level of staff experience.
Less than one week was needed to complete the ESR worksheet and document assumptions, strengths, and weaknesses of the approach. Greater time requirements would likely be encountered in a "real world" ESR application versus a hypothetical application completed by a single analyst. In the real world, company members from different business units, backgrounds, etc. must be brought together, educated on the basic concepts of ecosystem services, brought into the decision-making process, and have their input solicited and synthesized by the analyst. These time requirements may not be trivial, depending on the scope of the analysis, organizational culture, and baseline knowledge about ecosystem services within the organization.

1.5 Challenges encountered in sourcing and/or inputting data, noting whether these challenges were unique to this site or should be planned for in the future.
The analysis was relatively straightforward for a hypothetical case conducted by a single analyst familiar with the study area and general ecosystem services concepts.

1.6 Answers to corporate-relevant 'questions' posed to each tool, including:

1.6.1 *New Project Siting / New Project Development*

Where would be the ideal site for a new residential project in order to have the least impact ecosystem services? Why?
As the ESR is a qualitative tool that does not spatially map the location or quantity of ecosystem-services related project impacts, it relies on expert advising to answer questions about project siting and to follow general guidelines that minimize site impact (i.e., reducing project footprint, acres of land disturbed, acre-feet of water withdrawn, degree of site fragmentation, avoidance of more valuable land cover types, etc.).

Note from WRI: Expert judgment or focus groups could be used to determine the "best siting" This is the same technique used in structural equation modeling. We've seen this done. The "benefit" of this is that often you don't need an elaborate tool to make the "best choice" – or selectively run more complex modeling on the ES on which you want more detail.

1.6.2 *Existing Infrastructural/Project Expansion*
Where (and if possible how) would you expand growth of residential units on the US side of the border? Why?
See above – answers to this question would be nearly identical to the development of new projects.

1.6.3 *Land Management*
What are the areas where focused ecosystem service-related investments would offer potential benefits?
What are the recommended investments?
What ROI (quantitative or qualitative) would be realized on what time frame (e.g., payments from environmental market transactions, real estate sales, etc.)?
What might be ways to avoid regulatory exposure in light of:
Endangered species habitat sites?
Indigenous peoples / Native American claims sites?
Other?
Similar to the answer to question 1.6.1, investments might be made to maximize carbon sequestration and storage, minimize threats to biodiversity, and reduce water demand in the watershed (which also reduces the threat brought on by excessive groundwater pumping). Avoided regulatory exposure can most significantly be avoided by avoiding dewatering of the San Pedro's riparian ecosystem by limiting expansions to extraction, increasing water conservation, and bringing the San Pedro's water budget into balance. All these decisions will likely require increased political will to change economic incentives regarding water use and balance the San Pedro's water budget.

1.7 Reflections on corporate applications of your tool, such as:

1.7.1 Appropriate conditions and contexts in which to apply the tool.
ESR is strongest as a project scoping tool – to raise awareness of ecosystem services in corporate decision-making context, and to determine which services should be evaluated in greater detail (i.e., quantified through direct measurement, modeling, and/or mapping.

1.7.2 Relationship between environmental impact and ecosystem services, particularly in terms of how this tool might 'interface' with pre-existing corporate tools and processes for assessing impact.
ESR has been well developed and highly marketed as a corporate decision-making tool. It could interface well with quantitative and/or mapping tools (e.g., ARIES, InVEST, IBAT, Ecometrix, others) or valuation tools (e.g., Defenders of Wildlife Wildlife Habitat Benefits Estimation Toolkit) to more fully asses impact.

1.7.3 Building the business case of how this tool may improve corporate environmental systems and processes for decision-making.
This is well-documented by past ESR materials.

Component #2 – ESR Description

"The Corporate Ecosystem Services Review (ESR) is a structured methodology for corporate managers to proactively develop strategies for managing business risks and opportunities arising from their company's dependence and impact on ecosystems."
Excerpted from web page description: http://www.wri.org/project/ecosystem-services-review

The ESR has been developed by the World Resources Institute (WRI), the Meridian Institute, and the World Business Council on Sustainable Development (WBCSD). It is intended to "bridge environmental and corporate strategic considerations, starting with an evaluation of a company's interactions with ecosystems and finishing with a strategic plan to respond to these interactions."

The ESR methodology includes five steps:

1. ***"Select the scope.*** Define clear organizational boundaries within which to conduct the ESR. The purpose of this step is to focus the subsequent analysis, keep the process manageable, and yield more actionable results.
2. ***Identify priority ecosystem services.*** Evaluate in a systematic, structured, yet rapid manner the company's dependencies and impacts on more than 20 ecosystem services. This evaluation will help identify which of these are "priority" services—the ones most likely to be a source of risk or opportunity for the company. These priority ecosystem services are the focus of analysis in subsequent steps.
3. ***Analyze trends in priority services.*** Research and analyze the status and trends in the priority ecosystem services.

4. ***Identify business risks and opportunities.*** Evaluate the implications for the company of its dependencies and impacts on ecosystem services and of the ecosystem service trends. The purpose of this step is to identify the business risks and opportunities that might arise due to these dependencies, impacts, and trends. Risks and opportunities could involve corporate operations, government regulations, corporate reputation, market/product strategies, or access to capital.
5. ***Develop strategies for addressing risks and opportunities.*** Develop strategies for minimizing the risks and maximizing the opportunities. The purpose of this step is to provide a prioritized set of strategies for corporate managers to implement. Strategies may include changes in internal corporate practices, engaging sector peers or other stakeholders, or working with policymakers to create incentives for sustainable management of ecosystems and the services they provide."

The outputs of this ESR are provided in three formats:

(1) Excel spreadsheets – visually showing priority ecosystem services; (2) **Narrative reports** including summaries of key trends and drivers in priority ecosystem services, and (3) **List of business risks and opportunities,** including an 8-9 page memo and/or a PPT to management (outlining process, critical ecosystem services, key trends, risks, strategies, etc.)

The process of developing the ESR has included pilot testing and input from a range of industries and companies, from Akzo Nobel, BC Hydro, Mondi Group, Rio Tinto, through Syngenta.

With regard to the Working Group questions, the tool developers assert:

Assigning Values	**Assigning (and Balancing) Value?** • The ESR is not a valuation tool. Rather, it lays out a framework to identify and explore issues. • The methodology highlights where a review would be effective and how its impact compares to alternative strategies. • An example of how the ESR can provide a framework to facilitate the exploration of issues can be seen in the BC Hydro case study (within the ESR document, which will be sent by WRI prior to the webinar) which: (1) detailed every user of the river / water resources (boating, sailing, fisherman, town for water resources, etc.), (2) developed 20 distinct scenarios to explore, which ESR specialists assisted to examine for dependencies on ecosystem service dynamics (e.g., effects of climate change on other variables, such as water availability), rather than just a focus on impacts on these ecosystem services, and (3) held a series of meetings—with full, open access to information and data—until everyone agreed on a scenario to pursue. **Public Input Process into Assigning Value?** • Several interface points that the ESR recommends throughout the process: (a) including stakeholders in the identification of priority ecosystem services; (b) in the trends analysis where all stakeholders and their uses are defined, (c) in the risk and opportunities identification section and (d) in the strategies section where involving stakeholders and lead to more creative strategies. Because the ESR is an iterative methodology, as value stakeholder values are uncovered late in the process, previous steps can be easily revisited, possibly uncovering new opportunities. • The ESR has been developed to neatly mesh with the standard stakeholder engagement tools, such as the standard corporate stakeholder engagement as well as participatory rural appraisal (PRA) in developing countries. The ESR can also be run independently of these procedures, possibly uncovering new perspectives and ways to improve existing corporate guidelines.
Applying within Existing Corporate Decision-Making	**Use within Existing Corporate Processes for Stakeholder Engagement:** • In complex multi-year facilitated decision-making processes, the ESR has to be overlaid throughout the process to be effective.

Processes	• For example, in one of the pilot tests, there was insufficient data to undertake a full ESR. In response, the ESR team recommended multiple gatherings of key stakeholders over the course of 3 years, in order to jointly undertake a trends assessment of ecosystem services dynamics concurrent with the corporate dependencies assessment. • In other cases, a subset of the problem was identified, and 3 experts were contacted, providing a quick analysis of a single geographic area. • Overall, the ESR was designed to improve on existing processes. . **Fit with EMS' and/or EIAs?** • At present, it is recommended that companies integrate ESR into existing processes and protocols for environmental management. However, there are no specific guidelines for doing so to date. • The meshing of the ESR with EMS' and EIAs is the next step developing the methodology, which could entail creating a specific tool that would more systematically integrate ESR questions / analytical approaches to current decision-making processes within companies. **Interface Points with Existing Corporate Data Gathering and Decision-Making** • The ESR does not currently get to this level of detail.
Identifying Assumptions within Tools	**Assumptions?** • The ESR is based on the Millennium Ecosystem Assessment, which included a core premise about the interdependence of the ecosystems and the economy. Therefore, the ESR includes the same assumptions that: (1) the economy is dependent on healthy ecosystems and that there are tradeoffs between use of ecosystem services (e.g., crops, timber, and flows of water), and (2) the challenges that we have is how to draw more ecosystem services while not undercutting other services. • In addition, the ESR is premised on assumptions that a company is likely to: (a) Face real, material implications on the bottom line based on its *impacts* on ecosystem services, (b) Encounter real risks in contexts where ecosystem services which are *depended* upon become scarce or degrade—in the form of resource risk, regulatory risk, brand risk, and other risks, and (c) Strong economic opportunities exist for companies that proactively infuse ESR thinking into their operations, and (d) Be currently providing or have the potential to *provide* ecosystem services (e.g., a timber company provides both service of timber as well as carbon sequestration) **Interface with profitability goals?** • The ESR points to five types of risks and opportunities, including participation in environmental markets, fight to operate, brand identification, new products, among others.

InVEST

Component #1 – Overview of the Tool's Application to the San Pedro Watershed

1.1 Data needed for tool application.
To run the biodiversity, carbon, and water yield InVEST models, we used land use-land cover data from the Southwest Regional GAP Analysis (SWReGAP) project, which provides seamless data covering the U.S. & Mexican portions of the watershed. Additionally, the biodiversity model required user-defined "threats" data for highways, grazing lands, land ownership ("access to threats"), and wells. The first two of these layers were obtained from ALRIS, the last from the ADWR Wells-55 Database, with wells in Mexico obtained from INECOL. Highway and land ownership data for Mexico were obtained from the EPA San Pedro Data Browser. Finally, added layers were used to run the water yield model: a DEM from SRTM, soil depth and PAWC from the SSURGO and STATSGO databases, annual precipitation data from PRISM at Oregon State University, and potential evapotranspiration data from CGIAR's Global Aridity and PET database. Finally, data to parameterize the InVEST coefficient tables were obtained from the literature and an expert workshop convened in Tucson from Sept. 21-23, 2010. All data sources and model assumptions will be fully documented as part of the project report for the BLM-USGS Ecosystem Services Valuation Pilot, to be produced in the winter of 2010-2011.

1.2 Data acquisition methodology or process of identifying and sourcing data for your tool, specifically citing public agency data sets used and/or documenting the methodology used in gathering primary data.
See above – nearly all datasets were public (from academic, agency, or other research organizations), with sources to obtain spatial data and parameterize the InVEST data table obtained from the user guide and the analyst's familiarity with local through global scale spatial datasets.

1.3 Process for uploading data and preparing for tool application including data preparation.
All data must be placed in a common workspace and projected to a common projection (in meters), in this case NAD83 UTM Zone 12N. Certain layers (i.e., "biodiversity threats" such as highways and grazing lands) must be rasterized, and a point density layer of wells was created to show the density of wells per square km. Preparation of the SSURGO and STATSGO databases required the use of the USDA-NRCS Soil Data Viewer to aggregate soils data across horizons, producing a single value for each polygon (followed by rasterization of the vector data). Finally, in many cases, data from the U.S. and Mexican parts of the watershed had to be combined using the ArcGIS "mosaic" tool. Some care had to be taken to create these mosaiced data layers to ensure that concepts were similar on both sides of the border. This required reclassification of some layers. Parameterizing the InVEST data tables was the most time consuming and potentially subjective part of the modeling effort. This work required collecting and reading all references suggested by the InVEST modeling guide, collecting follow-up references, and making sometimes-difficult judgment calls when specific data were not available that corresponded to a particular land cover type (a frequent occurrence).

1.4 Time implications to source and/or prepare data for inputting into the tool, particularly highlighting staff time implications at what level of staff experience.
Perhaps four weeks of time (ca. 160 hours) were needed to collect and prepare data for the three InVEST models, run the models, and begin to improve them to "second generation" status using expert input from the Tucson workshop. A full "second run" of InVEST models may add an additional 2-3 weeks of time required. A basic level of proficiency with ArcGIS is necessary. Time required would be substantially greater for a user unfamiliar with the idiosyncrasies inherent in GIS datasets and their processing requirements. Time required would be substantially less if pre-prepared datasets and InVEST coefficient tables were available in a common format, for either direct use or as primary references, perhaps for a particular agency (BLM, USGS), department (DOI), or as a cross-department/cross-agency ecosystem services initiative.

1.5 Challenges encountered in sourcing and/or inputting data, noting whether these challenges were unique to this site or should be planned for in the future.
Several challenges were encountered, some likely to be inherent in any InVEST application, and others unique to the case study area. First, inherent to any InVEST application is the need to develop coefficient tables to link land use-land cover to ecosystem services provision. Despite decades of research on the ecology and hydrology of the San Pedro, many of the types of information required by the InVEST tool are still

unavailable for the area. This demonstrates the disconnect that has existed between past ecological and hydrologic research and the data needs inherent to ecosystem services modeling. This disconnect and often limited data availability forced me to make assumptions about the transferability of ecological knowledge that could be open to criticism from other scientists. Second, data preparation is a time consuming effort in InVEST. If InVEST were to be widely applied by a particular agency, department, or cross-agency effort, better databases containing InVEST-ready datasets could reduce these time requirements. These two challenges are common to any InVEST application. Other challenges apply specifically to the San Pedro. First, the San Pedro is a transboundary watershed, requiring the user to combine U.S. and Mexican or global datasets. This raises issues with proper convolution of data, which is a time consuming process and can cause further error if done incorrectly. Finally, because the San Pedro is in an arid/semiarid environment, several of the simplifying assumptions used in the water yield model were deemed significant by experts and decision makers in the area. There was strong resistance to using any of the water yield results in a decision context, as it was felt that the models lacked a proper foundation in arid and semiarid hydrology and would produce results that were overly naïve or were misleading in a decision context. These critiques will be passed on to the InVEST development team in hopes that they can inform development of stronger water modeling efforts in future applications to arid and semiarid systems.

1.6 Answers to corporate-relevant 'questions' posed to each tool, including:

1.6.1 *New Project Siting / New Project Development*

Where would be the ideal site for a new residential project in order to have the least impact ecosystem services? Why?
An ideal project site would have the following attributes: 1) related to the carbon models, new development should disturb minimal areas of high carbon storage (forest, riparian, oak woodland, mesquite, as opposed to ecosystems that store less carbon, like grasslands and desert scrub); 2) related to the biodiversity models, new development should be accompanied by minimal additional road infrastructure (i.e., be located near roads) and with minimal additional water demand (i.e., requiring as few new wells and groundwater extraction requirements as possible). Finally 3) the water yield model as currently run was deemed to be inappropriate for use in the San Pedro. Given the runoff relationships specified in the model, new development actually increases water yield, yet those negative impacts are not properly accounted for by the model. In particular, if the demand side of the water use equation is not included, results will appear biased in favor of maximizing impervious surface. This has known negative impacts on other ecosystem services, including erosion in the San Pedro (note that the InVEST avoided reservoir sedimentation model was not run for the San Pedro because erosion was not identified as one of the four key ecosystem service parameters to include in the analysis). A better comparison of tradeoffs related to hydrology might be obtained by running the water scarcity model (provided it can be run without accounting for dam characteristics, since there are no dams on the San Pedro) and by running the avoided sedimentation model, which can give biophysical outputs, but not economic value outputs when there are no reservoirs.

1.6.2 *Existing Infrastructural/Project Expansion*
Where (and if possible how) would you expand growth of residential units on the US side of the border? Why?
See above – answers to this question would be nearly identical to the development of new projects. Although not explicitly considered in the InVEST models, existing project expansion that is near currently developed areas would reduce the landscape and habitat fragmentation resulting from highly dispersed development.

1.6.3 *Land Management*
What are the areas where focused ecosystem service-related investments would offer potential benefits?
What are the recommended investments?
What ROI (quantitative or qualitative) would be realized on what time frame (e.g., payments from environmental market transactions, real estate sales, etc.)?
What might be ways to avoid regulatory exposure in light of:
Endangered species habitat sites?
Indigenous peoples / Native American claims sites?
Other?
Similar to the answer to question 1.6.1, investments might be made to maximize carbon sequestration and storage, minimize threats to biodiversity, and reduce water demand in the watershed (which also reduces the threat brought on by excessive groundwater pumping). Avoided regulatory exposure can most significantly be avoided by avoiding dewatering of the San Pedro's riparian ecosystem by limiting expansions to extraction, increasing water conservation, and bringing the San Pedro's water budget into balance. Given the

complex nature of the San Pedro's groundwater and the simplistic way InVEST deals with groundwater, its value to support decision-making about groundwater will probably remain limited until it can incorporate existing groundwater models (i.e., local applications of the MODFLOW model), perhaps as part of the InVEST Tier 2 models. All these decisions will likely require increased political will to change economic incentives regarding water use and balance the San Pedro's water budget.

1.7 Reflections on corporate applications of your tool, such as:

1.7.1 Appropriate conditions and contexts in which to apply the tool.
InVEST is primarily useful in evaluating alternative options for management of business owned lands or waters for ecosystem services (to optimize ecosystem services or determine where to manage for enhanced provision of certain services), such as where to locate new activities, determining the ecosystem service impacts of major business project investments, which may be relevant for compliance with regulations, demonstration of proper consideration of environmental safeguards or to gain license to operate, identifying which areas to avoid impacting and how current activities may be improved. In addition InVEST may be useful for seizing emerging markets and payments for ecosystem services (determining who should pay whom and how to scale up). Further interaction with corporate decision-makers would be likely to illuminate other ways InVEST is applicable to corporate decision-making.

1.7.2 Relationship between environmental impact and ecosystem services, particularly in terms of how this tool might 'interface' with pre-existing corporate tools and processes for assessing impact.
Depending on the proposed activity that is being assessed for impact, InVEST may be useful for evaluating potential impacts on ecosystem services (positive or negative), which would be appropriate to include in environmental impact documents. The World Resources Institute (WRI) has used InVEST and the Defenders of Wildlife's habitat benefits toolkit to do a Corporate Ecosystem Services Review.

1.7.3 Building the business case of how this tool may improve corporate environmental systems and processes for decision-making.
InVEST makes it easy for decision-makers to include the value of ecosystem services in decisions, resulting in improved sustainability and increased human well-being. InVEST will provide companies with critical ecosystem services information to minimize business risks and maximize opportunities. InVEST outputs are maps, which are useful for visualizing and communicating choices.

Component #2 – InVEST Tool Description

This table has been developed by corporate members of BSR's Working Group on Environmental Markets, Services and Tools to enable a side-by-side understanding of each of the multi-ecosystem services tools. Please complete as much as possible, using as brief a set of responses as possible.

understanding the Tool	• What is the objective of the tool / methodology? Enable a broad spectrum of users to quantify, map, and value the consequences of alternative land- and sea-use scenarios on ecosystem services and biodiversity. Scenarios may be driven by policy and management decisions and/or external drivers like climate change or population growth. InVEST was built to be a flexible tool that users can adapt to their own decision-making processes. Mapping the provision of multiple services under alternative scenarios allows users to identify where and when you get win-win situations and tradeoffs between services or between conservation and development. Including the value of ecosystem services in decision-making will improve human well-being. • Who are the intended users? Anybody who is affected by or affects land- and sea-use decisions, or who is affected by changing conditions in the land and sea (e.g. climate change, population growth), and who wants to analyze the ecosystem service consequences of choices they face. This may include government agencies in both developed and developing countries, businesses (particularly those with significant control over or impact on land or water), conservation NGOs, non-conservation NGO's (who impact land use or management), multi-lateral development banks, large private land owners, etc. Use requires some GIS proficiency and may also require some hydrological expertise to interpret and verify results. The aim is to keep the data input requirements and technical expertise relatively light, so that InVEST can be used anywhere in the world without extensive investment in data collection or expensive consultants. • What is the intended use of the tool? InVEST was intentionally built to be widely applicable to a range of policy process and decision contexts. It is meant to be used broadly and adapted locally to quantify, map, and value the consequences of alternative land use scenarios on ecosystem services and biodiversity. Scenarios may be driven by policy and management decisions and/or external drivers like climate change or population growth. It is intended to be used to visualize the impacts of land and sea use decisions, offer a transparent process for analyzing the consequences of changes, and for developing and sharing a vision of the future regarding ES and biodiversity across stakeholders in a policy or decision process. Maps help make it visual and quantification and location of services help to make nuanced decisions about management and policies that have varied/uneven consequences across a land/seascape. Use of scenarios provides opportunity to involve stakeholders in process of creating feasible storylines about the future based on existing information, beliefs, and desires from many stakeholders, contextualizing them into a quantitative, shared vision of the future. • What do outputs look like? o Excel spreadsheet? Narrative interpretation? Explicit mapping? Explicit maps of ecosystem services supply, use, and value and associated tables reporting outputs in biophysical and economic units.
Considering Analytical Parameters of Tool	• Which ecosystem services does the tool currently include? Carbon Storage and Sequestration Reservoir Hydropower Production (including surface water yield on the "supply" side) Water Purification: Nutrient Retention Avoided Reservoir Sedimentation

Managed Timber Production
Crop Pollination
Biodiversity: Habitat Quality & Rarity (not as a service but as an attribute of the ecosystem that supports services)

- Which ecosystem services does it omit?

Cultural and Aesthetic Values

- Are there any services being used as proxies for others? If so, which?

No.

- Do you have plans to build out the tool to include other ecosystem services? If so, on what timeline?

Marine ecosystem service models are in development and will be released in early 2011:

Coastal Protection (Inundation and Erosion)
Aquaculture
Capture Fisheries
Wave Energy
Recreation

Other marine ecosystem service models that will be released at a later date:

Biodiversity
Nursery Habitat
Transformation & Sequestration
Aesthetic (Views)

Terrestrial ecosystem service models that will be released at a later date:

Storm Peak Flow Mitigation
Water Yield for crop irrigation
Agricultural Production (yields and costs)
Open-Access Harvest (e.g. Non-Timber Forest Product, NTFPs)
Groundwater infiltration
In-stream processes added to hydrologic models

Assessing Data Requirements, Quality & Costs of Application	• What are the data requirements? **A) Preexisting databases: If the tool runs on databases:** - What are the database sources? - What issues exist with these database sources, if any? (e.g., quality, reliability, verification, replicability, availability) - What assumptions are embedded within these databases? Current models do not run on databases. The users provide all input data. **B) User provides data: If the tool requires input data**, what are the time and costs for acquisition and verification of data? • What is the quality of the data (reliability, verifiability, credibility): - on the input side? Tier 1 models are designed to work with globally available data, so that they can be used even in places where local data is scarce. However, many global data sources are coarse. - on the output side? The quality (resolution, accuracy, etc.) of outputs is only ever as good as the quality of inputs. • Is sensitivity analysis included? Qualitatively or quantitatively? InVEST users can run quantitative sensitivity analyses by iteratively changing coefficients and input variables. Currently there are no built-in sensitivity analysis functions. • Does the tool have capability for technologies to feed data into the tool? It is possible for technologies to feed data into InVEST because InVEST is built in ArcGIS, which can handle raw data from data collection technologies, such as remote sensing devices (e.g. LiDAR). However, the InVEST development team has not yet created any specific functionality to connect the outputs of specific devices/technologies to InVEST models. • Is the tool designed to interface with GIS, carbon measurement technologies, mesh networks or other technologies? Yes, InVEST is currently implemented entirely within GIS and is designed to be flexible enough to interface with other models and tools. • Are you exploring potential technology interface points or partnerships with large database firms (e.g., IBM or Microsoft)? Yes, in early stages of scoping, with more work to be done in the next 6-12 months. • What are the anticipated resource (human or otherwise) requirements of the tool? (Provide $$ and/or labor hour examples based on pilot projects) Depends on scope of analysis/scenarios, available data, and many other variables. A basic default human resource estimate for an application of InVEST would be 1-3 people for 2 months to 1 year to undertake full application of all ecosystem service models included in InVEST. *(Note:* Team would have to include a GIS analyst, with time to train in use of InVEST, and may also require a hydrologist). The extreme high end of the cost spectrum comes from the most extensive pilot project we've been involved with, which is across Eastern Africa's Arc Mountain range (Tanzania), an area as big as Montana. Analyses will include 5-6 services, focused on needs of

	policy makers, and is underway to meet highest academic standards. Cost: ~$3 million over 5 years. At the low end of the spectrum, InVEST is freely available online, and has been downloaded by ~1500 users. Students have downloaded the InVEST software to conduct their own analyses, with no budget.
Accessing the Tool	• What is the availability of the tool? InVEST is available through: a) Free, open-access download at: http://invest.ecoinformatics.org. The tool has been downloaded by ~1500 users since its release in October 2008. b) A book describing the science of the InVEST tool, with a focus on details for each module or service, will be published by Oxford University Press in 2011. c) A user's guide that provides step-by-step instructions for InVEST, including suggested data sources – available at http://www.naturalcapitalproject.org/InVEST.html • Specifically: - Will the tool be broadly available through online materials? It is already: http://invest.ecoinformatics.org - Will companies be required to work with the tool developers directly as the 'delivery mechanism'? No, for the time being, companies can download the tool and use it for free. - If neither, what are the plans? • What are future availability / 'delivery' plans for the tool? On what timeline? The Natural Capital Project is scoping other platforms for "delivering" InVEST and considering the costs and benefits of consulting arrangements. There is no deadline for a decision, so InVEST will remain available as it is currently into the foreseeable future.
Assigning Values within the Tool Application	• Does the tool / methodology assign value to ecosystem services? - *If so*, what type of value is assigned and how is it assigned? o Biophysical (e.g., pounds of fish, cubic feet of water) InVEST can quantify ecosystem service amounts in biophysical terms (e.g., tons of carbon, acre feet of water, etc.) o Economic: Monetary or non-monetary (e.g., dollar values or other nonmonetary expressions of human economic preferences) InVEST can also estimate economic values, using a range of economic valuation techniques, including avoided damage or treatment costs, market valuation, and production economics techniques. Many of the major assumptions (e.g. discount rate) are selected by the user. - *If the tool does <u>not</u> assign value in some economic unit,* then does the tool assign weight? If so, how?

	• How does the tool avoid double-counting (e.g., clean water to produce fish, if also counting fish)? Ecosystem services currently included in InVEST do not overlap in ways that might make double-counting a problem.
Exploring Stakeholder Engagement	• Does the tool include guidance on use within: - Internal stakeholder engagement processes? - External stakeholder engagement processes? - Other facilitated decision-making processes? Not yet published; the Natural Capital Project Policy and Finance team are putting together guidance documents which will include a chapter on how these types of stakeholder engagement processes can feed into InVEST and subsequently how InVEST outputs can feed into stakeholder engagement. Initial research is underway on effective and sustainable stakeholder engagement cognizant of the political and social dynamics that determine who "comes to the table," who has decision making power, and who implements land use decisions. • Specifically, does the tool have a process for including public input into assigning ecosystem service values? If so, is this a process for: - General public input? - Local / site-specific public input? InVEST is capable of estimating values based on market-derived information or stakeholder input (general or local). • In cases where there are a range of stakeholder values placed on the same ecosystem service flow, how does the tool balance these values? InVEST relies on the user setting values for a number of important assumptions relating to stakeholder values for ecosystem services (e.g. discount rate, carbon price). These values can be discussed and negotiated in deliberative and participatory stakeholder engagement processes. Alternative assumptions can be fed into InVEST in an iterative way to see how different assumptions affect results. • Does the tool rank these different stakeholder viewpoints on ecosystem service values? If so, how? Even though ranking stakeholder viewpoints is mostly a political process rather than a scientific one, since InVEST is capable of using stakeholder input for ecosystem service values, the user can choose their own standardized method for weighting the different values. • Is there a default weighting across services? If so, how? The default weight for tradeoffs *among* services (as opposed to between stakeholders' values) is that each service has equal weight. Changing the weights can be done outside of InVEST and is not technically complex.
Applying within Existing Corporate Decision-Making Processes	• What are the conditions of applicability of this tool in corporate decision-making processes? InVEST is primarily useful in evaluating alternative options management of business owned lands or waters for ecosystem services (to optimize ecosystem services or determine where to manage for enhanced provision of certain services), such as where to locate new activities, determining the ecosystem service impacts of major business project investments, which may be relevant for compliance with regulations, demonstration of proper consideration of environmental safeguards or to gain license to operate,

	identifying which areas to avoid impacting and how current activities may be improved. In addition InVEST may be useful for seizing emerging markets and payments for ecosystem services (determining who should pay whom and how to scale up). Further interaction with corporate decision-makers would be likely to illuminate other ways InVEST is applicable to corporate decision-making. • Is the tool being designed to fit within corporate Environmental Management Systems and/or Environmental Impact Assessments? If so, how? No. • Do you know whether this tool matches up with existing corporate data gathering and decision-making processes, whether they be voluntary (e.g., ISO 140001) or regulatory (e.g. Total Maximum Daily Load under the U.S. Clean Water Act)? If so, which? We do not know. However, if the Water Pollution: Nutrient Retention model is properly calibrated, it may be used with Total Maximum Daily Load. • Would the tool be useful for evaluating corporate land holdings for their value in terms of ecosystem services not accounted for in real estate accounting? Yes.
Identifying Assumptions within Tools	• What are the fundamental assumptions underlying your approach and methodology? Ecosystem services are modeled as simple production functions of land cover and associated attributes. The individual ecosystem service models embody many biophysical assumptions, which are outlined in the Oxford University Press book, which will be published in 2011. The user's manual also outlines some of the major assumptions in the models. We assume – and are currently exploring the validity of this assumption – that simple models provide useful information for certain stages and aspects of decision making in particular contexts, that can be complemented by more sophisticated and data-intensive analyses as needed and appropriate. • Can you provide examples of any assumptions? *(include article references, if applicable)* *Please* see the Oxford University Press book and the InVEST user's manual. • How does the tool—and/or these assumptions—interface with profitability goals? Can you provide examples? N/A • To what degree have the tool developers undertaken trends analyses of likely policy scenarios related to ecosystem services? If such scenarios have been developed, how have these scenarios been integrated? N/A
Exploring Broad-Based Application	• What kind of subject matter expertise would a user need? GIS proficiency and may also require hydrological expertise for hydrological ecosystem service models. Local policy context as relevant to implementing an ecosystem service approach and enabling the application of ecosystem service information to that context. Some

	basic economic valuation knowledge may be useful in interpreting and communicating appropriately any valuation results • What have been the challenges found in tool uptake (e.g., design elements practicality of application, comprehensiveness, flexibility of the tool)? Existing trade-offs, special interests & politics of policy-making mean that most 'sustainable' options in terms of ecosystem services are not always implemented even when results suggest action. Existing policy and institutional frameworks do not support multiple ecosystem service management. InVEST may be most useful in a heuristic / awareness raising fashion in contexts where more sophisticated models and data are available Additional analyses and models may be needed (beyond Tier 1) for some applications Can be difficult to get data (even at Tier 1). Some people prefer their 'own' tools – have to build sense of ownership and legitimacy of InVEST. InVEST is new and risky, not yet proven/verified. Lack of understanding of environmental economics concepts & jargon • Would the tool benefit from broader participation, uptake, engagement with other tool developers? If so, how? And where are areas you would benefit from collaboration with other tool developers? Maybe a strong link with the ESR e.g. using InVEST for more detailed explorations of ecosystem services that arise as important through the ESR. • Do you see opportunities for standardization or consistency across tools?
Understanding the Value Proposition	• What value proposition does this product provide? InVEST makes it easy for decision-makers to include the value of ecosystem services in decisions, resulting in improved sustainability and increased human well-being. • What is the business case for companies to: - Apply this tool? InVEST will provide companies with critical ecosystem services information to minimize business risks and maximize opportunities. - Apply this tool versus other tools that are emerging? InVEST freely available and can be used with limited resources. - Encourage/support public policy makers or others to apply the tool to private sector activities? InVEST will create opportunities for more sustainable and profitable private sector activities and improve the efficacy of regulations.

Natural Assets Information System by Spatial Informatics Group, LLC

Component #1 – Overview of the Tool's Application to the San Pedro Watershed

Not applicable. No case study has been implemented for the San Pedro Watershed given the late inclusion of this tool in the meeting.

Component #2 – NAIS Tool Description

What is the objective of the tool / methodology?
The Natural Assets Information Systems (NAIS) includes a database of literature on ecosystem services, a set of tools for querying, summarizing and reporting data from the database, and a process for conducting spatially-explicit value transfer using outputs from the database. While currently the database only contains information on monetary valuation of ecosystem services, it is in the process of being adapted to include non-monetary indicators of ecosystem service provision, such as tons of carbon stored.

Who are the intended users?
It is intended for anyone interested in ecosystem service assessment.

What is the intended use of the tool?
NAIS can be used as a stand-alone tool for those wishing to conduct value transfer or as a source of data for other ecosystem service modeling tools.

What do outputs look like?
The outputs of NAIS include: 1) a valuation summary table cross-tabulating ecosystem service value flow by land cover and ecosystem service type; 2) a gap analysis table cross-tabulating number of valuation studies by land cover and ecosystem service type; 3) a detailed valuation report giving high, low and mean valuation estimates listed hierarchically by study, ecosystem service type and land cover type; 4) map of land cover typology; 5) map of ecosystem service values by geographic summary units (e.g. watershed, parcel); and 6) maps and tables giving outputs under alternative scenarios (optional).

Which ecosystem services does the tool currently include or omit?
NAIS addresses any ecosystem service for which valuation literature exists. Currently our database includes valuation estimates for over a dozen ecosystem services (this number can vary depending on how ecosystem services are lumped or split). However, due to the fact that the literature is biased towards certain types of ecosystem services and to certain biomes (e.g. northern temperate), some of these categories are supported by relatively few studies. As the literature expands and as NAIS is improved to include non-monetary indicators of ecosystem service flow, we expect these biases to become less pronounced.

Are there any services being used as proxies for others? If so, which?
A database can only be as good as the literature it summarizes. Unfortunately many published studies are vague about the precise ecosystem service that is being valued or assessed. We have read these studies very closely and where there is ambiguity about whether a service is being valued directly or is being used as a proxy, it is so noted in our metadata. We then take this information into account to avoid double counting.

What are the data requirements?
NAIS is different from other tools in that it is data—in essence an aggregation and synthesis of a large literature. Hence, rather than requiring data, it provides data. With each implementation of NAIS, the database is augmented and expanded. Nonetheless, for each implementation of NAIS, additional data is needed for the mapping. The precise spatial data requirements depend on the needs of the client and the level of categorical and spatial precision in land cover that is desired. At the most basic level, land cover GIS data is needed. For more complex implementations, this may require extensive biophysical and socio-economic GIS layers. The database currently runs in MS Access (but is currently being updated to run in an enterprise database), and so can easily interface with ArcGIS, whose geodatabases can be edited and queried in Access.

What is the availability of the tool?

NAIS is a proprietary database developed by SIG. It is available through consulting fees or through licensing. Clients may not directly work with the database but can request reports or outputs which SIG will produce. Through licensing, a feed of it data can also be made available to serve as a component in ecosystem modeling tools

What are future availability / 'delivery' plans for the tool? On what timeline?
In the future, NAIS will be deployed on a server using an enterprise database framework. This will make it available to remote users, likely through a web portal. Licensed users will be able to run queries and make reports, but won't have access to the raw data. The expected completion date of this deployment is summer 2011.

Does the tool / methodology assign value to ecosystem services?
As described above, NAIS is primarily a value transfer tool. Value flows per unit area are extracted from studies (often requiring ancillary data to make these calculations) and recorded in the database in the currency year and type of the study. Often there are multiple estimates of values for a given study. When queries or reports are run, valuation summaries are updated into any currency year and type. Values can easily be converted from flows to stocks using differing discount rates or discounting methods. Also as described above, we are in the process of updating NAIS so that is will also include non-economic measures of ecosystem service flows, such as KG of nitrate processed, tons of carbon sequestered, net primary productivity, or biomass amount. When in place, users will be able to run queries that give both economic and non-economic summary reports. The non-economic reports will merely summarize all the indicators without weighting them.

How does the tool avoid double-counting (e.g., clean water to produce fish, if also counting fish)?
This has been an important step in every implementation of NAIS. Each record in NAIS has a field for metadata where we include information about potential hazards for double counting, when relevant. We have used a categorization of ecosystem service types that, we believe, minimizes the chance for double counting. This typology was developed in consultation with numerous clients and is generally fine-tuned for each implementation to account for the specifics of the site under consideration. Totally eliminating double is impossible in the value transfer field, but we feel that our approach minimizes it to the greatest extent possible. Despite significant scrutiny of our reports, we have heard of no complaints of potential double counting in our studies.

Does the tool include guidance on use within:

- Internal stakeholder engagement processes
- External stakeholder engagement processes?
- Other facilitated decision-making processes?

NAIS is not specifically designed for stakeholder input, but it could be easily adapted for that. We could easily adapt our data input form to allow for estimates from individuals rather than the literature.

What are the conditions of applicability of this tool in corporate decision-making processes?
NAIS could complement corporate decision making tools because its outputs are in dollars, which is the unit of analysis of all corporations. Nonetheless, when we implement NAIS we make it clear to all clients that our estimates of ecosystem service values represent only a "lower bound," incorporating only those services that have been adequately studied and measured. All those unmeasured services would only add to this estimate. Therefore, while we feel that value transfer outputs can be informative in some corporate environmental stewardship decisions, we believe that it should be just one of many tools and approaches used to weigh tradeoffs. That is, no one method offers a "silver bullet."

Is the tool being designed to fit within corporate Environmental Management Systems and/or Environmental Impact Assessments? If so, how?
It is not designed specifically for that purpose, but because of its broad applicability it could easily be used.

Would the tool be useful for evaluating corporate land holdings for their value in terms of ecosystem services not accounted for in real estate accounting?
We believe that NAIS would be an excellent tool for assessing and valuing the flow ecosystem services on large corporate land holdings. Its spatial integration makes it quite straightforward to visual assess the flow of ecosystem services on a map and to, for instance, identify critical watersheds or ecological regions. The more detailed the land cover typology used in an assessment, the richer it would be. NAIS could also be fruitfully

integrated with a spatial modeling tool like ARIES to address issues of spatial value flow across the landscape.

What are the fundamental assumptions underlying your approach and methodology?
All value transfer rests on a large number of assumptions. For a review of these assumptions see the 2006 special issue of Ecological Economics on value transfer (See, for instance, Loomis and Rosenberger 2006; Rosenberger and Stanley 2006; Spash and Vatn 2006; Troy and Wilson 2006; Wilson and Hoehn 2006).[7] These assumptions or too detailed and abstract to discuss here, but we are well aware of the limitations to the value transfer method.

To what degree have the tool developers undertaken trends analyses of likely policy scenarios related to ecosystem services? If such scenarios have been developed, how have these scenarios been integrated?
We have run scenarios for clients in the past using NAIS. For one client we ran a scenario to see how the flow value of ecosystem services on Maury Island in Puget Sound would change if a gravel mine were to be built and if there was to be full buildout of the island under allowable zoning. In another case we ran a scenario analysis to see how a large wildfire in northern California would impact the flow of ecosystem services.

Would the tool benefit from broader participation, uptake, engagement with other tool developers? If so, how? And where are areas you would benefit from collaboration with other tool developers?
We believe that NAIS could complement existing ecosystem service modeling tools. Where most of the other tools presented in this workshop focus on modeling, NAIS focuses on providing, aggregating, synthesizing, and summarizing data. We have found from experience that data integration is generally much more difficult and time consuming than expected. This, then, provides a major stumbling block for the application of many modeling tools. NAIS could become an important component to many of these existing modeling tools by providing a source of aggregated and organized data that is ready to deploy. As such, it is not in competition with any of the existing tools, but is rather complementary.

What kind of subject matter expertise would a user need?
NAIS requires little expertise to conduct its basic functions, like queries and reports. However, it takes significant expertise in both environmental economics and in geographic analysis to implement fully. This background and experience is needed for making tough decisions about how the ecosystem service and land cover typologies will be built and how studies will be filtered, which in turn determines how values will be averaged and aggregated. However, once these decisions are made, NAIS functions can be run by those with less training.

Would the tool benefit from broader participation, uptake, engagement with other tool developers? If so, how? And where are areas you would benefit from collaboration with other tool developers? Do you see opportunities for standardization or consistency across tools?
We at SIG believe that NAIS has the potential to both bridge and complement existing ecosystem service modeling tools. NAIS itself is not a dynamic modeling tool. However, as a database, it is an industry leader, not just in terms of the breadth of information contained, but also in terms of the extent to which that information is vetted, distilled, interpreted, synthesized and organized. Its high level of organization combined with its robust architecture make it easy to query, filter, and summarize large amounts of information. Given this, it can easily be adapted to feed data to ecosystem modeling tools. To the best of our knowledge, no other modeling tool incorporates a database that is as rich in information or as easy to query. Hence, we believe that NAIS could become a complementary component of many modeling endeavors. As we move NAIS into an enterprise, server-based environment, this integration will become even more feasible.

[7] Loomis, J. B. and R. S. Rosenberger (2006). "Reducing barriers in future benefit transfers: Needed improvements in primary study design and reporting." Ecological Economics **60**(2): 343-350; Rosenberger, R. S. and T. D. Stanley (2006). "Measurement, generalization, and publication: Sources of error in benefit transfers and their management." Ecological Economics **60**(2): 372-378; Spash, C. L. and A. Vatn (2006). "Transferring environmental value estimates: Issues and alternatives." Ecological Economics 60(2): 379-388; Troy, A. and M. A. Wilson (2006). "Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer." Ecological Economics 60(2): 435-449; Wilson, M. A. and J. P. Hoehn (2006). "Valuing environmental goods and services using benefit transfer: The state-of-the art and science." Ecological Economics 60(2): 335-342.

Wildlife Habitat Benefits Estimation Toolkit

Component #1 – Overview of the Tool's Application to the San Pedro Watershed

Not applicable. No case study has been implemented for the San Pedro Watershed.

Component #2 –Tool Description

What is the objective of the tool / methodology?
To provide an easy-to-use tool that systematically analyzes the findings of the published valuation literature to quantify the economic value of a range of uses provided by a specific undeveloped area.

Who are the intended users of the tool?
State wildlife agencies, conservation organizations, community planners, private land owners

What is the intended use of the tool?
Generation of credible value estimates at low cost to the user.

What do outputs look like? Excel spreadsheet? Narrative interpretation? Explicit mapping?

Considering Analytical Parameters of Tool
Which ecosystem services does the tool currently include?
Recreation, open space premiums, passive uses; wetland models: Flood prevention, water quality and quantity, recreational fishing, commercial fishing, bird hunting, bird watching, visual amenities, habitat provision, storm water retention.

Which ecosystem services does it omit?
Carbon sequestration, food and fiber production, erosion control, air quality, among others.

Are there any services being used as proxies for others? If so, which?
No

Do you have plans to build out the tool to include other ecosystem services? If so, on what timeline?
Not currently. We do provide links to carbon estimators in the Toolkit manual.

Assessing Data Requirements, Quality & Costs of Application
What are the data requirements?
Information on the types of ecosystem services provided by an area (e.g., a wetland); information on number of homes and median home values in area of interest (open space property value premium model); percent change in population of particular species that results from proposed action or percent of population that is supported by the area (passive use value models).

A) Preexisting databases: If the tool runs on databases:
What are the database sources?
What issues exist with these database sources, if any? (e.g., quality, reliability, verification, replicability, availability)
What assumptions are embedded within these databases?
Models use results reported in published valuation study databases or individual peer-reviewed studies.

B) User provides data: If the tool requires input data, what are the time and costs for acquisition and verification of data?
Wetland models: may require consultation with biologist/ecologist to identify services provided; passive use models will require consultation with biologists/ecologists to identify relative quantitative importance of an area for a particular species; open space model requires information on number of homes and median home values. The Toolkit guides users through using Census data, but ideally this data should be obtained from local assessor's office. Cost of each of these data should be in the low hundreds of dollars if not available free of charge.

What is the quality of the data (reliability, verifiability, credibility) on the input side? on the output side?

Input side: all peer-reviewed (values) or factual (types of services provided; number of houses and median house values), so likely fairly accurate, reliable and verifiable.

Is sensitivity analysis included? Qualitatively or quantitatively?
No, except that for most services/uses included in Toolkit, both valuation models and average value tables can be used, which allows comparison of the estimates generated via the two approaches.

Does the tool have capability for technologies to feed data into the tool?
No.

Is the tool designed to interface with GIS, carbon measurement technologies, mesh networks or other technologies?
No.

Are you exploring potential technology interface points or partnerships with large database firms (e.g., IBM or Microsoft)?
No.

What are the anticipated resource (human or otherwise) requirements of the tool? (Provide $$ and/or labor hour examples based on pilot projects)
Consultation of user manual and collection of data should require one to two days for most areas (up to several hundred acres). If area is very large, the open space property value model will need to be run separately for each population center in or adjacent to the area.

Accessing the Tool
What is the availability of the tool?
Free, online.
Specifically:
Will the tool be broadly available through online materials?
YES
Will companies be required to work with the tool developers directly as the 'delivery mechanism'?

No
If neither, what are the plans?

What are future availability / 'delivery' plans for the tool? On what timeline?

Assigning Values within the Tool Application
Does the tool / methodology assign value to ecosystem services? *If so*, what type of value is assigned and how is it assigned? Economic (e.g., pounds of fish, cubic feet of water): Monetary or non-monetary?
Yes. Use values (recreation, residential open space value premiums), passive use values (threatened, endangered or rare species), ecosystem service values (wetland models), most of which are indirect use values.
If the tool does not assign value in some economic unit, then does the tool assign weight? If so, how?

How does the tool avoid double-counting (e.g., clean water to produce fish, if also counting fish)?
This is an issue only in the wetlands models and the terrestrial habitat model. The user manual directs users to set the respective habitat or fishing/hunting variables at zero on the wetland models if the outputs of hunting and fishing models are intended to be added to those of the recreation models.

Exploring Stakeholder Engagement
Does the tool include guidance on use within:
» Internal stakeholder engagement processes?
» External stakeholder engagement processes?
» Other facilitated decision-making processes?

The introduction to the Toolkit explains why the values the Toolkit estimates are important from an economic perspective, and why they should matter to decision-makers.

Specifically, does the tool have a process for including public input into assigning ecosystem service values? If so, is this a process for:

» General public input?

» Local / site-specific public input?

The Toolkit can accommodate local input on number of users and also values, but the Toolkit user must enter these values manually into the spreadsheets (in most cases this requires unlocking the password-protected spreadsheets or individual cells).

In cases where there are a range of stakeholder values placed on the same ecosystem service flow, how does the tool balance these values?
The values used to estimate the models draw on many observations reported in the published literature, so they do include a range of values assigned to particular services by individuals.

Does the tool rank these different stakeholder viewpoints on ecosystem service values? If so, how? Is there a default weighting across services? If so, how?
No

Applying within Existing Corporate Decision-Making Processes
What are the conditions of applicability of this tool in corporate decision-making processes?
With the exception of the property value premium model, the models that make up the Wildlife Habitat Benefits Toolkit generate estimates that include passive use values, and the value measure generally is consumer surplus (net benefits to users). To the extent that a corporate decision-maker is interested in this value measure (as opposed to producer surplus, or gross market value), the Toolkit is applicable.

Is the tool being designed to fit within corporate Environmental Management Systems and/or Environmental Impact Assessments? If so, how?
No.

Do you know whether this tool matches up with existing corporate data gathering and decision-making processes, whether they be voluntary (e.g., ISO 140001) or regulatory (e.g. Total Maximum Daily Load under the U.S. Clean Water Act)? If so, which?
No, the Toolkit is not designed for such purposes.

Would the tool be useful for evaluating corporate land holdings for their value in terms of ecosystem services not currently accounted for in traditional real estate accounting?
Yes. The toolkit can be used to assess wetland services and threatened or endangered species habitat provision services, plus recreational values in case private or public access for recreational purposes is granted.

Identifying Assumptions within Tools
What are the fundamental assumptions underlying your approach and methodology?
Benefits transfer can yield reasonable value estimates. The value estimates generated by the Toolkit rely on benefit transfers. The user manual explains when such an approach to valuation is justified and what conditions must be met for the resulting estimates to be valid. The valuation models contain variables identified as significant in the meta-analysis of the literature upon which the estimation models are based. By setting these (binary) variables to the appropriate values for their site of interest, the models allow users to tailor the outputs to their specific area.

Can you provide examples of any assumptions? (include article references, if applicable)
How does the tool—and/or these assumptions—interface with profitability goals? Can you provide examples?
The tool is not designed to measure profitability impacts (changes in producer surplus) of ecosystem services. It mostly focuses on consumer surplus from ecosystem services, which is not readily captured in established markets.

To what degree have the tool developers undertaken trends analyses of likely policy scenarios related to ecosystem services? If such scenarios have been developed, how have these scenarios been integrated?
None of the above.

Exploring Broad-Based Application

What kind of subject matter expertise would a tool user need to effectively apply the tool?
Very little. The manual provides all the information needed to apply the Toolkit. However, the wetland value models do require information of which of the services include din the model are being provided the wetland in question. This requires input from biologists/ecologists/hydrologists familiar with the wetland, in case such an analysis has not yet been carried out.

What have been the challenges found in tool uptake (e.g., design elements practicality of application, comprehensiveness, flexibility of the tool)?
None so far to our knowledge.

Would the tool benefit from broader participation, uptake, engagement with other tool developers? If so, how? And where are areas you would benefit from collaboration with other tool developers?
The Toolkit is a self-contained package that integrates the relevant information available as of 2007. It is a useful complement to other tools that estimate services not quantified in the Toolkit, as for example carbon sequestration. At this point, the most useful link to other tools would be something that integrates GIS capability to our open space property value premiums to link the model to spatial information on number of houses and median values.

Do you see opportunities for standardization or consistency across tools?

Understanding the Value Proposition
What value proposition does this product provide?
What is the business case for companies to:

- Apply this tool?
- Apply this tool versus other tools that are emerging?
- Encourage/support public policy makers or others to apply the tool to private sector activities?

The Toolkit was designed for the primary purpose of helping local and state planners identify the value of conserving particular priority lands or conservation opportunity areas identified in State Wildlife Action Plans, focusing specifically on the value of the public benefits those areas provide. As such, the Toolkit is not geared towards enhancing the profitability of private lands. However, all else but ownership status equal, the conservation-related values on private lands are identical to those on public lands. Thus, the Toolkit could be used by private land owners to make the case for tax reductions or exemptions or for public cost share for conservation actions that conserve or enhance the public benefits from the land.

Background on BLM-USGS Comparative Study of ARIES & InVEST Tools

Note: Excerpted from BLM-USGS Project Materials

"BLM and USGS are collaborating on a pilot project to assess the usefulness of ecosystem services valuation to BLM's land use decision making process. While there is a relatively large body of research identifying ecosystem services (i.e., the benefits that various ecological functions provide to humans) and analyzing the relationships between various ecological functions, less work has been done on valuing the services ecosystems provide.

The purpose of this ecosystem services valuation pilot is twofold:

» to determine which, if any, methods for valuing ecosystems are ripe for operational use at the BLM

» to explore the usefulness of an ecosystem services valuation framework to BLM's land use decision-making process

BLM and USGS developed several criteria for selecting a site for the pilot project:

Since the pilot focuses on valuing (both monetary and non-monetary) ecosystem services, the site to be selected should have had extensive research characterizing its ecology in a landscape framework, including the effects of human uses, so that information may be readily expressed in an ecosystem services framework.

» The presence of urban growth as a stressor

» The presence of multiple management issues related to multiple ecosystem services

» The presence of native or cultural heritage issues is desirable, because it would require the project to consider how to value benefits not readily addressed through monetary techniques

When evaluated in light of these criteria, both the BLM and USGS agreed that the San Pedro Watershed in southeast Arizona is the preferred site for the pilot. This area contains the San Pedro National Conservation Area, and has been studied extensively by members of the San Pedro Partnership (BLM and USGS are members), as well as other government agencies and academic institutions. While the BLM has limited jurisdiction over the resources in this area, the San Pedro Watershed presents a robust example of the types of real-world resource allocation dilemmas faced by the Bureau around the country, and provides a good opportunity to test numerous valuation methods on a variety of resource issues.

Given that ecosystem services as a research framework is in its infancy, it is unrealistic to expect that this project will result in a detailed "cookbook" that can provide a template for operationalizing ecosystem services valuation across the BLM. Instead, the project is being planned with the following goals in mind:

» meet immediate management needs;

» demonstrate the potential usefulness of an ecosystem services framework;

» develop a framework for institutional learning regarding the incorporation of ecosystem services in decision-making.

Ecological & Social Context on Study Site

By Ken Bagstad, Technical Advisor to Comparative Tool Assessment

The San Pedro River is located in northern Sonora, Mexico and southeast Arizona. The river's headwaters originate in the Sierra Mariquita and Los Altos ranges in Sonora. The river flows north into the United States within a broad valley bounded by the Huachuca, Whetstone, Rincon, and Catalina Mountains to the west and Mule, Dragoon, Winchester, and Gailuro Ranges to the east. Near Winkelman, Arizona, the San Pedro joins the larger Gila River, one of Arizona's major watersheds. The San Pedro is typically divided into:

» the "Upper San Pedro," which runs from its headwaters to a geologic constriction north of Benson, known as "The Narrows," and

» the "Lower San Pedro," running from The Narrows to its confluence with the Gila.

The San Pedro flows through Chihuahuan Desert and grasslands in the upper watershed grading into Sonoran Desert in the lower watershed. The Chihuahuan Desert receives much of its rainfall as summer monsoonal rains, while the Sonoran Desert has a bimodal rainfall pattern with rainy seasons in the summer and winter. These multiple rainy seasons enable species to partition resources (i.e., between warm and cool-season annuals and grasses), increasing potential diversity.

Although rainfall is low, precipitation is much higher in the surrounding "Sky Island" region of the southwest at the confluence of four major biomes – the Rocky Mountains to the north, Sierra Madres to the south, Sonoran Desert to the north and west, and Chihuahuan Desert to the south and east. Snowmelt and runoff from these mountains provides water to a regional aquifer, which maintains surface flow in the river during drier parts of the year.

These unique conditions have resulted in exceptionally high biodiversity, with over 750 plant species, 80 mammal species, 100 butterfly species, 100 breeding bird species, and 250 migratory bird species (Stromberg and Tellman 2009).

Like most Southwestern rivers, the San Pedro's fish fauna has been decimated by reductions in surface flow and nonnative species, though several of the smaller, generalist native species persist in small populations along the river's main stem and its tributaries. The San Pedro is also home to several species of conservation concern, including the Sonoran tiger salamander, desert pupfish, Southwestern willow flycatcher, lesser long-nosed bat, Huachuca water umbel, Madrean ladies' tresses, and Mexican spotted owl.

Like many desert rivers, the San Pedro harbors many species for at least part of their life cycle. Along with the fact that parts of the river flow year-round, its north-south orientation makes it a major migratory bird flyway. Since the Lower San Pedro is sparsely settled, the Lower San Pedro Valley is also a key migration corridor for large mammals migrating between the Sky Island mountain ranges. Since such mountains are often undeveloped public land while valley floors are typically developed or used for cattle grazing in the west, the Lower San Pedro is relatively unique in providing such an unfragmented migration corridor.

Along with this high biodiversity and persistence of perennial flow, the San Pedro is also undammed – a rarity for southwestern river. This lack of flow regulation is a likely explanation for the fact that, while present and abundant along parts of the river, tamarisk is not as dominant along the San Pedro as other southwestern rivers8. These characteristics led The Nature Conservancy to designate the San Pedro as one of its "Last Great Places."

Key conservation lands in the region include the Bureau of Land Management's San Pedro Riparian National Conservation Area (SPRNCA), established in 1988 and stretching from the U.S.-Mexico border to Saint David, as well as many smaller conservation properties, including a series of Nature Conservancy lands established along the Lower San Pedro in the past 15 years. These lands were protected in part to maintain and improve the river's endangered surface flow. Their management entailed protection of in-stream flow rights, cessation of agriculture and grazing, and restoration of native plant communities.

[8] Tamarisk establishes following summer high-flow periods, which are common when dams are operated for hydroelectric generation, as electric demand in the southwest is at its highest in summer. Cottonwoods and willows are more adapted for establishment following naturally occurring spring flood pulses.

HISTORICAL CONTEXT & TODAY'S FEATURES

The first Spanish, Mexican, and American settlers in the San Pedro found a river far different from the current system. The San Pedro was dominated by wetlands (known as "cienegas"), with trees relatively uncommon, and sacaton grasslands abundant farther from the river.

Several key changes in the late 1800s led the San Pedro to incise: extirpation of beaver, overgrazing of rangelands, cutting trees to feed mills along the river, and a major earthquake in 1887. These changes led the river to downcut, with an entrenched floodplain now found 10-15 feet below the older river terraces. Channel entrenchment left behind few wetlands aside from riparian marsh immediately adjacent to permanently flowing parts of the river.

Today there are only three major wetland complexes along the U.S. length of the river:

- St. David Cienega
- Bingham Cienega, near Redington, and
- Cook's Lake, south of Dudleyville.

Since groundwater and surface water are connected, pumping of groundwater can create "cones of depression" that lower the riparian groundwater. This has caused parts of the river to stop flowing year-round.

However, the entire river was not historically perennial. Like most small southwestern rivers, milder climates, shallower bedrock, and greater precipitation at higher elevations led to perennial flow in the Upper San Pedro, while deeper valley fill alluvium, hotter summer temperatures, and lower precipitation caused the river to naturally go dry along parts of the Lower San Pedro. Yet, historical records make it clear that human activities have led to substantial drying on many reaches of the river.

Within a wide floodplain, a meandering stream channel led to establishment of different aged bands of Fremont cottonwood and Goodding willow, leaving behind today's dominant vegetation type on the San Pedro – the cottonwood-willow gallery forests. Along river reaches where surface flow is intermittent to ephemeral, tamarisk becomes co-dominant with cottonwood and willow or dominates more completely. Mesquite can also occur in the floodplain of drier river reaches. Along the old river terraces above the floodplain, mesquite is typically the dominant species. A period of mesquite expansion in the 1970s-1980s saw mesquite largely replace sacaton grasslands and other vegetation types, likely due to fire suppression and climatic factors.

The river's current vegetation structure is unlikely to persist in the future, as cottonwoods and willows are relatively short-lived species and the river channel has come into balance with erosion and deposition cycles, making it less likely to migrate in the future. This means that cottonwoods and willows may become less common in the coming decades. Further, climate change and management activities such as fire and mesquite management, grassland restoration, beaver reintroduction, and declines or restoration of groundwater levels will likely change the future makeup of the San Pedro's riparian community.

ECONOMIC SETTING

Since permanent Anglo settlement of the San Pedro following defeat and resettlement of the Apaches after the Civil War, the economy of the San Pedro has been characterized by boom and bust cycles.

Initial settlement in the region centered on the gold and silver mines of Tombstone, and on mill communities built along the river to support the mines. Flooding of the Tombstone mines led to population decline and abandonment of the mill communities.

The late 1800s saw a cattle boom in southeast Arizona. Although the Spanish and Mexicans attempted to ranch along the San Pedro, the Apache presence limited such efforts. Following U.S. settlement of the region, relatively wet years and lush native grasses were able to support large numbers of cattle. However, the range was quickly overgrazed. This long-term degradation along with severe drought in the late 1800s led to massive cattle die-off, and future grazing did not occur at such a large scale. In the twentieth century ranching continued adjacent to the river, and irrigated agriculture was used to grow alfalfa and other forage crops.

The establishment of the BLM's San Pedro Riparian National Conservation Area in 1988 led to purchase of land and water rights in the Upper San Pedro from private landowners to establish the conservation area. In

recent decades the economic viability of alfalfa growing has declined, leading a number of ranches on the Lower San Pedro to sell land and water rights to The Nature Conservancy, which is undertaking hydrologic restoration on this part of the river.

Aside from some remaining alfalfa and ranching operations along the river, more diverse crops are grown in the small farming communities of St. David and Pomerene. Agricultural land use on the Mexican side of the border is primarily for grazing, with much of the land managed by communally-owned ejidos. It is uncertain how much the past decade's ejido privatization movement has affected operations or economic pressure on the Upper San Pedro's ejidos.

Copper mining has also played a major role in the region's economy. Today, the Cananea Mine in the San Pedro's headwaters supplies 2-3% of the world's copper. ASARCO has a major mining and smelting operation located in the towns of Hayden, Ray, and Winkelman near the San Pedro's confluence with the Gila River. Although these operations are located outside the basin, they use groundwater from the San Pedro and employ workers in towns along the Lower San Pedro. In addition to these active mines, the Copper Queen Mine in Bisbee was once one of Arizona's most productive copper mines, but closed in 1975, and the San Manuel mine was closed by then-owner BHP in 1999.

Fort Huachuca, located just north of Sierra Vista, is by far the largest employer in the San Pedro watershed. Established during the Apache campaigns, Fort Huachuca today provides support to training and electronic intelligence missions. The geologic makeup of the nearby Huachuca Mountains provides conditions found nowhere else in the United States for achieving these goals, so the Fort helps meet unique military and national security needs. In recent decades, Fort Huachuca has also played a key role in water conservation and threatened and endangered species management. For example, the fort has received praise for its water conservation programs, which have lowered annual water use by over 50% from 1993-2008 (U.S. Department of Energy 2010).

Like much of Arizona, the population of the Upper San Pedro has boomed in recent decades as the region was touted as a retirement destination. Climate in the Upper San Pedro is milder than the lower deserts of Phoenix and Tucson, which has helped attract retirees. Cochise County's population has grown from 31,488 in 1950 to 129,518 in 2009, with further growth forecast in the coming decades.

Groundwater decline and threats to the river's base flow have largely been attributed to this population growth. This growth has largely taken place in and around Sierra Vista. However, the opening of Kartchner Caverns State Park in 1999 also spurred a smaller development boom near Benson. Prior to the recent collapse of the real estate market, proposals were on the table to build subdivisions of thousands of housing units near Sierra Vista, Benson, and San Manuel, presumably to lure retirees or long-distance commuters to Tucson.

Although its impact is smaller than the above economic activities, bird watching remains and important industry on the San Pedro. The diversity and quality of the region's aviafauna leads birders from all over the world to visit the San Pedro and nearby birding areas, a significant portion of these being "life listers" who fly in from across the country or world to view new species in a high-quality natural setting. Orr and Colby (2002) found that visitors to the San Pedro and Huachuca Mountains added $17-28 million per year in economic activity to the local economy through birdwatching-associated expenditures and local economic multiplier effects.

SOCIO-CULTURAL SETTING

Today's San Pedro River is populated by diverse cultural groups along its length. In Mexico, aside from the copper mining town of Cananea, the population and land use are largely rural, with much land of the land owned and managed by ejidos. On the U.S. side of the Upper San Pedro, the presence of a major military employer, Fort Huachuca, and retirees have brought much of the population growth seen in recent decades.

This recent population growth is set against the backdrop of rural farming and ranching communities that have persisted in the San Pedro valley for over a century. Like other rapidly growing regions, the potential for conflict exists between traditional "rural lifestyles" and the newcomers whose arrival may shift local political priorities and land prices, making traditional rural lifestyles more difficult to maintain.

The sociocultural setting of the Lower San Pedro is far different from the Upper San Pedro. The San Pedro from Pomerene north to San Manuel is sparsely settled. Residents of this region have periodically fought

efforts to pave roads and increase accessibility, which they fear will leading to population growth that will endanger their way of life. From San Manuel north to the Gila confluence, small towns like San Manuel, Mammoth, Dudleyville, and Winkelman have based their economies on copper mining and small-scale ranching and agriculture.

Like much of the rural west, the San Pedro's political culture reflects a long tradition of independence, private property rights, and mistrust of excessive government involvement. Generally, there has been reluctance among county and city governments to limit growth or mandate water conservation in the face of scientific evidence linking groundwater decline to long-term damage to the riparian ecosystem. Some local groups clearly advocate for conservation, but others may view the benefits of preserving the river going to "outsiders" from Tucson and beyond, and resent what they view as interference in local decision-making. Additionally, the transience of large segments of the area's population from military and retiree communities has been another hurdle for water conservation-based outreach.

Watershed alliances have been formed in the region to attempt to bring together diverse stakeholders and bridge the divides between diverse political and sociocultural groups. In 2004, the Upper San Pedro Partnership (USPP) was mandated by the U.S. Congress to bring the San Pedro into water balance by December 31, 2011, though few current stakeholders expect to meet this goal. In addition to the USPP, the Community Watershed Alliance was more recently formed to address similar issues in the Benson area.

Although there is essentially no Native American land within the San Pedro,[9] numerous Tribes retain historical and cultural links with the San Pedro. The U.S. EPA is currently engaged in a Tribal Ecosystem Services Pilot Study designed to better understand how different Native American groups place value on the overall landscape and specific landscape components that provide value for culture, history, and goods and services that contribute to daily living.

KEY MANAGEMENT QUESTIONS

Protection of groundwater and surface flows

By far the most important management question on the San Pedro concerns protection of its perennial surface flows and the groundwater that sustains surface flow. Many of the other management questions on the San Pedro—including beaver reintroduction, fire and vegetation management, and threatened and endangered species habitat management—play out within the context of overall ground and surface water management.

Rapid population growth, especially in the Sierra Vista and Benson areas, has led to the formation of "cones of depression," whereby wells deplete groundwater, reducing its ability to feed surface flows in the river. Monitored groundwater depths and flow frequencies have declined markedly in recent decades.

In 2005, the Charleston stream gage went dry for the first time since the gage's establishment in 1942. Numerous actions and proposals have been put forth in the past two decades. Many of these have focused on the supply side of water management, seeking to "improve recharge" of groundwater at the mountain fronts, to recharge groundwater closer to the river, or to extend the Central Arizona Project canal from Tucson to the San Pedro to supply water. Some demand-side management has also occurred, most aggressively by Fort Huachuca, where centralized decision making by the military has effectively mandated conservation measures.

For the political reasons, consensus on managing overall human demand – a function of total population and per capita use – has been elusive. While BLM maintains the water right to protect the San Pedro, it has been hesitant to fully enforce it out of a desire to maintain good relations with neighboring communities. Yet as population continues to grow, water levels decline, and the effects of drought and climate change are felt, this status quo may prove untenable.

Such complex, multi-stakeholder decisions are also set against the backdrop of traditional western water law, along with state water laws that fail to recognize the connection between groundwater and surface water, contrary to decades of well-established principles in the field of hydrology. The threat of multi-decade litigation, which has occurred in other western water conflicts, is another reason why many stakeholders would prefer a consensus-based approach over a confrontational one.

[9] A small section of San Carlos Apache Reservation is located in the far northern part of the San Pedro watershed.

Climate change
Although climate in the San Pedro watershed is likely to get hotter, there is some uncertainty over whether the future will be “warm and dry” or “warm and wet.” Additionally, along with global climate change, natural interannual and multidecadal climate cycles exist in the southwest.

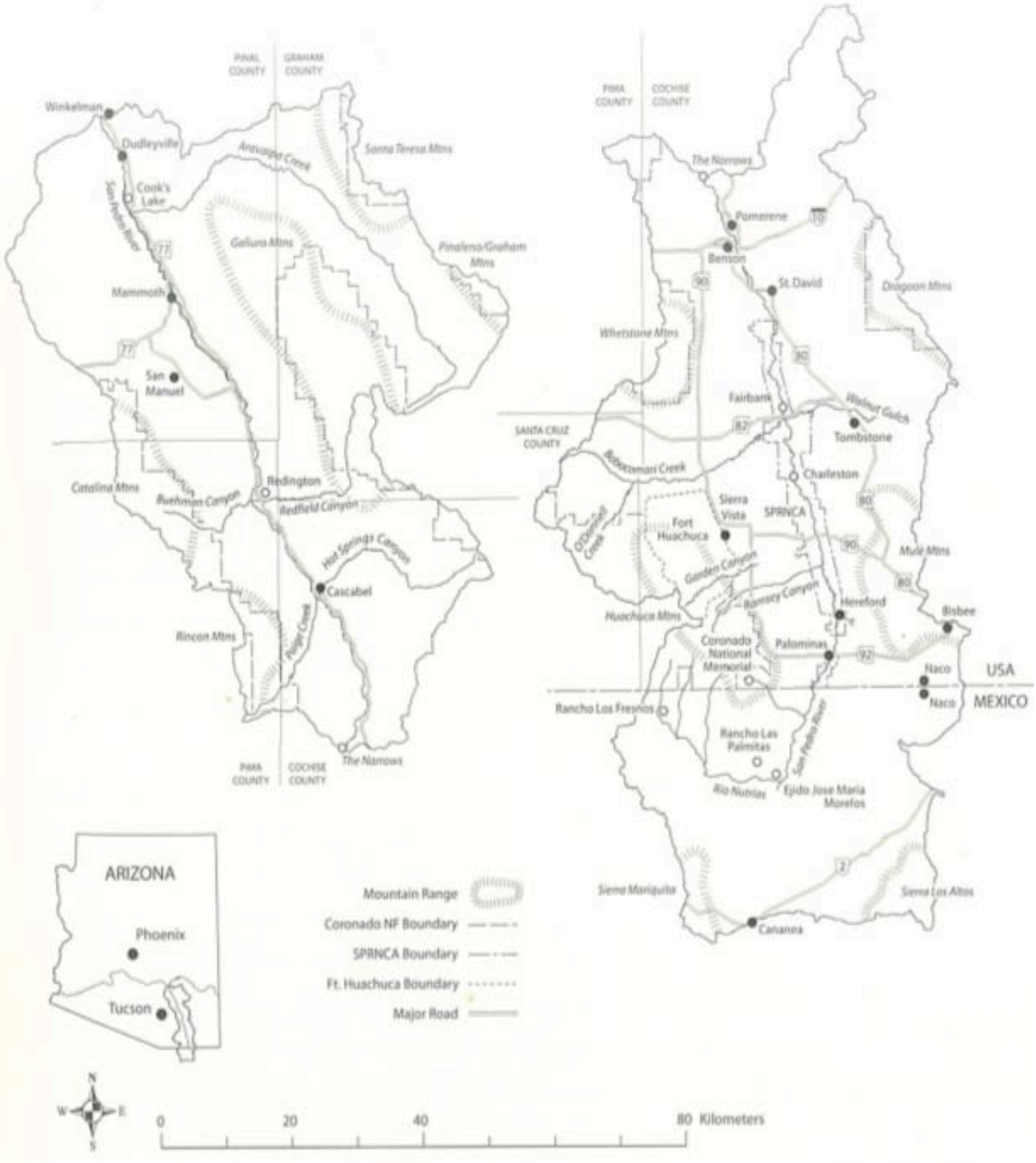
The region has currently been in a drought cycle for the last decade, with wetter periods in the 1970s-1980s corresponding to mesquite expansion. Thus, short- and long-term climate cycles can greatly influence vegetation, groundwater, surface water, and habitat on the San Pedro, and we should expect future climate, stream flows, riparian biota and to look different from the present.

Border issues
Habitat fragmentation is a concern in several parts of the San Pedro. On the U.S.-Mexico border, the controversial border fence has been touted as a solution to illegal immigration and the drug trade. The San Pedro is a major corridor for illegal immigrants, as it offers water and shade that the surrounding desert lacks. Immigrants have been seen as a nuisance by residents and visitors, as they have left behind trash, added traffic to the riparian corridor, and are perceived by some as threatening to safety. The drug trade, on the other hand, is often viewed as a more serious threat to public safety. Regardless of the border fence’s impacts on immigration and the drug trade, it has the potential to isolate non-bird wildlife populations on one side of the fence, split populations in half, and separate summer and winter habitat for some species.

Habitat fragmentation
Along with habitat fragmentation caused by the border fence, urban growth and subdivision of rural property for development carries the typical consequences for habitat fragmentation as found in suburbanizing landscapes elsewhere in the U.S. On the more remote Lower San Pedro, the isolated and relatively undeveloped riparian corridor offers a rare opportunity for larger mammals to migrate between the Sky Island mountain ranges. Threats to this area have included periodic proposals to pave the road from Benson to San Manuel. More recently, routes for the proposed SunZia transmission line have crossed the more remote parts of the San Pedro valley, threatening to bring development, habitat fragmentation, and changes in rural lifestyles of the region[10].

[10] The SunZia transmission line is being planned to carry electricity between new solar and wind facilities in Arizona and New Mexico to population centers including Tucson and Las Cruces, NM; see http://www.sunzia.net.

Figure 1: San Pedro Basin Map[11]



[11] Source: Stromberg and Tellman 2009

DATA SOURCES

The following are several publicly available spatial data sources for the U.S., available through government agencies like the USGS, NRCS, and Forest Service. These data do not cover the Mexican portion of the San Pedro:

http://seamless.usgs.gov	USGS Seamless Map Server
http://nhd.usgs.gov/techref.html	National Hydrography Dataset
http://svinetfc4.fs.fed.us/vectorgateway	US Forest Service data gateway
http://datagateway.nrcs.usda.gov/	NRCS Data Gateway: soils, climate, elevation, high-resolution orthophotos , etc.

In addition to these nationwide data sources, several other key sites offer spatial data specifically for the San Pedro and/or Southwest:

http://www.epa.gov/nerlesd1/land-sci/san_pedro/	US EPA San Pedro data browser (includes data for Upper San Pedro and Mexico)
http://gapanalysis.nbii.gov	Southwestern Regional Gap Analysis (habitat and LULC data)
http://azconservation.org/downloads/multi/category/gis/	The Nature Conservancy – Arizona conservation science program GIS data

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Process for Each Tool Applied to the San Pedro Watershed Case

	ARIES	InVEST	EcoAIM	EcoMetrix	ESR	ESValue
Data Needed for Application	**Carbon models data**: tree canopy cover (from NLCD for the U.S. & UMD-GLCF globally) land cover from SWReGAP for the U.S. and CONABIO for Mexico, climatic data from PRISM at Oregon State for the U.S. and WORLDCLIM for global data soils data from SSURGO/STATSGO for the U.S. and UN-FAO globally slope data from the SRTM fire return interval data from SWReGAP and TNC carbon sequestration and storage data from the NBCD for the U.S. and ORNL, NBII, and FAO globally anthropogenic emissions data from the VULCAN project for the U.S. and LANDSCAN population density and per capita emissions from EIA for the global scale.	**For biodiversity, carbon, and water yield models** used: Land use-land cover data from the Southwest Regional GAP Analysis (SWReGAP) project, which provides seamless data covering the U.S. and Mexican portions of the watershed. **Biodiversity model** also required: User-defined "threats" data for highways, grazing lands, land ownership ("access to threats"), and wells, which was gathered from ALRIS and the ADWR Wells-55 Database, with wells in Mexico obtained from INECOL. Highway and land ownership data for Mexico were obtained from the EPA San Pedro Data Browser. **Water yield model:** a DEM from SRTM, soil depth and PAWC from the SSURGO and STATSGO databases,	**Biodiversity data** included: Property ownership (public or private), potential habitat (for amphibians, birds, mammals, and reptiles), species richness, and special protection status, vegetation types, and impervious surfaces. *Note: Given that this tool application was done pro bono, no other services were evaluated for this workshop.*	EcoMetrix relies on **primary data collected from the site** with a focus on specific landscape attributes associated with vegetation, soil, water, and other key parameters for assessing production functions. Data from pre-existing databases are utilized where needed and available; database and GIS spatial data sources used vary, depending upon the location of a given site.	A method, or process, the ESR requires minimal data to "run." Data on the size of the project impact, magnitude of other impacts (i.e., water use for the San Pedro), are helpful for comparing relative impacts but not strictly necessary. What is essential is a good understanding of the project site, potential impacts, and ecosystem sensitivity to a particular change (e.g., groundwater pumping), as well as alternatives to minimize impacts and a consensus on system boundaries of the projects impacts (i.e., direct site impacts, impacts from other resources used during the project, life cycle impacts, etc.).	Four data requirements: A list of key ecosystem services valued by stakeholders and decision-makers, • Input from scientists on the key determinants of ecosystem service quality (to be used in ecological relationships that specify, for example, the impact of development on riparian habitat quality as a function of groundwater levels, proximate population density, and habitat fragmentation) Input from stakeholders and decision-makers on their preferences for different ecosystem services, and Commonly available GIS layers to conduct a spatial analysis with a minimal amount of processing.

	Water model data: climatic data from PRISM & WORLDCLIM, springs data from ALRIS hydrologic modeling results from SWAT (available via the USEPA San Pedro Data Browser) impervious cover from NLCD and UMD-GLCF a manually-created surface diversions layer, well locations and total use from ADWR's Wells-55 database, soils, climate, tree cover, and land use data sources mentioned above for carbon. **Aesthetics model data:** elevation data from SRTM, highways from ALRIS, transmission lines from the USEPA San Pedro Data Browser, land cover types from SWReGAP, housing locations and values from Pima and Pinal County GIS departments, land ownership from ALRIS, riparian condition class from Julie Stromberg's	annual precipitation data from PRISM at Oregon State University, and potential evapotranspiration data from CGIAR's Global Aridity and PET database. Finally, data to parameterize the InVEST coefficient tables were obtained from the literature and an expert workshop convened in Tucson from Sept. 21-23, 2010. All data sources and model assumptions will be fully documented as part of the project report for the BLM-USGS Ecosystem Services Valuation Pilot, to be produced in the winter of 2010-2011.				

	datasets on the San Pedro, population density data from the Census Bureau. **Recreation models:** biodiversity data from UA-USGS, species habitat data from SWReGAP, trails data from SPRNCA, and previously-noted data for population density, land cover, land ownership, and access. **Data to parameterize the ARIES models** were obtained from the literature and an expert workshop convened in Tucson from Sept. 21-23, 2010. All data sources and model assumptions will be fully documented as part of the project report for the BLM-USGS Ecosystem Services Valuation Pilot, to be produced in the winter of 2010-2011.					
Data acquisition methodology or process of identifying and sourcing data	Data are: downloaded, placed onto the ARIES server, pre-processed as necessary (a different process for each data	See above – nearly all datasets were public (from academic, agency, or other research organizations), with sources to obtain spatial data and	Data downloaded from: the Southern Arizona Data Services Program, Arizona Game and Fish Department, and USGS.	Attribute data are collected separately for areas of relative homogeneity within the project site, which are treated as distinct "map units" and are scored based on the specific	The only primary data needed—to define the scope of the analysis, though quantitative analysis—included: per capita water use (from ADWR) and	Four steps to identifying and sourcing data for the application in the San Pedro watershed: A stakeholder framing session and follow-up webinar to identify the

	layer, but potentially including reprojection of certain data, rasterization of large data layers, and mosaicing other data layers), tagged with the proper ARIES modeling concept (to enable it to be accessed seamlessly by ARIES models), and placed onto the ARIES Geoserver, which handles all future data management. This iterative process to build up the ARIES database means that future applications become progressively easier – for instance, future applications in the Southwestern U.S. will already have significant data requirements completed as a result of the San Pedro project.	parameterize the InVEST data table obtained from the user guide and the analyst's familiarity with local through global scale spatial datasets.	All data were in ESRI shapefile format. Species maps were first screened for presence in study area.	attribute data collected within the map unit. The data collection process is guided by a data sheet that structures all information into a hierarchical system. Public data searches and downloading is the focus for external data. If not available, then the function is assessed to determine if there is a surrogate for that attribute, or potential to identify a new attribute.	an estimate of the initial project size.	key ecosystem services of concern, Cardno ENTRIX economists and scientists applied expert elicitation approaches to estimate the appropriate form of the ecological production functions in the San Pedro. Gathered input on relative ecosystem service values from stakeholders through a workshop and follow up webinar. Collected some of the numerous GIS data available for the middle San Pedro area to apply tool findings to alternative residential site locations in the middle San Pedro.
Process for uploading data and preparing for tool application	See above.	All data must be placed in a common workspace and projected to a common projection (in meters), in this case NAD83 UTM Zone 12N. Certain layers (i.e., "biodiversity threats" such as highways and grazing lands) must be rasterized. Preparation	Data were downloaded from source websites and uploaded into ArcGIS software.	Field data is entered into the system (currently a linked GIS/Excel spreadsheet), either manually (when paper data sheets are used) or automatically entered (when handheld machines are used).	Not Applicable	The GIS-based site information was converted to a table format and entered directly into the tool. Information from stakeholders and experts was also directly entered into the tool during the framing session and webinar.

		of the SSURGO and STATSGO databases required the use of the USDA-NRCS Soil Data Viewer to aggregate soils data across horizons, producing a single value for each polygon (followed by rasterization of the vector data). Finally, in many cases, data from the U.S. and Mexican parts of the watershed had to be combined using the ArcGIS "mosaic" tool. Some care had to be taken to create these mosaiced data layers to ensure that concepts were similar on both sides of the border. This required reclassification of some layers. Parameterizing the InVEST data tables was the most time consuming and potentially subjective part of the modeling effort. This work required collecting and reading all references suggested by the InVEST users' guide, collecting follow-up references, and making sometimes-difficult judgment calls when specific data were not available that		External data needed is downloaded and incorporated into the office data collection methodology. In the case of web-mapping services, the service is added to the map document.		

		corresponded to a particular land cover type (a frequent occurrence).				
Time Implications	Approximately five weeks of time (ca. 200 hours) were needed to collect and prepare data for the ARIES models, run the models, and begin to improve them to "second generation" status using expert input from the Tucson workshop. Additional time was needed to develop agent-based ecosystem services flow models for services that had not been previously developed. Further work will continue to refine the models and integrate them into the online ARIES browser. The above work was completed by the ARIES technical team, who have substantial past experience developing case studies and ecosystem services models using the ARIES system. Once data are input and the system	Approximately four weeks of time (ca. 160 hours) were needed to collect and prepare data for the three InVEST models, run the models, and begin to improve them to "second generation" status using expert input from the Tucson workshop. A full "second run" of InVEST models may add an additional 2-3 weeks of time required. A basic level of proficiency with ArcGIS is necessary. Time required would be substantially greater for a user unfamiliar with the idiosyncrasies inherent in GIS datasets and their processing requirements. Time required would be substantially less if pre-prepared datasets and InVEST coefficient tables were available in a common format, for either direct use or as	Staff spent approximately 25 hours reviewing, identifying, downloading, converting, and uploading data into EcoAIM. This time can be broken down into administrative staff spending 8 hours downloading, and scientist level staff spent the remainder of the time.	Field data collection, data entry, and data verification can range from 15-60 minutes per acre depending on the complexity of the site. External data sourcing and preparation requires a background in GIS analysis and database design / development and likely several days. However, this is a one-time time constraint. As the tool is applied to different geographies, some adaptation to the lookup tables used for scoring may be needed.	Less than 40 hours was needed to complete the ESR worksheet and document assumptions, strengths, and weaknesses of the approach. Greater time requirements would likely be encountered in a "real world" ESR application as corporate representatives from different business units, would be brought together, input solicited and synthesized by the analyst. These time requirements may not be trivial, depending on the scope of the analysis and baseline knowledge about ecosystem services within the organization.	Approximately 240 hours of time by Cardno ENTRIX staff including: 100 hours on gathering input from stakeholders (not including about 10 hours of time spent by each stakeholder) 100 hours preparing the GIS data, meeting with scientists and collecting expert opinion, as well as setting up the ecological production functions 40 hours on running the tool and analyzing the results. We would estimate that a typical project, run completely by a company's or agency's staff, would require about 400 hours of staff time.

	becomes fully operational, minimal time is needed to run an ARIES session for an existing case study region. The user simply accesses the pre-developed data and models using the online interface.	primary references, perhaps for a particular agency (BLM, USGS), department (DOI), or as a cross-department/cross-agency ecosystem services initiative.				
Challenges Encountered	When collecting and inputting spatial data, there are almost always numerous small barriers to quick implementation of ARIES, ranging from incomplete metadata, incorrect projections, the need to preprocess certain data, proper handling of transboundary data, etc. Once these barriers are overcome, however, the data and models become consistently available as part of the ARIES system, with no further work needed on the part of the user. Ongoing work will be needed as part of the San Pedro to continue testing and refining the tool, integrate existing models (e.g., MODFLOW groundwater model), add functionality, etc. Many of these features are under development	Several challenges were encountered: Inherent to any InVEST application is the need to develop coefficient tables to link land use-land cover to ecosystem services provision. Despite decades of research on the ecology and hydrology of the San Pedro, many of the types of information required by the InVEST tool are still unavailable for the area. This demonstrates the disconnect that has existed between past ecological and hydrologic research and the data needs inherent to ecosystem services modeling, which forced the technical analyst to make assumptions about the transferability of ecological knowledge that could be open to criticism from other scientists.	Challenges included converting older versions of shapefiles into usable formats for ArcGIS and understanding the information displayed on species coverage maps. These challenges are dependent on the study site and the available information for the site.	There were no challenges encountered in this pilot application. However, it is worth noting that since the system relies on primary data, site access is always a consideration. In addition, when using external data sources, there is always the potential for data gaps in the static downloaded data and web-mapping services. To protect against this, secondary attributes that can be used as surrogates are developed, or at least researched for all attributes generated from external data sources.	The analysis was relatively straightforward for a hypothetical case conducted by a single analyst familiar with the study area and general ecosystem services concepts.	Challenges included: scheduling meetings with stakeholders and educating them about how the tool works and provides value (our first contact with CWA was in early May, the focus group was held on September 21st); and identifying the best approach to collaborate with scientists (each discipline has its own approach to understanding and specifying ecological relationships, and showing them that this tool's standardized process can capture the unique aspects of their discipline is always a challenge).

	but are not yet part of the online ARIES tool.	Data preparation is a time consuming effort which would be greatly eased were there better databases containing InVEST-ready datasets could reduce these time requirements. Transboundary nature of the watershed required the technical analyst to combine U.S. and Mexican or global datasets, which raised issues with proper convolution of data—a time consuming process that can cause further error if done incorrectly. The arid/semiarid environment meant that the simplifying assumptions in the water yield model did not adequately include groundwater processes, so it produced results that were misleading. The tool developers are currently working on fixing this problem.*(Note that the InVEST team asserts that they were aware of, and identified, this problem before the experts and decision makers in the area.)*				

Summary of Field Time with Parametrix Team to Develop EcoMetrix for the San Pedro River, Arizona

By Ken Bagstad, Technical Advisor to Comparative Tool Application

Parametrix, a Northwest-based consulting firm, has developed a tool called EcoMetrix that is intended for use as a field-measurement based ecosystem services assessment tool (Parametrix 2010a). Unlike landscape scale tools that incorporate only GIS data (i.e., InVEST, ARIES), EcoMetrix is intended for use at the site scale, drawing on both some GIS data for inputs (soil data and climate information (which are used as modifiers, for example) in addition to field data. EcoMetrix was initially developed for use in the Pacific Northwest and New Mexico.

For BSR's 2010 "Roundtable Discussion of Emerging Ecosystem Service Tools and Applications within Private and Public Sector Contexts," Parametrix applied the EcoMetrix tool to the San Pedro River in Arizona and Sonora specifically and southwestern riparian systems more generally. Since the tool's use relies on field data and its results have not yet been comprehensively documented and published, BSR consultant Ken Bagstad accompanied a Parametrix field team for two days in order to better understand and report on how EcoMetrix is developed and applied for a new region of interest. This field report is intended to improve the transparency and understanding of how EcoMetrix can be applied toward ecosystem services-based decision making in the public and private sectors.

Methods

Sites and field conditions

A Parametrix field team visited five sites along the San Pedro River in Southeast Arizona from July 26-29, 2010. BSR consultant Ken Bagstad accompanied the team in the field on July 28-29. Over these four days, the field team visited five sites of varying ecological quality. All sites were located on public land owned by the Bureau of Land Management, with four as part of the San Pedro Riparian National Conservation Area and a fifth site located on a small parcel of BLM land located north of Pomerene, AZ (Table 1).

Table 1. Summary of sites visited

Site name	Surface flow frequency	Predominant vegetation communities	Relative site quality
Highway 90	Perennial	Cottonwood-willow gallery forest, perennial flow channel & riverine marsh, scrub-shrub, backwater channels & wetlands incl. beaver dams, grasslands	Highest
Charleston Bridge	Perennial	Perennial flow channel & riverine marsh, middle aged-to mature cottonwood, mesquite shrubland, mesquite-sacaton savanna	High
Fairbank Bridge	Intermittent	Intermittent flow channel & streamside, mesquite shrubland, cottonwood-willow woodland	Moderate

St. David	Intermittent	Deciduous forest, incl. cottonwood and tamarisk, scrub-shrub, intermittent flow channel & streamside	Low
The Narrows	Ephemeral	Ephemeral flow channel & streamside, mature tamarisk & mesquite shrubland, upland mesquite-graythorn shrubland	Lowest

At the time of the site visits (late July), southeast Arizona had been experiencing its monsoon rainy season for several weeks. All five of the field sites had surface flow, and flow was highly variable across even the four days of the survey period – at one site, water marks and debris lines indicated that water was as much as 5-6 feet higher just several days ago than it was at the time of the field visit. Flow in the river typically carries high levels of sediment, so the floodwater was quite brown, opaque, and the aquatic plants that are evident during low-flow periods were either uprooted or not visible through the flood waters. Because of the monsoon floods, streamside riverine marsh (i.e., bulrush and cattails) had been beaten down by floodwater in sites where it grew, and scour had likely buried or uprooted herbaceous vegetation in lower-lying parts of the floodplain. The rain and flood pulse was also triggering the growth of annual and perennial plants in the floodplain and uplands. In most cases these were at immature life stages, making identification difficult.

Had the field visit taken place a month earlier or later, conditions on the San Pedro would likely have looked much different. In the June dry season, field staff would likely have found very low levels of streamflow (with streamflow absent at all but the perennial flow sites), abundant aquatic and riverine marsh vegetation near the stream at the wetter sites, and low levels of herbaceous cover in the floodplain. By late August and early September, field staff would likely find much greater herbaceous diversity, taller vegetation, and numerous species in flower as the rainy monsoon season begins to draw to a close. However, not all years will have a wet monsoon season. The 2010 monsoon season was a relatively wet one. Within the last decade, the monsoon rains have been quite variable, with the monsoon almost absent in some years.

The Parametrix field crew noted that usually when field sampling for EcoMetrix they would survey during low to moderate flow periods of the year along a given river. However, if a survey is necessary during high flow periods, best professional judgment and/or information from local landowners/biologists is used to characterize the condition when the site is not under water. For the Southwest this presents obvious challenges, and we were far from the lowest flow period during our sampling efforts. [12] A single sample period also misses risking an important event that happens at some sites over a short period during the year (i.e., in providing habitat for a migratory species, presence/absence of a nonnative species during a shorter period of the year[13]). For example, at one site the nonnative London rocket (*Sisymbrium irio*), a spring annual, was abundant though it was dead by the late July sampling period. While the surveys take note of dead vegetation, they do not explicitly account for instances like this, though in our case we did add this species to the list of nonnative species at the site, given its abundance. Yet if the standing dead plants had been washed away by floods, trampled by grazing, or otherwise been unobservable, we would have missed its presence at the site by only visiting at a particular time of year. It is because of these situations that obtaining local landowner/biologist input before collecting data is an important step in EcoMetrix data collection.

This situation raises the difficulty of trying to classify “what’s normal” in highly variable environments like southwestern deserts – both within and between years – when classifying sites, ranking their ecological

[12] It is noteworthy that this is a challenge in every location. Project timing seldom accommodates our desires. Accordingly, as stated above, we have a protocol for sampling during non-low flow periods. However, if there is particular issue of concern for the site for which low-flow measurements would be necessary – (stream morphology for example) - we recommend follow-up sampling for best results (it really depends on the focus or issues of concern driving the need to use a metric in the first place.

[13] The presence of exotic species in abundance is an attribute used in the application of the EcoMetrix tool.

quality, and trying to make statements about their habitat quality and levels of ecosystem service provision. By comparison with the Pacific Northwest, one of the primary locations where EcoMetrix has been developed and applied, the southwest is highly variable from year to year. Several of the questions in the datasheets reflected the assumption that you can make statements about "what's normal" (i.e., size of the annual peak flow in a river); such questions may be of lower relevance in systems like the southwest. Two of the three Parametrix field staff and the independent consultant were experienced in southwestern field surveys, so the field team was at least aware of this issue while surveying.

Step 1: Map unit delineation

Before surveying a site, Parametrix staff typically contact a scientist, landowner, or land manager familiar with the area's human and natural history in order to gain information that will better inform the mapping process. In this case, the independent consultant served that role, having spent several field seasons researching vegetation, hydrology, and disturbance on the San Pedro. The independent consultant also ranked the five sites by vegetation quality and diversity, groundwater depth, and surface flow frequency.

At each site, a team of two scientists (ideally one specializing in wildlife and one in vegetation) surveys a roughly 20-acre area. The team used a high-resolution aerial photograph of each site combined with a field survey to delineate a series of "map units" (ranging from about 10-20 map units per site, depending on site complexity). Map units are intended to be internally homogeneous in terms of dominant vegetation, soils, and elevation relative to the channel. Map units must be of a minimum size. The smallest map unit was perhaps 300 ft^2, and the largest was perhaps 6-8 ac. Small map units that are deemed especially important for habitat purposes (e.g., vernal pools, narrow bands of cottonwood trees, cliff faces) are more likely to be separated into distinct units than larger map units with slight internal homogeneity. Additionally, man-made features that alter the ecological function of the site or adjacent map units are also treated as their own map units (e.g., parking lots, bridges, bridge abutments, or stormwater conveyance facilities). Agricultural land uses would also be treated as distinct map units. Rights of way are typically ignored unless the right of way is within the project area or will be incorporated into a management plan/activity. Streams are broken into segments, typically 100, 200, or 400 m in length and are separated by riffle and pool features. Beaver dams would also be used to split aquatic map units.

Step 2: Data collection for map units

After delineating map units, a set of datasheets is filled out for each map unit. Each set is a check-box based, 24-page description of the site's dominant vegetation, soils, disturbance regime, hydrology, and terrestrial and aquatic habitat characteristics. Though the set of datasheets is large, it is not overly time consuming to complete once the field scientist is familiar with the methods and questions. In addition, the section on aquatic characteristics can be skipped for terrestrial map units and vice versa. Each question is designed to measure an ecological characteristic that is relevant to provision of a particular type of habitat or ecosystem service. Parametrix has a field guide to describe how to complete the datasheets, though a field scientist familiar with biological surveys can learn the process by being taught in the field by a more experienced analyst. Parametrix also plans to create a tablet PC (i.e., iPad) application for the datasheets, which would reduce the length of the questionnaire (i.e., by automatically skipping sections not relevant to the type of map unit in question).

The field questions are designed not to require sampling – of vegetation, soils, wildlife surveys, etc., and are intended to be able to be completed entirely in the field. Many questions are designed so that the analyst reports a range of cover (e.g., 5-10% basal grass cover, 10-30% litter cover). Reporting values within a range, rather than discrete values, reduces subjectivity between field analysts. For example, while two separate analysts might report 35% and 40% tree cover in a mapping unit, they would both report 30-60% tree aerial cover if asked to report a range rather than a discrete percentage.

While the dominant plant species are recorded, it is not necessary to identify all plant species or even to key all plants to species. The more important information is the number of dominant species (i.e., there are three herbaceous species with >5% aerial cover), and whether these species are native or nonnative.

Step 3: Deriving "ecosystem services curves"

(Technically this step is just function curves – we have a separate step for determining how functions aggregate to provide services. We measure individual functions and then develop a conceptual model for how those functions combine to allow ecosystem services to be performed. Essentially this means we need to better define the "benefit" being provided as the ecosystem service. I can send the table we put together for water provisioning as an example. In that example we focused the service benefit on the ability of a properly functioning ecosystem to avoid excess loss of surface water and soil moisture, the ability to slow run-off thereby maintaining a more moderate hydrograph, and the ability to contribute to water storage. For each of these benefits we identified the relevant functions and determined how those functions combined to provide the benefit. (However, ultimately, what I am writing here should be considered after the next comment to be in proper sequence).

Once field data are collected and summarized, two key questions must be answered: first, how do field-measurable data translate to performance of ecological functions, and second, how do these functions aggregate to ecosystem services? A third, optional question not yet addressed by EcoMetrix is how these services are economically valued.

Each of the function scores is calculated using algorithms developed for the EcoMetrix database. Each algorithm is developed through a standard process that includes the following steps:

1) A conceptual model is developed to describe how the function is performed on the landscape (see Figure 22). This conceptual model identifies the attributes that are relevant to the function being performed, how they contribute and whether there are certain conditions that need to exist for the function to be performed, or that will alter how the function is performed.

2) The identified attributes are broken into quantitative, or where appropriate, qualitative ranges so that they can be measured in the field with greater sensitivity than mere presence absence. Care is taken to not create ranges that cannot be easily repeated by subsequent data collection efforts.

3) Scoring curves are developed for each of the quantitative and qualitative attribute ranges based on how increasing/decreasing or changing the attribute type will affect the performance of the relevant function (see Figure 23). The scoring curves are then used to generate lookup tables that are tied to the relevant data entered from the field datasheets.

4) The algorithm is then created by aggregating the attributes pursuant to the conceptual model that was developed in step 1. The database is developed by tying the algorithm to the scoring tables developed for each attribute's contribution to each function.

The algorithms used in EcoMetrix have been developed over a five year period with testing at a variety of sites in varying geographies. Where the relationship between attributes and functional performance varies within a unique geography, the algorithms are adjusted accordingly. Because of the nature of the attributes being collected, there are typically few adjustments necessary. An example, of a change to the scoring was provided during system testing in New Mexico. During the test it became apparent that for application in the Southwest, it was necessary to re-scale the ranges for the vegetative species richness attribute (i.e., the number of different types of plant species found within a map unit).

The first step in this process is thus to link field data to an assumed level of ecosystem service or habitat quality provision via an ecosystem services "production function" (Parametrix 2010a, Parametrix 2010b). Assuming field staff are able to rank site quality, either independently or (ideally) verifying their assumptions with a local expert, landowner, or land manager, Parametrix staff can then draw curves relating site quality to a particular level of ecosystem function (Figure 1). The goal of drawing these curves is to be able to represent how a site's ecosystem service provision will change as site attributes or management strategies are changed through alternative development or conservation practices. This enables the comparison of scenarios where sites are developed or managed, and on a finer scale to note how ecological functions and ecosystem services change as fine-grained development alternatives themselves are altered (e.g., between "conventional" or "green" building).

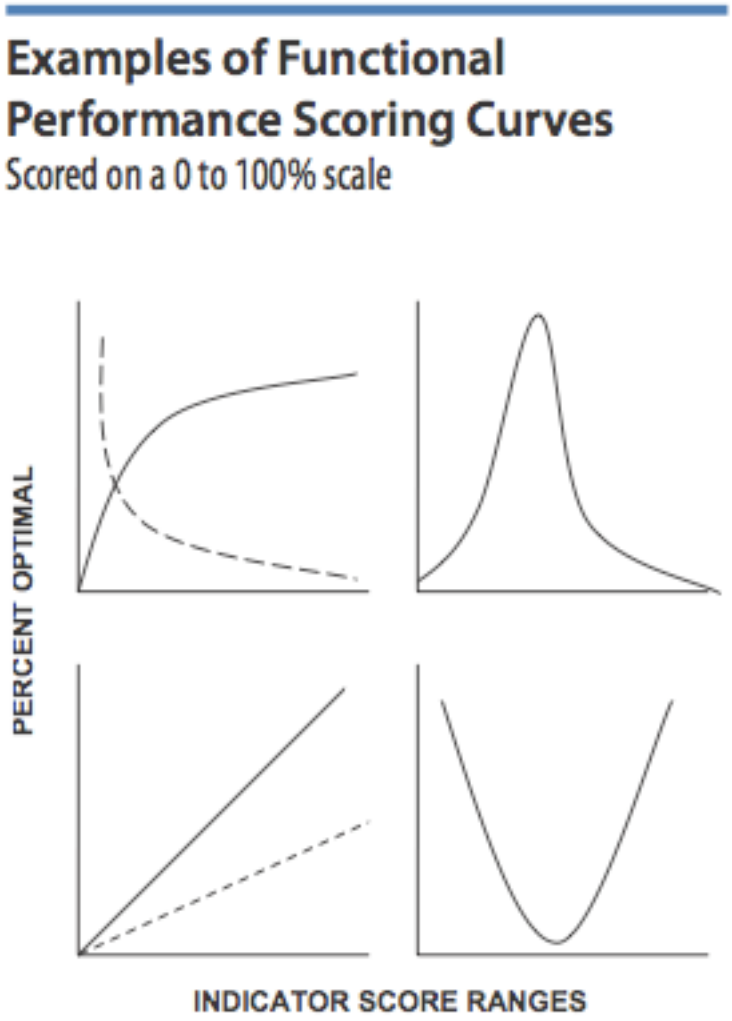


Figure 1. Sample ecosystem service curves (Parametrix 2010a).

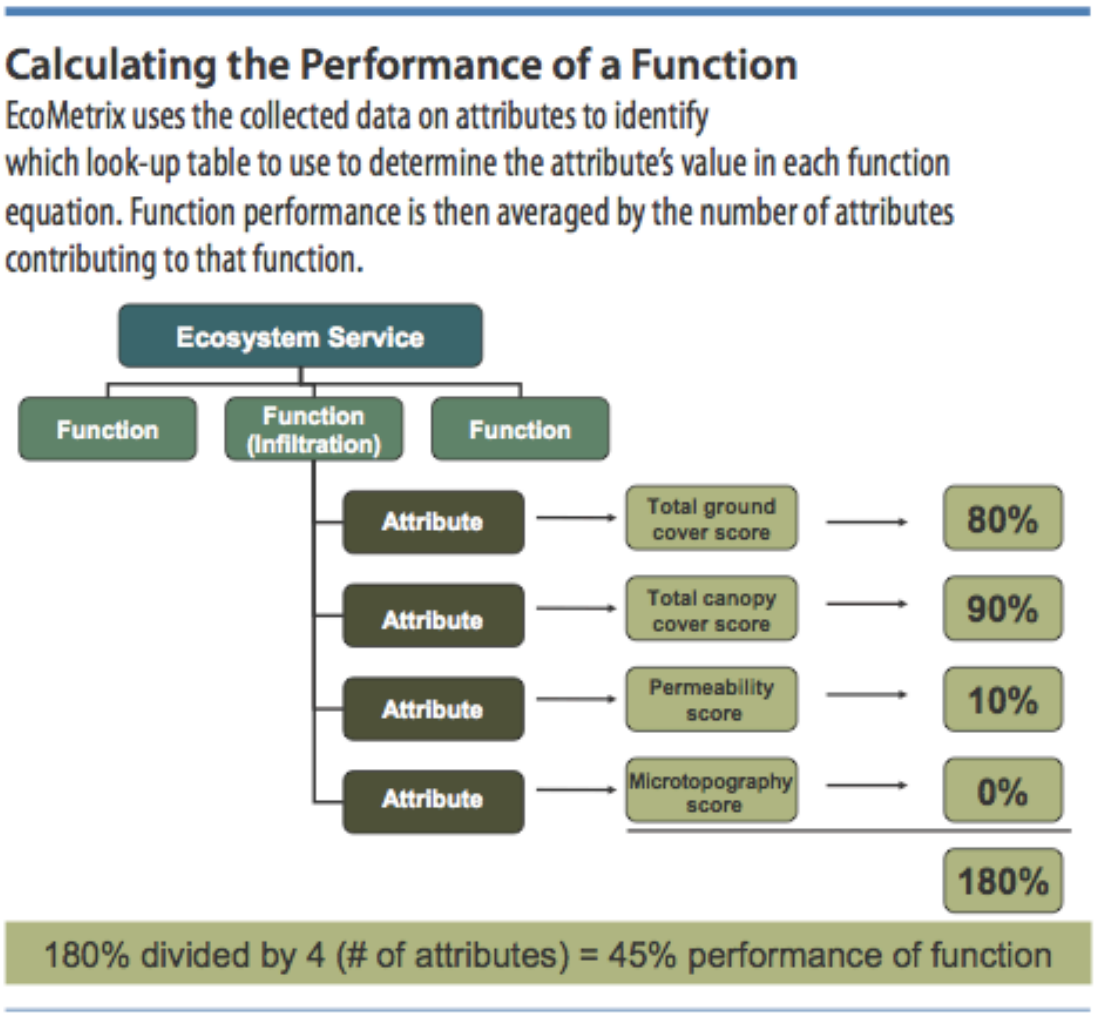


Figure 2. Sample ecosystem service production function (Parametrix 2010a).

Parametrix staff then search the scientific literature and confer with experts to develop a list of ecological functions that will be important to provision of a particular ecosystem service or habitat type. Staff familiar with a particular ecological field will serve as the initial ecosystem service curve/production function developer (i.e., for water quality, fish habitat, erosion regulation). Production functions will go through internal peer review, followed by solicitation of expert input from state and federal agencies, academics, and NGOs familiar with the particular ecosystem service of interest. The end goal is the development of an ecosystem services production function that links field-measured attributes to a level of ecosystem service provision. Variables are aggregated using weighted averages as shown in Figure 2 (Parametrix 2010a, Parametrix 2010b).

Weighting factors or adjustments can be made upward for nonnative but naturalized species that fill important functional roles (e.g., tamarisk) or downward for native species that are invasive or otherwise considered undesirable (e.g., juniper, mesquite). This could potentially be a controversial practice, and should ideally be done after arriving at some degree of consensus among local experts.
This is a critical point. The adjustment can be made for any function, habitat type or attribute. The weighting factor adjustment is a means of ensuring that the final scoring reflects the agreed upon ecological context of the area. These weighting factors are essentially the means by which the non-economic ecosystem service values are accounted for in the final scoring.

However, in its current form, we recommend that weighting factors only be applied based on clear prioritizations from watershed assessments, application of a landscape level tool that provides agreed upon

prioritization (this is one of the intersection points we see between metric scales) or consensus amongst stakeholders as to the regions ecosystem priorities.

In any future web-based application, this would be a restricted access aspect of the system (restricted to an agreed upon system administrator).

Step 4: Application

Once field-based measurements are linked to ecosystem services provision using the above-described approach, alternative sites and alternative site layouts can be compared by projecting change in ecosystem service provision based on how ecological functions are altered. The key question of interest at a proposed development or restoration site is how close to optimal are the ecological functions and ecosystem services provided on the site. For a set of mitigation sites or a single site with alternative proposed management strategies, potential tradable credits or mitigation values can thus be estimated. For development scenarios, development alternatives can be compared, allowing estimation of which alternatives minimize impacts to key ecosystem services of interest and mitigation credit needs, if applicable.

When using EcoMetrix to calculate change in performance, the datasheets are re-done based on the development or restoration design. This typically means re-drawing map unit boundaries based on proposed activities and completing a new data-sheet for each of these map units that captures changes to attribute conditions. For restoration activities, the vegetative condition for the new data sheets is based on 15 to 20 year projected growth. Accordingly, it is important to recognize that the scores reflect the desired future condition. However, EcoMetrix can be used in the site monitoring process to track the projected increases in functional performance to ensure that they are occurring as planned. The alternative analysis process can assess multiple potential designs at a single site, or it can be used to compare a potential design footprint at multiple sites."

General observations

The EcoMetrix field process

Like any process that involves drawing lines on a map to separate ecosystems or habitat types, there is a degree of subjectivity in delineating map units, and the possibility that independent analysts might draw map units differently. However, in riparian systems, especially in the southwest, where distinctions between vegetation, groundwater depth, and inundation frequency are fairly clear, this risk is reduced somewhat.

The entire process of delineating map units and completing data sheets ranged from 4-6 hours per site for a team of 2-3 field scientists. This time would be reduced for an experienced field crew, as the time requirements were extended in teaching a new individual the survey methods and in providing a detailed justification for the survey protocol. For extremely simple sites (e.g., agricultural fields), the survey could take as little as 5 minutes, though this is an extreme case. The site surveying process – delineation of map units and completion of datasheets for each map unit – was relatively straightforward for an experienced field biologist to learn and apply successfully.

EcoMetrix clearly takes proxy measurements of ecosystem functions rather than direct measures of function. It would be interesting to apply EcoMetrix to an area that is well-instrumented ecologically to measure these functions (e.g., carbon sequestration, soil erosion, nutrient regulation), and compare results between the two methods (i.e., to see if EcoMetrix's proxy values are similar at least in magnitude and difference between sites as field-measured values). It would also be interesting to directly compare EcoMetrix production functions to those of other ecosystem services tools, as well as the magnitude of change found as a result of alternative scenarios, to compare tool outputs when using consistent underlying data and development or restoration scenarios.

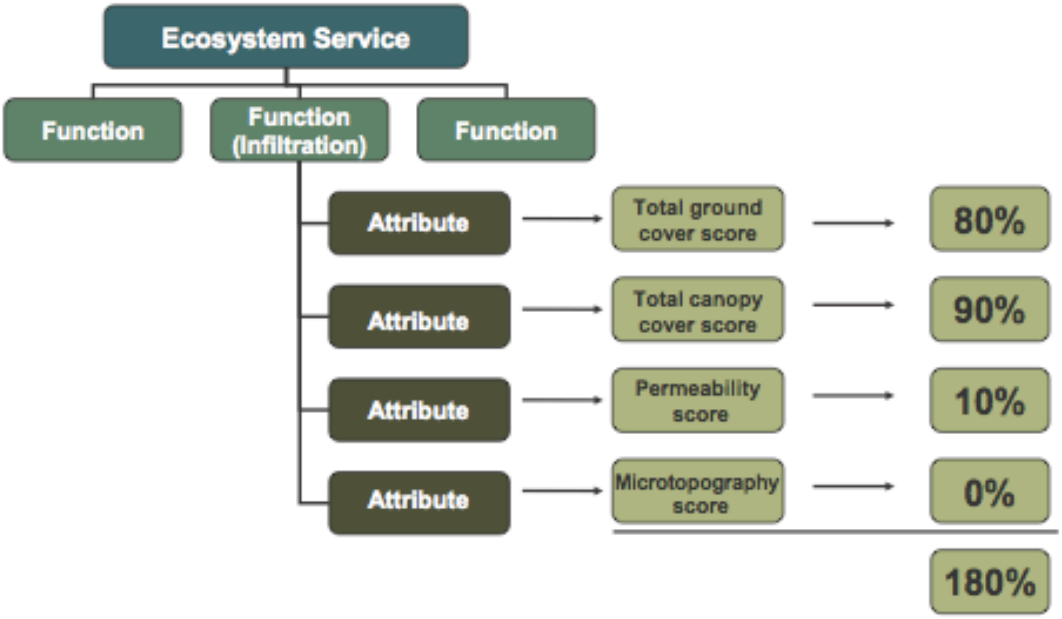
Potential strengths and limitations of the EcoMetrix approach

Like most ecosystem services tools, EcoMetrix is only as good as the quality of its ecological production functions. In other words, if poor assumptions go into the process of developing production functions, faulty

results will be produced. Thus field testing of the function algorithms was conducted in the Southwest to extend EcoMetrix's functionality from the Pacific Northwest, where some underlying ecological processes are different. some, because for many abiotic functions the processes (including many of those that feed into climate regulation and water quality services) are the same and the things we measure are the same. For example, evaporation, transpiration, interception, infiltration, etc. are all physical processes bound by the same physical laws in the SW as in the NW (if only we could get our environmental laws as uniform). Of course, the extent to which those physical processes are performed within a given region may depend on climate factors within the region – but these are already built into our algorithms. This is no different from other ecosystem services models and tools, and the different tool developers likely have much to learn from each other if incentives that reward collaboration over competition can be developed.

Calculating the Performance of a Function

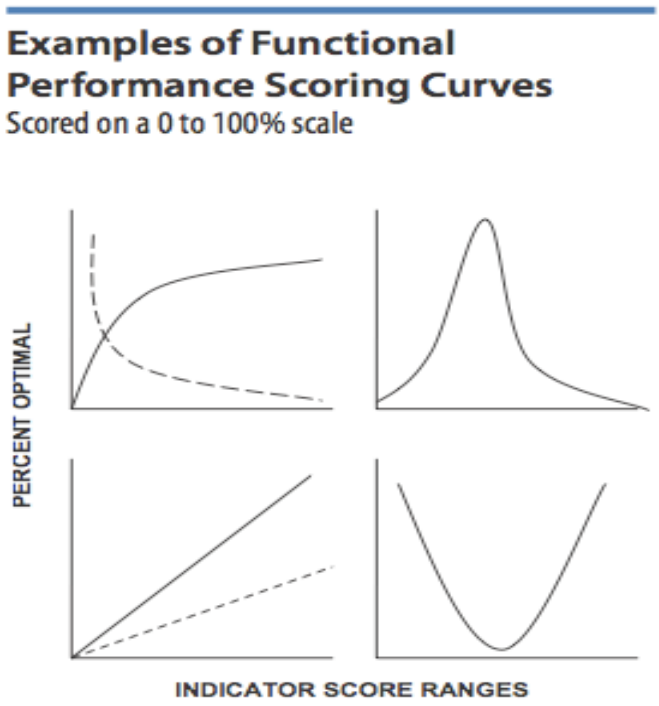
EcoMetrix uses the collected data on attributes to identify which look-up table to use to determine the attribute's value in each function equation. Function performance is then averaged by the number of attributes contributing to that function.



180% divided by 4 (# of attributes) = 45% performance of function

EcoMetrix remains the only site-level, field measurement-based ecosystem services tool yet reviewed by the BSR Ecosystem Services working group. While it is likely not suitable for landscape-scale analysis, it could be paired with a tool like ARIES, InVEST, or EcoAIM that works at the landscape scale. The landscape scale tool could be used to select more specific sites for analysis, for which EcoMetrix would be more appropriate. EcoMetrix also currently lacks an economic valuation component, which is another potential point of synergy with other ecosystem services valuation approaches.

EcoMetrix could support ecosystem services based decision-making in the public and private sectors. For the private sector, questions about impact minimization when choosing between potential sites or design alternatives often quite important and could be addressed by EcoMetrix. For the public sector, similar siting or management questions could be asked for projects on public lands or using public funding. Additionally, EcoMetrix could support environmental markets for both public private sector stakeholders by demonstrating impacts and available environmental credits through site management and restoration.



both are and

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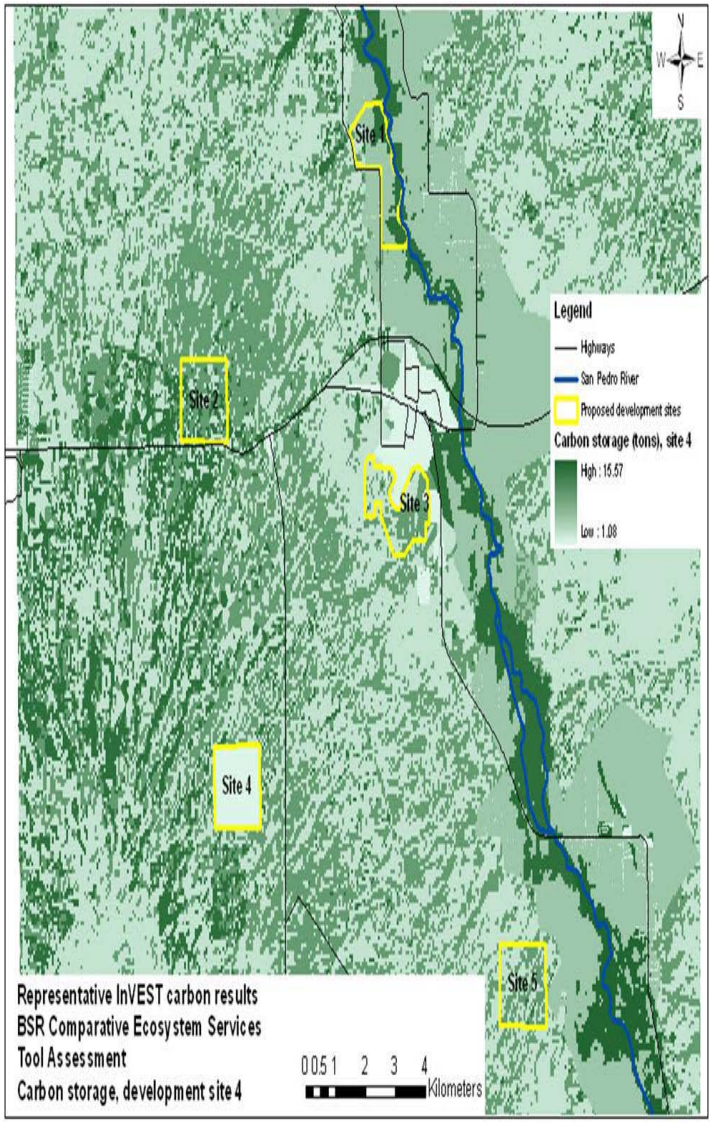
Parametrix. 2010b. Carbon sequestration function. Parametrix: Portland, OR.

ARIES & InVEST Side by Side Comparative Results from San Pedro Watershed Assessment

Carbon Storage (tons) Versus Carbon Sinks (tons/time)

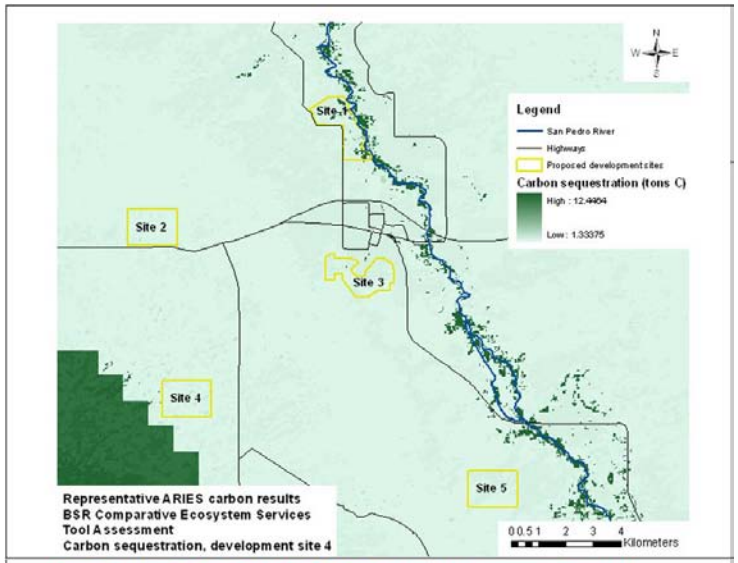
InVEST

Carbon sequestration / storage *(same as previous)*



ARIES

Atmospheric carbon sinks and uncertainty



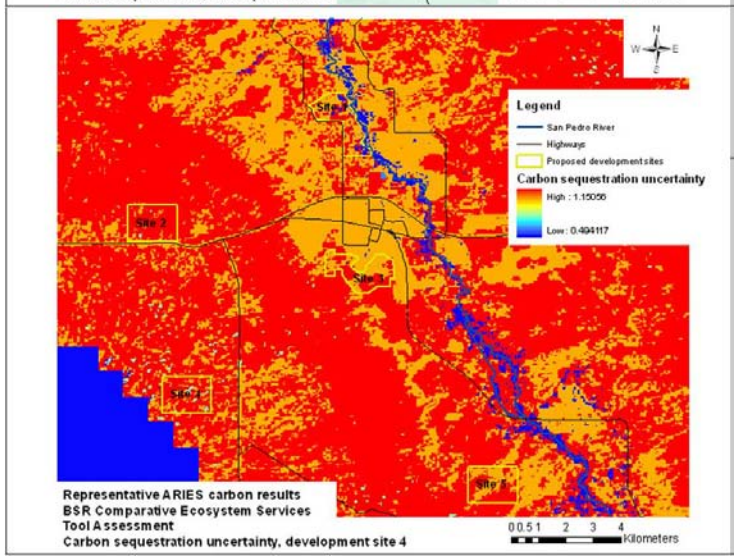
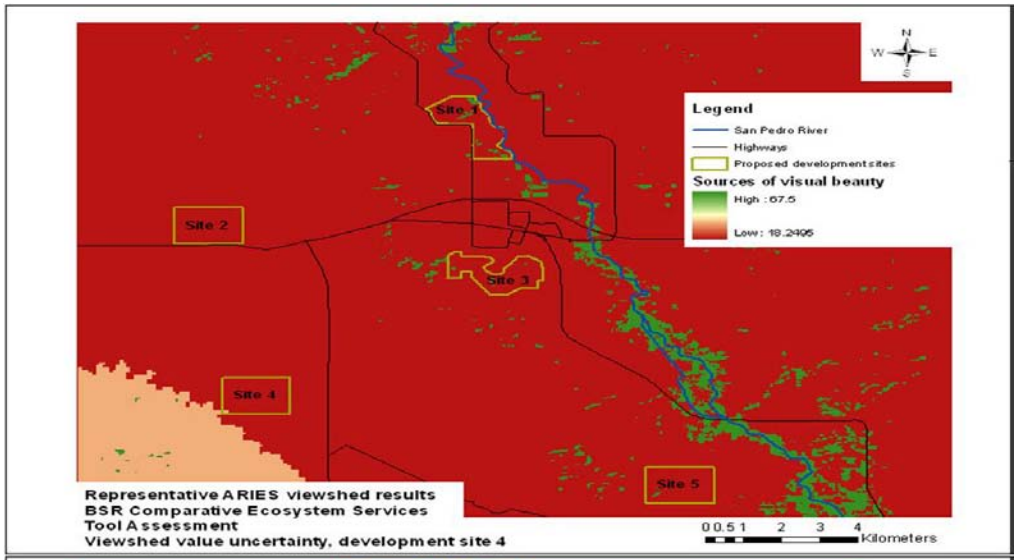


Figure 6. Aesthetics: Viewshed Values, *(No Comparable InVEST Model (Comparable InVEST Model not available at the time of analysis, but is availab*

ARIES

Viewshed values



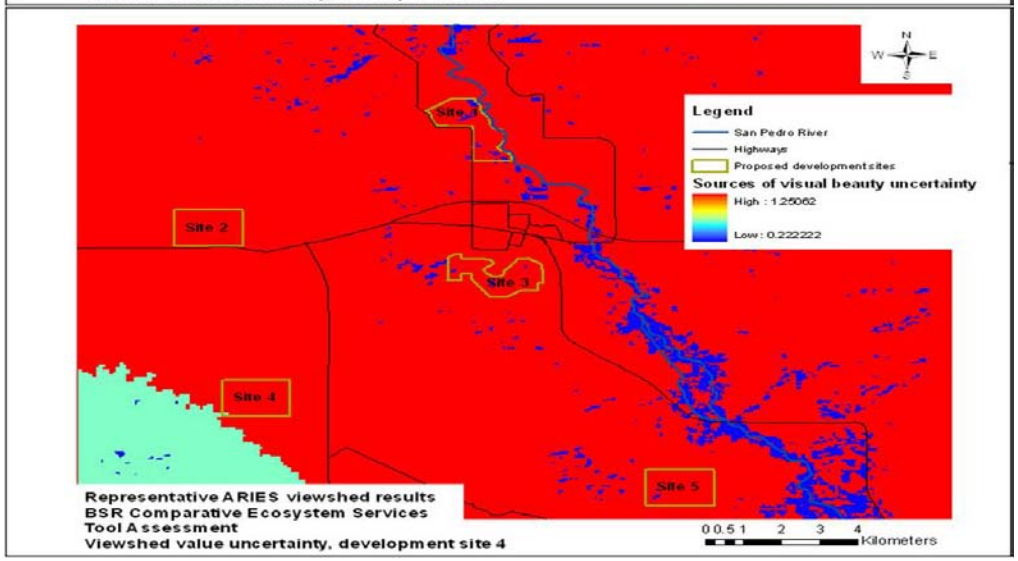
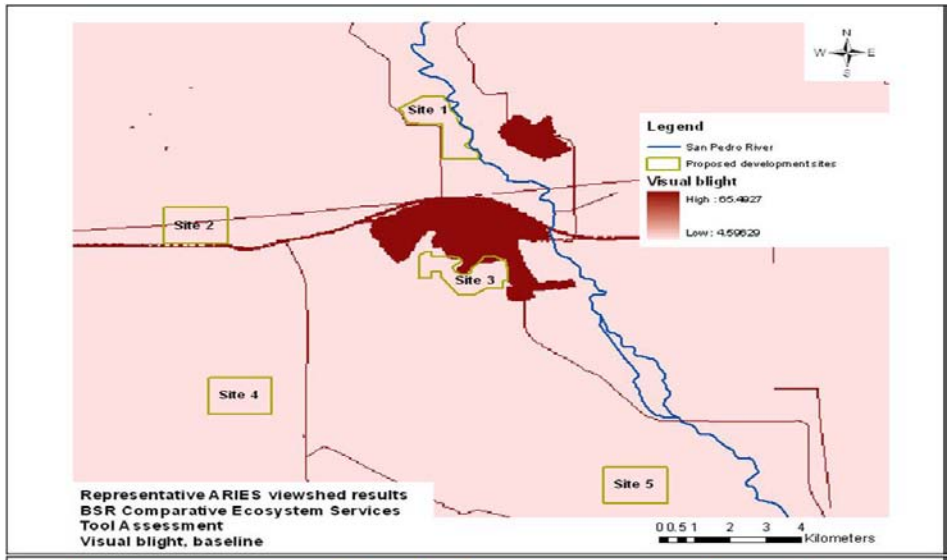
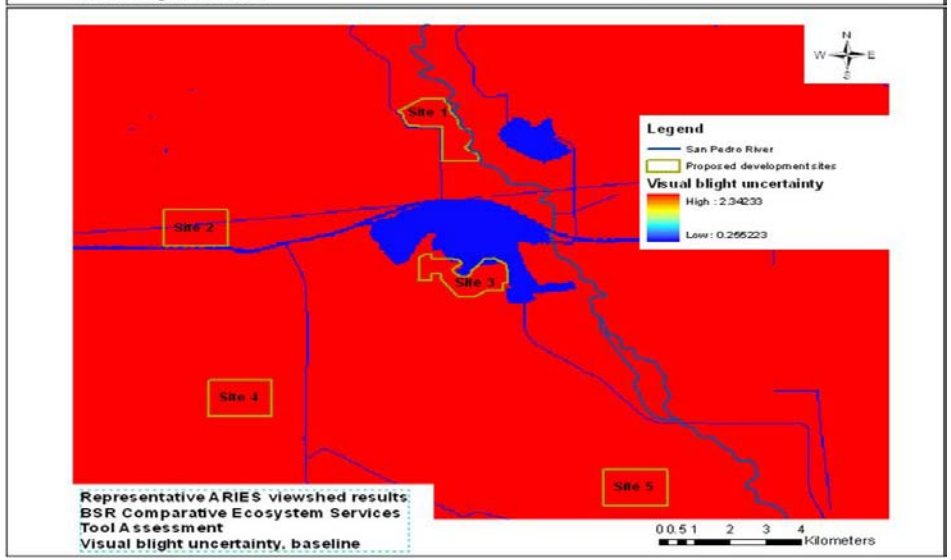


Figure 7. Aesthetics: Visual Blight Values, *(No Comparable InVEST Model)*

ARIES

Visual blight values





Preliminary Reflections on Tools Strengths & Weaknesses based on San Pedro Watershed Application

Tool	Weaknesses	Strengths
ARIES	» Time requirements associated with finding underlying data » Reliant on strong data sets, without which certainty levels will plummet and results are of limited use (thereby requiring time/funds spent on collecting additional data) » Requires significant time and technical expertise to develop new case studies and interpret findings as numerous maps of potential and actual service delivery are produced as outputs » Models need to be calibrated and validated	» Tool has potential for application across landscapes to assess ecosystem services flow pathways, as well as identify impacts and opportunities associated with large-scale business operations » Carbon module offers potential for pilot corporate applications due to regional approach » Handling of uncertainty is clear » Online interface improves accessibility » Appears to be compatible with other tools, such as ESR—to structure the process for prioritizing ecosystem services, in order to make it more transparent and less subjective—and EcoMetrix to conduct site-level assessments
InVEST	» Time requirements associated with finding underlying data, spatial and otherwise, for the models » Lack of treatment of (a) uncertainty and (b) spatial flows of services	» Underlying assumptions are well documented » Models have gone through peer review processes prior to publication in scientific journals as well as an Oxford University Press Book » Free for download and use by anyone with purchase of ArcGIS » Applicable anywhere in the world with globally available data and within parameters set by the users' guide
EcoAIM	» Tool was only applied to biodiversity in this comparative test; need to see additional layers of other ecosystem services to assess value » Unclear level of effort to apply, as the tool is designed to be customizable to accommodate multiple spatial scales as well as data inputs	» Can be customized to accommodate various levels of effort and application objectives as well as varying levels of stakeholder engagement to develop valuation of ecosystem service tradeoffs » Provides user with ability to explore sensitivity of assumptions regarding stakeholder preferences and other variables » Flexibility of the tool allows for the incorporation of other ecosystem services and is capable of assimilating results from other scientifically-vetted ecological models
EcoMetrix	» Need greater assurances that data collection approach is not subjective / dependent on technical analyst (and thus would	» Appears to have potential as a scientifically-based ecosystem services measurement tool at a project

	be reproduced by different analysts) » Need more examples of, clarity on, applicability and experience in ecosystems other than US Pacific Northwest » Important to couple with a landscape- or watershed-level tool guiding decision-makers on what sites to examine (such as ARIES or InVEST)	level, particularly in combining data sets with field data collection » Very transparent, can see functions » Experience working with public agencies and ensuring relevance of models to government relations / discussions
ESValue	» Double counting in model, that then had to be corrected, thus requiring strong facilitation from someone familiar with model » No hardwired ecological production functions, so need to solicit expert input and requires that key ecological relationships are broadly known » Requires iteration between ecological and social valuation pieces to ensure common definitions/understanding of terms and units » Needs clearer documentation about how to use the tool, the tie-in between stakeholders values and science, and the circumstances when the tool will add value compared to other methods.	» Surface people's dependencies on ecosystem service » Benefit was a systematic approach to stakeholder engagement around scientific issues of ecosystem services, though many stakeholders did not want to value and prioritize ecosystem services » Adaptable to many landscape scales and types of ecosystem service impacts » Can identify primary impacts and values even if data is sparse » Values ecosystems in metrics other than money » Incorporates impact of uncertainty
ESR	» Potential to be subjective, depending on consultation process » Qualitative tool or process, does not quantify or map impacts	» Good for screening / identifying ecosystem services in an area » Good to start dialogue around ecosystem services » Relatively easy to use » Good for garnering social components of ecosystem services
NAIS	» Key analytical approach of this tool—value transfer—can be subjective	» Potential inputs for other models, should the approach be seen as appropriate / credible for an area » As one of the few comprehensive sources of synthesized metadata on valuation studies, NAIS could complement other tools as an input to extend functionality

BSR's Summary Review of Selected Database Tools that May Complement Ecosystem Services Tools

Assessment Criterion	IBAT
Purpose / Objective of Tool	*The IBAT Vision: Decisions affecting critical natural habitats are informed by the best scientific information and in turn decision makers support the generation and maintenance of that scientific information.* Seeks to provide to private and public section decision-makers: » Access for private and public sector decision-makers to accurate and reliable information on biodiversity and critical habitats at finest scale possible to inform a range of activities (such as planning new operations; assessment of risks associated with sourcing practices, development of national or regional development strategies, and practical implementation of environmental safeguard policies and industry best practice standards), and » Support for use of biodiversity information at earliest stages of project planning through a web-enabled decision support system that integrates and interprets the most critical biodiversity information available
Tool Developer / Partners	» *Developer:* IBAT Alliance, consisting of BirdLife International, Conservation International (CI), International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). Software development is by QPQ Software Ltd. » *Corporate sponsors::* Bank of America, BP, Cargill, Chevron, JPMorganChase, supplemented by corporate partners in UNEP-WCMC's Project Proteus addressing the World Database on Protected Areas (17 companies, including BP, Chevron, ENI and Shell, among others) » *Public sector partners?*
Target Audience(s)	Tool is targeted toward public and private sector organizations involved in biodiversity risk assessment. It is not targeted at specific industry sectors, although interest has been greatest from companies operating in the oil & gas and mining & minerals sectors, with more limited interest from agriculture, construction and consultancies. A major target audience is public and private organizations in the finance sector (e.g. International Finance Corporate, Equator Principles Financial Institutions, development banks).
Year of Creation / Tool Launch	Launched at the World Conservation Congress, October 2008
Scope / Applicability ***ideally including illustrative questions to which the tool can be best applied***	Tool is global in scope. Primary expected tool application within companies is likely to be: » high-level corporate geographical biodiversity and protected area risk exposure assessments » location selection and site planning for new projects and operations, and » assessment of biodiversity and protected area risks associated with sourcing practices. Examples include:

	» Determining the location of a new development (by providing ability to scope particular regions and sites during the early stages of decision-making process, thus facilitating narrowing of site options and identifying risks likely to require budgets for avoidance and mitigation measures) » Supply chain management (by identifying potential issues associated with locations of sources of raw materials, thereby informing design of strategies to effectively manage biodiversity risks within a company's supply chain, such through discussions with suppliers on biodiversity conservation policies and management practices) » Support for company biodiversity performance reporting (by allowing company to identify whether/where it is operating in/near areas of high priority for biodiversity in a region or globally Other key anticipated uses will be by multilateral development agencies reviewing projects against biodiversity-related policies and guidelines, such as World Bank Operational Policy 4.04, International Finance Corporation's (IFC) Performance Standard 6, and the Inter-American Development Bank (IADB) Policy Directive B.9.) Approach is to integrate and layer information about locations and characteristics of both protected and unprotected globally-identified high priority sites for biodiversity conservation (rare and endangered species, key biodiversity areas and protected areas). User can screen geographical locations of current/potential business activity against this information. Focus is currently pitched as an early screening tool. It can help inform and prioritize subsequent data collection, assessment and planning in the project cycle, but is not intended to replace these processes
Databases Used	» IUCN Red List of rare and endangered species (managed through Species Information Service and presented at www.iucnredlist.org) » World Biodiversity Database – the management tool for Important Bird Areas and Key Biodiversity Areas, currently a joint project between BirdLife International and Conservation International » World Database on Protected Areas, managed by UNEP-WCMC in partnership with IUCN's World Commission on Protected Areas
External Input Data Required / Possible	None required. Users download results of tool application into their own systems and maps to work with further as they may desire.
How the Tool Operates	Provides the following main features: » Summary country/territory information for species, sites and protected areas, with links through to a searchable database on each, and then links through to the source external sites for more detailed information » Map tool, providing a typical set of mapping functions (pan, zoom, query, print), site fact sheets, deep-links to external web-sites providing more detailed information, intersection report, download of the source information in either .shp or .kml format » Supporting information Anticipated future enhancements include » Additional point-based intersection report » Google-type imagery for backgrounds » Mobile-device (e.g. i-phone) aware » Series of guidance videos to help with use and interpretation » (possible) Guidance to other resources, such as key institutions on the ground in region/country

Geographic Coverage of Databases	Datasets are global. Tool data layers describe degree of coverage.
Database Quality & Maintenance	Intent is for IBAT data to be credible (globally recognized), trusted, accurate, current, updated over time, reliably available, relevant, easily understood by non-scientific audience. Data layers in the tool are updated periodically to reflect significant changes in the underlying data sets, and at a minimum of once per year. Tool's data layers describe degree of completeness and coverage. BirdLife data are generally high quality and well maintained. UNEP-WCMC depends on national government, supplemented by NGOs, to provide WDPA data, so that quality will vary by country. KBAs have been identified according to international conservation organization protocols, but IUCN is undertaking a broad community consultation to converge on common global standards for identification of sites of biodiversity conservation significance (e.g., key biodiversity areas)
Format of Outputs	» Spatial data can be downloaded in either .shp or .kml format » Intersection report generates a .rtf report » Print can be to screen, html or pdf
Transparency of Tool Design and Operation	Tool is highly transparent. Information about processes involved in designing and populating underlying data bases can be obtained from key organizations responsible for them (e.g. BirdLife, UNEP-WCMC).
Key Assumptions Built into Tool	IBAT tool contains no key built-in assumptions. The underlying databases accessed by the tool are based on field observations by conservation scientists (primarily in public and non-governmental organizations) and mapped to internationally recognised standards that based upon several decades of experience. However, those databases may have built-in assumptions not obvious to IBAT user.
Key Limitations of Tool (e.g. scope, scale dependence, data, etc.)	The tool is for early screening, not a replacement for a subsequent in-depth Environmental Impact Assessment or a range of other biodiversity impact identification, assessment and mitigation activities that may be needed for a specific project or activity. Ground-truthing of data likely to be necessary/desirable for local site-specific purposes. Mapping functions of the tool are fine-scale. The scale and precision of tool application in specific areas of the world are dependent on the scale and precision of data for those areas available in the underlying data bases. Widely-accepted global standards for identifying/defining key biodiversity areas have not yet been formally established under IUCN (see *Data Quality and Maintenance* above).
Ease of Use & Time / Personnel Demands for Applications	Quick and easy to use, requiring no GIS experience required or third-party applications.
Availability to Users (current/planned)	The tool is available for a subscription fee to private sector users through IBAT for Business website (http://www.ibatforbusiness.org), operated by BirdLife International on behalf of the IBAT Alliance. Subscription costs for companies are based on company's annual revenue: » Large business (annual net revenue >US$1 billion), cost is US$25,000 (excluding applicable taxes) for 12 months

	unrestricted access to the system » Medium business (annual net revenue >US$100 million and <US$1 billion), cost is US$10,000, (excluding taxes) for 12 months unrestricted access to the system » Small business (annual net revenue <US$100 million), cost is UK£350 (excluding taxes) for access for 14 consecutive days (from the date of registration), together with permission to download a single country/territory data set. There is a subscription option for individuals only for their personal (no commercial) use. It provides access to the system for 14 consecutive days (from the date of registration), together with permission to download a single country/territory data set, for a cost of UK£350 (excluding taxes). However, individual users, if they are from the not-for-profit sector, may be able to access the version of IBAT known as *IBAT for Research and Conservation Planning*.
Potential Corporate Activity/Decision Interface(s)	» Corporate strategy: High-level risk assessments for exposure to biodiversity and protected area risks in specific geographic locations » Business operations: new project planning involving identifying siting risks and options » Supply chain management: identification of potential risks associated with supplier activities in specific geographical areas associated with globally important biodiversity and/or designated protected areas
Current Corporate Sponsors? **Users?**	Corporate sponsors are those supporting IBAT development, together with those in Project Proteus through UNEP-WCMC. These are Anglo American, Bank of America, BHP Billiton, BP, Cargill, Chevron, ConocoPhillips, ENI, ExxonMobil, JP Morgan Chase, Premier Oil, Repsol, Rio Tinto, Shell, Statoil, Total. It is not clear which of these companies, if any, have used the tool, as there are no case studies or company-specific application information on the website. Customized versions of IBAT have been developed for several multilateral development organization users (International Finance Corporation and Inter-American Development Bank). Again, no information on whether/how the tool has been used by those organizations is publicly available.
Existing/Potential Future Links to ES Tools	Expansion of the underlying data sets to include ES being considered. No clear potential links between this tool and any of the broader ES tools being reviewed by the BSR WG currently identified.
Who to Contact for More Information	Martin V. Sneary Programme Director Integrated Biodiversity Assessment Tool Email: martin.sneary@iucn.org US cell: 202 270 5432 c/o Conservation International, 2011 Crystal Drive, Suite 500, Arlington, VA 22202

Assessment Criterion	NatureServe Vista
Purpose / Objective of Tool	Vista is a decision-support system (consisting of both a process and software) to help users integrate conservation with land use and resource planning of all types. It is sophisticated, powerful, flexible and spatially-explicit, and applies commercial grade design and engineering. Vista covers a wider spectrum of conservation assessment and planning than any other single tool that NatureServe is aware of, but also is designed to be implemented in toolkits with other tools to provide complete assessment and planning solutions. Its core strengths are cumulative effects assessment and mitigation planning.
Tool Developer / Partners	» *Developer*: NatureServe (a non-profit conservation organization whose mission is to provide the scientific basis for effective conservation action), headquartered in Arlington, Virginia, USA. NatureServe represents an international network of biological inventories known as natural heritage programs or conservation data centers, operating in all 50 U.S. states, Canada, Latin America and the Caribbean, with a strong focus on information about rare and endangered species and threatened ecosystems » *Primary partners in tool development*: NatureServe has been advised by many academic, commercial, and non-profit organizations in Vista's development but it has been built completely in-house. » *Primary funders for development/endowment*: Doris Duke Charitable Foundation; U.S. National Aeronautical and Space Administration (NASA); the SURDNA Foundation; Packard Foundation; Chevron; Environmental Defense Fund; Georgia Department of Natural Resources
Target Audience(s)	Planners, resource managers, scientists, conservationists in diverse types of organizations (government agencies, companies, and others)
Year of Creation / Tool Launch	First version of tool publicly released in 2004. Current version is 2.5.1 (fourth generation of the software), launched in 2010
Scope / Applicability ***ideally including illustrative questions to which the tool can be best applied***	Tool can help users conduct conservation planning and assessments; integrate conservation values with other planning and assessment activities (e.g. land use, transportation, energy, natural resource, and ecosystem-based management); evaluate, create, implement and monitor land use and resource management scenarios designed to achieve conservation goals within existing economic, social and political contexts. Tool can be used for a wide variety of projects, including comprehensive land use planning, review of development projects within context of existing plans, infrastructure planning, inventory and monitoring. Potentially of most interest to companies is its usefulness for conservation planning (core to Vista functionality). Conservation planning within the Vista methodology is the act of allocating areas of land and water to compatible land uses and reliable policies for the maintenance of conservation elements. These elements can be components of biodiversity (e.g., species, ecosystems) or items of cultural value such as scenic viewsheds, historic sites, or farms. Vista can integrate a variety of ecosystem services as "conservation elements" the same as it integrates any mapped conservation element. By integrating with hydrologic models such as has been done with NOAA's N-SPECT software, Vista can readily accommodate

	watershed and water quality services. Other services can be modeled in other programs such as InVEST and then imported into Vista for assessment and planning purposes. Tool's decision-making framework can help: » Manage projects through complete lifecycle, including analysis, planning, implementation and monitoring » Gather and document knowledge and values of experts and stakeholders » Assess and quantify cumulative impacts of any plan, proposed project, or modeled event (like sea level rise) » Mitigate conflicts on or off site » Create land use or resource management plans that reflect user's unique situation and values » Improve efficiency of user's planning process » Enhance consistency and repeatability of planning efforts » Improve communications and build consensus with interested parties » Develop documentation and visualizations that support user's land use or resource management decisions Illustrative questions for which a company might want to use the tool: 1. What conservation elements may be affected (positive or negative) by a proposed activity and how serious is that impact? 2. How will my project act cumulatively with other impacts to affect conservation elements? 3. What sites within an area would have the least impact on conservation elements? 4. Using my land use as a conservation element, how can I assure I meet my objectives while not impeding other (conservation) objectives? 5. Where are opportunities on and offsite to mitigate project impacts? 6. How can my mitigation be designed to leverage other conservation activities to have better outcomes? 7. What is the best plan to appropriately balance an activity (e.g., timber production) and conservation values of the company's forested land holdings? 8. What are optimal approaches to avoid or minimize conflict with a population of an endangered species in a specific area in which the company is considering locating a new facility or conduct other land-disturbing activity? No ESTM WG member companies appear to have actually used Vista. However, one company's analysis of the tool from website information suggests particular potential value for companies (especially in review of surplus properties) of the following Vista features: » Conservation value analysis (especially quantification of how a property supports or detracts from the viability of a population of a listed species on the property, thus understanding potential value of the property if used for conservation vs. other activities) » Land use scenarios (especially ability to compare impacts of land use decisions on ecological features, such as wetlands and forests, as well as species) » Standardized display and reporting (especially ability to use mapping/visual component to display land use compatibility and conflict) » Automated functions and references (especially the list of typical data sources or typical data used in analysis in User Manual, which would also likely be useful to companies not using Vista) » (Potentially) Conservation solution functions (especially to address issues of individual species conservation) Vista can be downloaded to run with sample data already provided by NatureServe, to facilitate user evaluation whether Vista would be useful for user's desired project.

Databases Used	Tool contains no built-in databases other than those needed to allow integration of a variety of data sets from multiple sources into a single conservation planning database. User identifies, collects and inputs data sets used for context-specific use of the tool. Vista relies on ArcGIS and Microsoft Access database engines and thus does not require high end enterprise database software.
External Input Data Required / Possible	Tool's database structure is designed to incorporate a variety of data from local, regional and global information sources. GIS layers form backbone of tool database. Additional non-spatial information is also required to record conservation element viability requirements such as minimum required occurrence size, overall retention goal (optional, i.e., percent or acres of current distribution), and most importantly—response of the element to the list of land uses.. Data scale and attribute detail will determine types of analyses that can be done and precision of results, so scale and quality of data provided by user need to match user's decision needs as in any GIS analyses. Basic types of inputs will be: » Planning regional reference information (boundary required, optional layers include streams, roads, place names, topography, digital orthophotos, etc.) » Element distribution maps (e.g., rare and endangered species occurrences, fish and game species habitat maps, vegetation cover maps, modeled distribution maps, scenic views, historic sites, etc. including other land uses for which you'd like to meet a minimum area objective) » Element occurrence attributes (data confidence and condition—the latter can be modeled in Vista) » Element information (name, weight, goal, conservation unit, minimum required area, etc.) » Scenario information (any scenario can be created and assessed, generally we recommend a current actual land use scenario and then a "future" or proposed scenario. Best analyses will result from scenarios that map all uses and features affecting elements and are typically comprised of land use (current, allowable, proposed, infrastructure (roads, transmission), public land management, and existing conservation areas. Vista has an extensive built in User Manual that contains a list of input data required with associated specifications in order to produce described outputs.
How the Tool Operates	Operates on the ESRI desktop ArcGIS platform; supports ArcMap 9.2 and 9.3, currently being tested on 10.0. Uses Windows 2000 or Windows XP, likely compatible with 7.0. Tool's planning focus is "conservation element", which represents features user wants to conserve in relevant area. (Conservation elements can include biodiversity – both species and ecosystems, ecosystem services, cultural features, and other land uses user wants to represent at specified level. The tool installs as an extension to ArcMap with its own menu tab and project management tab but otherwise is fully open to all other ArcGIS functions. While the tool does not enforce a rigid workflow, there are basic first steps required to 1) set up the project with a boundary, and 2) establish a list of conservation elements and their requirements. From there a variety of analyses can be conducted including: » Combine any group of elements and their characteristics to create "conservation value summaries" that for example can answer questions such as "where are concentrations of legally-protected elements,""where are areas relatively free of conservation values,""where are the areas of highest/lowest habitat condition" » Examine any site to understand the inventory of elements and land uses at that location and how the site is performing in

	terms of supporting or impacting elements and what land uses are responsible. » Importing maps to define a current or any alternative future scenario and understand the proportional mix of land uses and policies in a region » Evaluate any scenario against any group of elements to understand how it performs overall in supporting element retention goals, quantify amount and location of impact, visualize conflict hotspots, and visualize portions of element distributions likely to be lost. » Identify locations (using a companion NatureServe tool) offsite that can mitigate for impacts » Create site mitigations or entire new plans by specifying changes to land use or policy for sites or collections of sites. » Models can also include water pollution as modeled by NOAA's Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT) (interoperable with Vista, and most accurate for medium-to-large watersheds with moderate topographic relief) » Generate conservation solutions (facilitated by Vista use of two tools – MARXAN1 and SPOT – commonly used by conservation experts around the world) » Create maps and reports for scenarios, sites, conservation value summaries, and scenario evaluations ready for HTML. Tool also designed and demonstrated to work with a number of other planning and modeling tools, such as CommunityViz (for land use planning) .
Geographic Coverage of Databases	Determined by databases user brings into the tool. (NatureServe's network of member programs can be a very useful source of information about rare and endangered species and threatened ecosystems. Quality and comprehensiveness of these data are very strong for all of North America. Geographic coverage is much less comprehensive, but being improved, for Latin America and Caribbean.)
Database Quality & Maintenance	Dependent on quality and maintenance of databases user brings into the tool. NatureServe can be used as a database management tool to constantly update information based on new maps or field inventory.
Format of Outputs	All map outputs are standard ArcGIS Grid files. Report outputs are HTML with embedded maps for all elements and analyses. Reports can be easily published online and can be exported to software programs such as Microsoft Word or Excel.
Transparency of Tool Design and Operation	Vista's data models and analyses are straightforward and completely documented in the user manual. Operation by users with basic GIS experience is fairly simple. Technical support and training programs are offered for a fee. Tool's capability to generate maps and reports enables user to thoroughly document each input step in the planning and decision-making process (including reference citations, assumption, and logic of each decision), This is intended to deliver transparency in the process and use of the tool, as well as to support communication of process and outputs to others
Key Assumptions Built into Tool	Analytical assumptions are created and documented by the user (e.g., this element has a negative response to this land use), this minimum occurrence size and goal are required for element viability).
Key Limitations of Tool (e.g. scope, scale dependence, data, etc.)	Tool is designed to operate at multiple scales - from small local to larger regional applications. Scalability will depend on whether user has sufficiently precise data to support desired analytical scale. Some ESTM WG companies that have looked at, but decided not to use, Vista did so in part because the tool was more complex and powerful than needed for the type and scale of the company activity/small size of land area being analyzed. Vista can be downloaded to run with sample data already provided by NatureServe, to facilitate user evaluation whether Vista would

	be useful for user's desired project. Tool is appropriate for projects where ArcView (rather than ArcInfo) will meet computational needs for the project. It cannot process combination of layers that exceed 1 billion pixels, and requires tradeoffs for planning areas exceeding 1 million hectares (2.2 million acres) such as reducing pixel resolution of outputs. Vista has been used successfully for areas as large as 6 million acres at fine spatial resolution. Data limitations are dependent on question (both content and precision) user needs answered. Free global data exists to make use of the tool practical anywhere for simpler coarse scale results. Tool does not cover all processes of conservation planning; therefore some evaluations must be conducted using other tools, custom GIS analyses, and professional opinion. For example Vista does not incorporate species demographic information and analyses, so post-processing Vista results with a population viability analyses tool is recommended when those questions are important. Vista also has limitations in analyzing fragmentation, so post-processing with a fragmentation tool (e.g., HPP, fragstats) would be useful when fragmentation is a key concern. Vista User Manual identifies limitations relating to data input and a number of other topics.
Ease of Use & Time/Personnel Demands for Applications	Vista was designed to support assessment and planning work by computer literate but otherwise lay users with support by GIS and subject matter experts for portions of the process. It has very high end graphical users interfaces integrated with the help manual supported by technical support and training services. Tool provides utilities to facilitate collecting information, inputting and documenting data, and conducting thorough data validation functions that run in the background The amount of data needed is dependent on questions user wants to answer and level of precision required. Actual processing time for individual analyses will also vary, depending on complexity of problem user attempting to address, precision of data sets, and overall size of the planning area. The most time consuming steps in the planning process will be priority setting (e.g. what questions does user hope to address using Vista and what data are required to answer them), and (similar to most projects using GIS tools) collecting the data and inputting into the tool. The most time demanding aspect is obtaining the element subject matter expert input (minimum required occurrence size, element response to land uses, retention goal, etc.). Skills/expertise needed to apply the tool will depend on analyses to be performed. Those likely to be needed to effectively implement full range of tool functions will include project coordination & management, GIS, data management, metadata documentation, ecology, zoology, and non-biological domain expertise, such as farmland conservation or archaeological sites). Vista website (http://www.natureserve.org/prodServices/vista.jsp) contains a significant amount of information to explain the tool and support users. Key features of tool included guided data entry, GIS automation, wizards to walk user through specific analytical steps, and easy installation, registration and integrated on-line help. NatureServe can provide a variety of technical support, training and consulting services as described on the tool website.
Availability to Users (current/planned)	Anyone can download the tool for free. NatureServe has an endowment for Vista and plans to support and evolve Vista indefinitely.

	No new major releases are currently under development. However, NatureServe will continue to address priority improvements as resources allow with version 2.5.2 with incremental improvements expected before end of 2010. NatureServe also has an extensive list of desired improvements and software expansions to increase performance for large regions and assist usability through online collaborative information sharing. Significant opportunities exist for added functionality, primarily by building on NatureServe's approach of building interoperating tool kits (such as companion tool to support offsite mitigation planning, and tools in ecosystem services and return on investment analyses). NatureServe continues to encourage partnerships with resources to improve and expand the tool.
Potential Corporate Activity/Decision Interface(s)	» Corporate Strategy: Rationalization of company's land-holding portfolio for purposes of identifying conservation/development value tradeoffs » Consideration of conservation values in Business Operations: o New projects – evaluation of facility and siting options, assessment of potential activity impacts and mitigation approaches o Ongoing Site Management and Asset Retirement planning for optimal conservation/development value
Current Corporate Sponsors? Users?	No current corporate sponsors. (Chevron provided funding for an earlier version of Vista, and Centex (now part of Pulte Homes) provided ¼ of the endowment). ExxonMobil has provided funding to NatureServe, although not specifically for Vista. Corporate users have included Potlach Corp. (to analyze company's forest land tracts in south-central Arkansas), and consulting firms. NatureServe is not aware of any publicly-available case studies of corporate uses of Vista other than the Potlach Corp. case study on the NatureServe website. However, since Vista is a free download, NatureServe is only familiar with a small number of applications of the several hundred registered users. NatureServe staff are not aware of any ESTM WG company using Vista. Chevron and ExxonMobil have both looked at Vista for possible company use. Chevron sees significant potential value in the tool in concept, but has not to date identified a clear business need to use it. ExxonMobil also sees significant potential value in the Vista for evaluating surplus properties, but relevant staff did not have access to current versions of internal software needed to run the tool.
Existing/Potential Future Links to ES Tools	**InVEST:** According to NatureServe staff, NatureServe and the Natural Capital Project had a few conversations about the potential for using Vista with InVEST and walked through a theoretical integration of the tools that was then partially tested in a project in Colombia. The test successfully showed that Vista's capabilities for scenario characterization could feed current and future land use scenario information into InVEST (which InVEST needs but can't produce itself). InVEST then can model ecosystem services distributions and values from those scenarios. Also discussed, but not tested, was the import of the InVEST ecosystem services information back into Vista, to be combined and assessed with a large diversity of other conservation and recreation values that Vista can provide. Vista could then provide information back on impacts to ecosystem services and, most importantly, is able to create a plan in Vista to restore or conserve ecosystem services (which InVEST can't do directly). Vista creates its own biodiversity-ecosystem service layer and has successfully imported a more limited set of data, such as watershed integrity and water quality. However, InVEST provides economic quantification (something that can't be measured in Vista) for a much broader set of ecosystem services. So the two organizations feel the tools appear to be highly

	complementary. However, NatureServe and NCP have no current plan to explore formal linkage of the two tools though the value of such has been discussed. **Other ES tools:** NatureServe staff have not looked at potential complementarities with any of the other ecosystem services tools being reviewed by the ESTM WG. However, the fairly basic and open Vista data model was designed to facilitate integration with a large number of tools. So NatureServe staff feel the potential complementarities with other ES tools may be significant.
Who to Contact for More Information	Patrick Crist, Director, Conservation Planning and Ecology (Patrick_Crist@ Natureserve.org; telephone +1-703-797-4810)

Assessment Criterion	WBCSD Global Water Tool
Purpose / Objective of Tool	Tool helps companies and organizations map their water use and assess risks relative to their global operations and supply chains
Tool Developer / Partners	» Developed by World Business Council for Sustainable Development, with company member CH2M Hill as a project leader and tool developer and stewardship by WBCSD's Water Working Group. » Advisory board of 22 WBCSD member companies in wide range of industries (including DuPont and Shell), provided oversight and pilot testing (full list of companies is below). » "Expertise" (undefined on WBCSD website) provided by Global Reporting Initiative (GRI) and The Nature Conservancy in terms of GRI approval the way the tool generated its water-related indicators and TNC assistance in ensuring the best water datasets included in the tool
Target Audience(s)	Companies and any other organizations who need to better understand the water issues in their operations and that of their extended supply chain
Year of Creation / Tool Launch	Launched in 2007, updated in 2009 and 2010
Scope / Applicability ***ideally including illustrative questions to which the tool can be best applied***	Tool is global in scope. WBCSD has identified potential benefits of tool as including: » Ability to compare company's water uses (including staff presence, industrial use, and supply chain) with key external water-related data » Calculation of water consumption and efficiency » Creation of key water GRI Indicators, inventories, risk performance metrics and geographic mapping » Identification of relative water risks in the company's portfolio to prioritize action » Support for effective communication with internal and external stakeholders on the company's water issues Illustrative questions for tool application:

	» How many of the company's sites are in extremely water-scarce areas? Which sites are at greatest risk? How will that look in the future? » How many of the company's employees live in countries that lack access to improved water and sanitation? » How many of the company's suppliers are in water scarce areas now? How many will be in 2025?
Databases Used	» AQUASTAT from UN Food and Agriculture Organization (FAO) » Data from World Health Organization (WHO) and UNICEF Joint Monitoring Program (JMP), World Resources Institute (WRI), University of New Hampshire in USA, International Water Management Institute (IWMI) and UNDESA Population Division.
External Input Data Required / Possible	2 options available: » Data required are the lat./long. coordinates of sites and/or suppliers. Inputting this geographical information is easy and can already produce useful outcome including charts and maps. » Data required is site specific water use information (withdrawals and discharges per source, how much is recycled/reused, productions/sales for water intensity metrics).
How the Tool Operates	Tool is comprised of: » an Excel workbook for inventory, calculation of key water GRI Indicators, external data connection, and metrics calculations o All company data inputs are on a single sheet » Online mapping (accessible from the Excel workbook) based on inventory of company site locations o Includes mapping of site locations (including supplier sites if desired) with external water and sanitation datasets and external water maps) and Google Earth interface for spatial viewing (including one-click ability to view all sites on Google Earth) Map datasets are provided for key country and watershed metrics (e.g. annual renewable water resource per capita, mean annual relative water stress index, and access to improved water sanitation). Company data is kept secure by user, not saved on WBCSD website.
Geographic Coverage of Databases	Databases ostensibly have global coverage. Neither WBCSD website nor the tool itself appears to provide detailed information about the precise scope and coverage (including gaps and limitations) of individual databases. Definitions and sources of all external datasets included in the tool itself.
Database Quality & Maintenance	WBCSD website states only that datasets are available in the public domain, are "considered valid by the global community of water stakeholders", are "recent" and "will be updated". Neither the website nor the tool itself appears to provide any other information on database quality and maintenance. WBCSD is committed to update the tool as updated datasets become available. This has happened twice already, in March 2009 and September 2010.
Format of Outputs	Automatic outputs include GRI water indicators and downloadable metrics charts with combined company, country and watershed data
Transparency of Tool Design and Operation	Tool design and use are transparent.
Key Assumptions Built into	Tool assumes site-level water-related risk is based only on physical availability of water. The background datasets also

Tool	include some demographical, economic and social information aiming to capture a better idea of the pressures exercised on the resource at the local level.
Key Limitations of Tool (e.g. scope, scale dependence, data, etc.)	Tool does not provide specific guidance on local situations, which require more in-depth systematic analysis. WBCSD's website does not provide any other statements regarding tool limitations. Tool does not provide guidance on ecosystem services related to water such as water provisioning. No data input fields related to upstream land use patterns, infrastructure development, type of land cover, amount of human settlement, etc. Accuracy and completeness of tool results is partially dependent on accuracy and completeness of underlying datasets. Neither website nor the tool appears to clearly identify key data limitations, so those lack transparency for tool user.
Ease of Use & Time / Personnel Demands for Applications	Tool easy to use. Time and personnel demands for applications will depend on type and scale of use by the company. Data fields include site locations (via specific address or latitude/longitude coordinates), water withdrawal from freshwater, groundwater sources, freshwater discharge by receiving body, non-freshwater discharge by receiving body, recycling/reused, water intensity (production/sales number of units and type), and number of site workers. Materials explaining the tool and demonstrating its operation are located on WBCSD website. Beyond those materials, and periodic updates to the tool, WBCSD does not provide support for implementation of the tool.
Availability to Users (current/planned)	Tool is free and easily downloaded from WBCSD website.
Potential Corporate Activity/Decision Interface(s)	Corporate strategy: Assessment of operational and reputational risks to company and its activities associated with water scarcity and use for one or more company site locations (including comparisons among multiple sites) Business operations: Assessment of actual and potential site risks for new projects and ongoing operations Supply chain: Assessment of water-related risks associated with supplier activity locations
Current Corporate Sponsors? Users?	Advisory Board: Air Product and Chemicals, Alcan, Alcoa, AngloAmerican, Borealis, Conoco Philips, Degussa, Dow Chemical Company, DuPont, GrupoNueva, Holcim, ITT Corporation, Kimberly Clark, Lafarge, PepsiCo, Suncor Energy, Rio Tinto, Sanyo, Shell, Suez, Syngenta, Unilever WBCSD unable to determine actual users as the tool is freely downloadable from the WBCSD website. But we estimate that more than 300 companies have used the tool.
Existing/Potential Future Links to ES Tools	No clear potential links between this tool and any of the broader ES tools being reviewed by the BSR WG currently identified.
Who to Contact for More Information	WBCSD: James Griffiths (griffiths@wbcsd.org; +41 (22) 839-3114); Anne-Leonore Boffi (boffi@wbcsd.org; +41 (22) 839-3193) at WBCSD Head Office, 4, chemin de Conches, 1231 Conches-Geneva, Switzerland