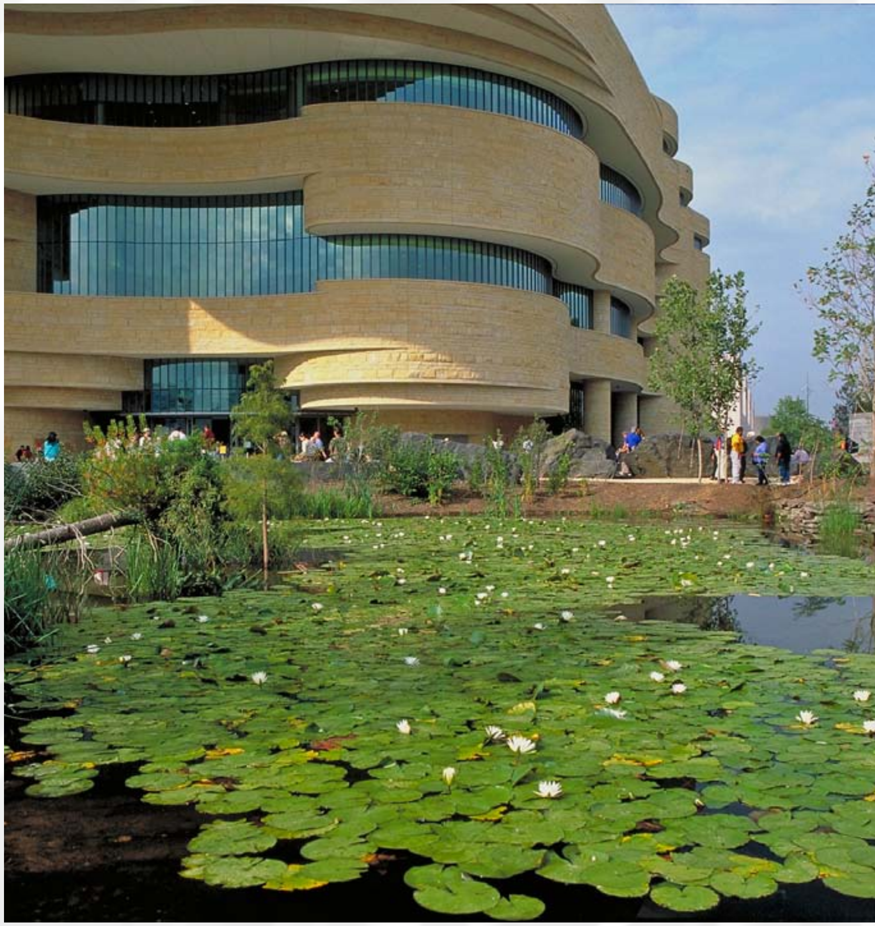
Landscape Biodiversity Planning & Design System

Technical Report



Spring 2013

AECOM

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2000 Olympic Village, Newington at Homebush Bay, NSW, Australia

Executive Summary

The landscape biodiversity planning system is an approach for planning, designing, and communicating the biodiversity and habitat benefits of a project. This landscape-based system can help guide habitat preservation, restoration, urban form, and landscape enhancements in urban or rural settings including urban forests, private and public realm landscapes, and community open space networks. This approach is proving to be a valuable tool for AECOM's sustainable communities and conservation development projects when there is a need to demonstrate measurable habitat benefits. Elements of the system have been applied in infill master planning efforts in urban environments in Singapore and Portland, Oregon, USA; greenfield conservation development projects in Toronto and California; and large-scale strategic planning efforts for municipalities and utilities.

Leading sustainable communities are increasingly embracing native biodiversity within the built environment. While traditional regulatory drivers may focus on minimizing impacts to protected species and sensitive ecosystems, new approaches seek more comprehensive strategies. As land planners, we are often required to demonstrate how land development projects can not only protect, but improve local ecology. This is especially important in sensitive exurban locations at the urban fringe. While these sites may not be pristine natural areas, they often include remnant natural ecosystems, agricultural lands, or other natural resource management history, and are often the focus of land conservation efforts, greenbelts, or other urban growth management initiatives. The system can be a useful tool for quantitatively demonstrating the benefits of smart growth and conservation development as a means of enhancing biodiversity, ecosystem services, and achieving the conservation vision for these sensitive locations.

This issue is not unique to greenfield locations, urban areas are also the focus of biodiversity improvement efforts. These projects often have goals surrounding providing equitable access to nature; balancing high density living while maintaining a connection with nature; maximizing benefits major infrastructure upgrades; climate change adaptation; are associated with popular design trends including biophilic design and

Coastal Dune Management, Perth, Australia

Landscape Biodiversity Index scoring for existing and planned landscapes in Portland, OR. A more than 100% increase in both landscape biodiversity and residential population density was demonstrated.

biomimicry; or as a part of rating systems such as the living building challenge. Many of the recent high-profile sustainable urban development concepts, including the 2008 Beijing and 2012 London Olympics, have developed unique architectural identities and the highest performing sustainability concepts by rigorously designing for ecology and biodiversity in very urban contexts.

This system was originally developed in response to the need for a quantitative measurement protocol for biodiversity as a part of sustainable communities planning efforts using AECOM's Sustainable Systems Integration Model (SSIM™). SSIM efforts address the multiple themes of sustainability (e.g. transportation, energy, water, landscape, social, etc), and include quantitative measurements of a variety of sustainability performance indicators such as greenhouse gas emissions, energy and water use, hydrologic indicators, etc. The landscape biodiversity planning and design system and Landscape Biodiversity Index (LBI) now allows us to address biodiversity in a quantitative way along with these other indicators. Such quantitative measurements allow projects to develop detailed, comprehensive, and defensible estimates of performance of design solutions in terms of both benefits and costs.

The LBI scoring system and measurement protocol tracks performance of multiple indicators (typically up to 10 or more) of landscape biodiversity. Indicators include the structural and pattern characteristics of landscapes such as priority species, habitat quality, connectivity, and total habitat area. Indicator importance weighting, measurement metrics, performance thresholds, and scoring criteria are defined by the planning team and calibrated for each project context and local ecology. Scoring criteria are based on habitat requirements of target species, local ecosystem characteristics, policies, empirical data when available, or other built or natural landscape characteristics. Because the system is calibrated for local ecology and priorities, it can be applied anywhere and performance relative to local biodiversity is assessed. In other words, the LBI emphasizes how well a project protects and enhances its local biodiversity. LBI scores are evaluated using a combination of Excel and GIS-Based calculations. Index scores and maps can be a powerful tool for evaluating alternative scenario performance, plan refinement, and external communication of project benefits. Indicator weighting and performance thresholds can also be adjusted based on stakeholder input, making the tool useful for project negotiations and gaining stakeholder buy-in.

The first step in applying the system involves "site calibration" to determine priority areas for preservation, to frame goals for biodiversity enhancement, and to "calibrate" LBI scoring criteria to local ecology and priorities. At this point the system can be used to identify areas for preservation, management priorities, or inform the development of conceptual landscape design concepts. A second step can include developing alternative design and/

Overarching Landscape Ecology Indicators

	Indicator Categories	Sample Metrics	Assumption
1	Habitat Area	% project area preserved	The total amount of landscape area is the foundation for biodiversity. More landscape area is assumed to indicate more potential for biodiversity, whether it is preserved, restored, or provided through cultural landscapes. The amount of preservation, outside of a planned development footprint, is often an early conservation in land use planning.
2	Habitat Area	area of landscape within development	Landscape footprint within a development is often an important consideration that is closely related to many other community sustainability indicators and urban design considerations. Percent landscape area on parcels and within land uses is often required by codes and is also a foundation for potential biodiversity in more urban areas.
3	Habitat Variety	% area priority habitats avoided	Priority habitats, often guided by regulatory priorities, cultural preferences, or management practices, are often the most important biodiversity indicator considered.
4	Habitat Variety	% historic habitat types present	The variety of native habitat types, often relative to historical site conditions or other benchmarks, provide an indication of the overall level of biodiversity that may exist at the site.
5	Habitat Quality	% structural layers present in landscapes	Whether plants are native or non-native, the presence or absence of the vegetation and ecosystem structural layers, as compared to layers present in native ecosystems, is assumed to indicate value for native biodiversity. For example, in forests, layers could include canopy, sub-canopy, understory, and ground cover. Hydrological, physiographic, soil or other structural layers may also be considered. Layers may be emphasized that support target species.
6	Habitat Quality	# target plant species within structural layers	The existing or planned plant species composition, often relative to the species composition of structural layer in a native ecosystem benchmark, is assumed to indicate overall biodiversity. Plant species are emphasized because they can be controlled and measured in both existing and planned landscapes, whereas presence of faunal species cannot be measured as concretely in planned landscapes. Target species may be emphasized within layers.
7	Habitat Patch/ Corridor Size and Shape	habitat patch area	Larger patches have less edge relative to area, providing more interior habitat conditions for native biodiversity. Larger patches provide more area for natural processes such as succession, disturbance, dispersal, or continuous areas of natural habitat structure and larger populations of species, all important indicators of higher biodiversity.
8	Habitat Patch/ Corridor Size and Shape	habitat corridor width	Corridors provide movement and migration of species between patches. As corridors become wider they exhibit greater interior conditions and the ecological characteristics of a patch, allowing species adapted to interior habitat conditions to move and migrate.
9	Habitat Connectivity	distance gap between patch or corridor	Habitat patches or corridors that are closer in proximity to others are assumed to indicate higher biodiversity for both habitats. Visual continuity, species mobility characteristics, dispersal strategies, and adjacent land use character can also impact biodiversity benefits of habitat proximity. This indicator addresses the ability of species to move between habitat patches and between corridor segments.
10	Habitat Connectivity	network consistency	The biodiversity value of habitat areas can be increased or decreased depending on the quality of habitats in its broader network. In other words, a low quality habitat patch or corridor that is near a high quality patch or corridor is assumed to be more valuable than if the same patch or corridor were near a another low quality patch or corridor. This indicator also addresses the ability of species to move along networks of habitat "stepping stones" or corridors.

Additional Potential Landscape Ecology Metrics

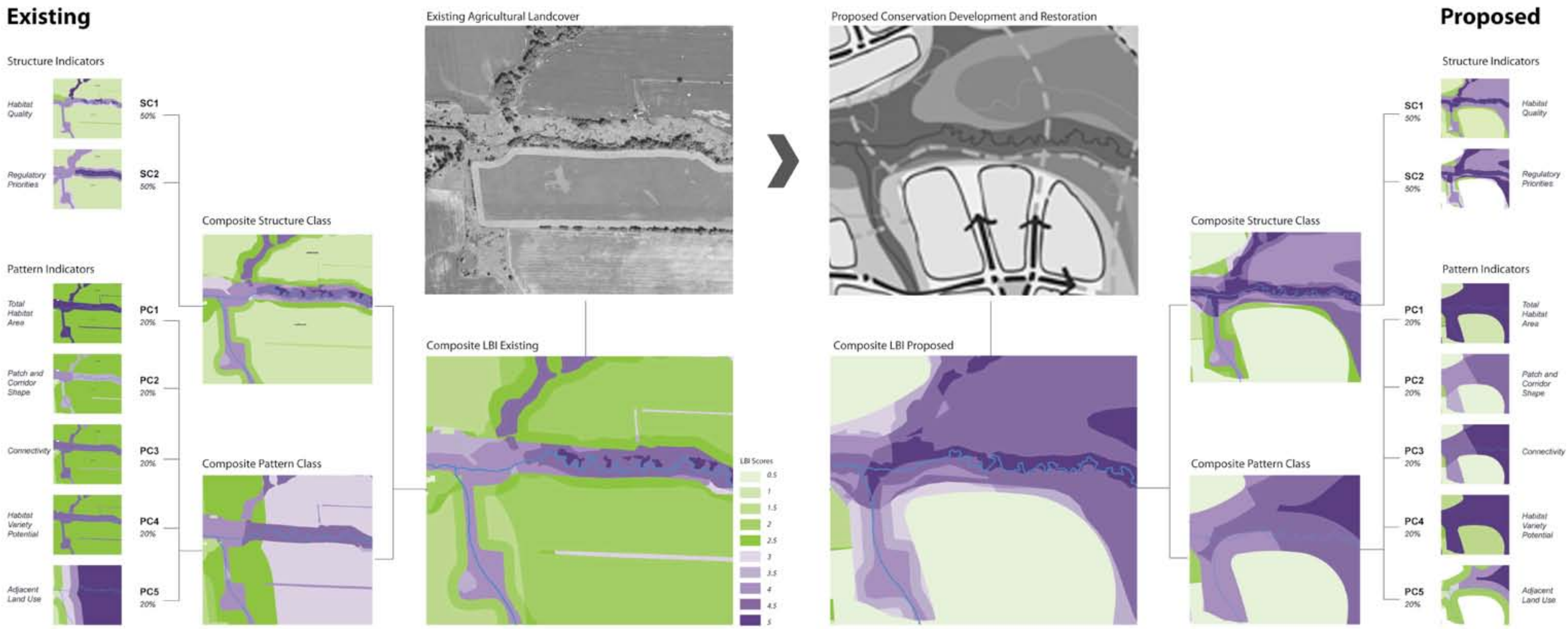
Structural Metrics	priority species / habitats	structural quality	population size	rarity	cultural value / mgn't capability	re-creatability	endemism	species richness
Pattern Metrics	ecosystem benchmark	habitat type balance	connectivity within habitat type	connectivity across habitat type	off-site connectivity	ecotones preserved	natural processess accomodated	matrix interactions priorities

Sample landscape biodiversity indicators and metrics. These and others can combined into the Landscape Biodiversity Index or program scenarios and comparing LBI performance for each. Many projects seek to create a plan that achieves improved biodiversity value relative to the existing condition, a historic natural condition, or a business as usual development “benchmark” scenario. A final step can include assessing and optimizing cost/benefit relationships, selecting and documenting a preferred program scenarios, crafting detailed landscape designs or design guidelines that achieve LBI performance targets, and creating implementation and monitoring plans.

In design projects, the LBI can help create and implement high performance landscape master plans and ecological enhancement strategies. In policy projects, the LBI can be used as a basis for decision support tools or design guidelines for individual parcels, land uses, or zones to achieve a desired level of biodiversity performance across an entire community, planning area, or region. The LBI can also be used as a standard to compare performance between multiple projects across municipalities, regions, or globally.

An important benefit of the LBI is that it allows many opportunities for “calibration” of metrics for specific contexts considering the wide variety of conservation priorities, local ecosystem characteristics, and project economics. This detailed approach can provide defensible measurements and guide design strategies to improve project performance, help communicate project benefits, and can ultimately support wider implementation of conservation development, smart growth, large-scale landscape, and sustainable communities projects.

JVC Master Plan, Guadelajara, Mexico. Urban form creates an ecological transition, gateway and overall focus on the adjacent National Park.



Conservation development framework assessment using the Landscape Biodiversity Index. Past applications range in scale from 10's to 10,000's of hectares.

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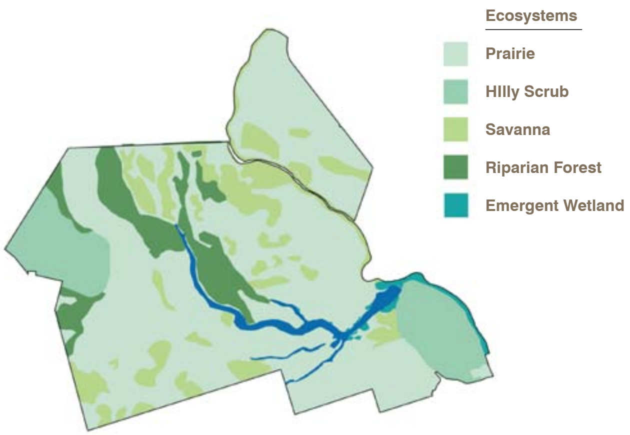
Civano Master Plan - project by Andres Duany, Stefanos Polyzoides, and William McDonough and others

Landscape Biodiversity Planning and Design System

Introduction

Many leading sustainable communities are embracing native biodiversity within the built environment. Traditional regulatory drivers may focus on minimizing impacts to protected species and sensitive ecosystems. This system is designed to address these drivers, but also expands them to achieve more comprehensive biodiversity strategies that demonstrate “enhancement” in addition to minimizing negative impacts. This is especially important in increasingly sensitive exurban, or “greenfield”, development locations at the urban fringe. While these sites may not be pristine natural areas, they typically include a combination of remnant natural ecosystems, agricultural lands, or other natural resource management history, and are often the focus of land conservation efforts, greenbelts, or other urban growth management initiatives.

This issue is not unique to greenfield locations, urban areas are also the focus of biodiversity improvement efforts for a variety of reasons including: providing equitable access to nature; balancing high density living while maintaining a connection with nature; or associated with architectural trends including biophilic design, biomimicry, or rating systems such as the living building challenge. Many of the recent high-profile sustainable urban development concepts, including the 2008 Beijing and 2012 London Olympics, have



The landscape biodiversity planning system assesses the value of existing, preserved, and new landscapes for biodiversity potential.

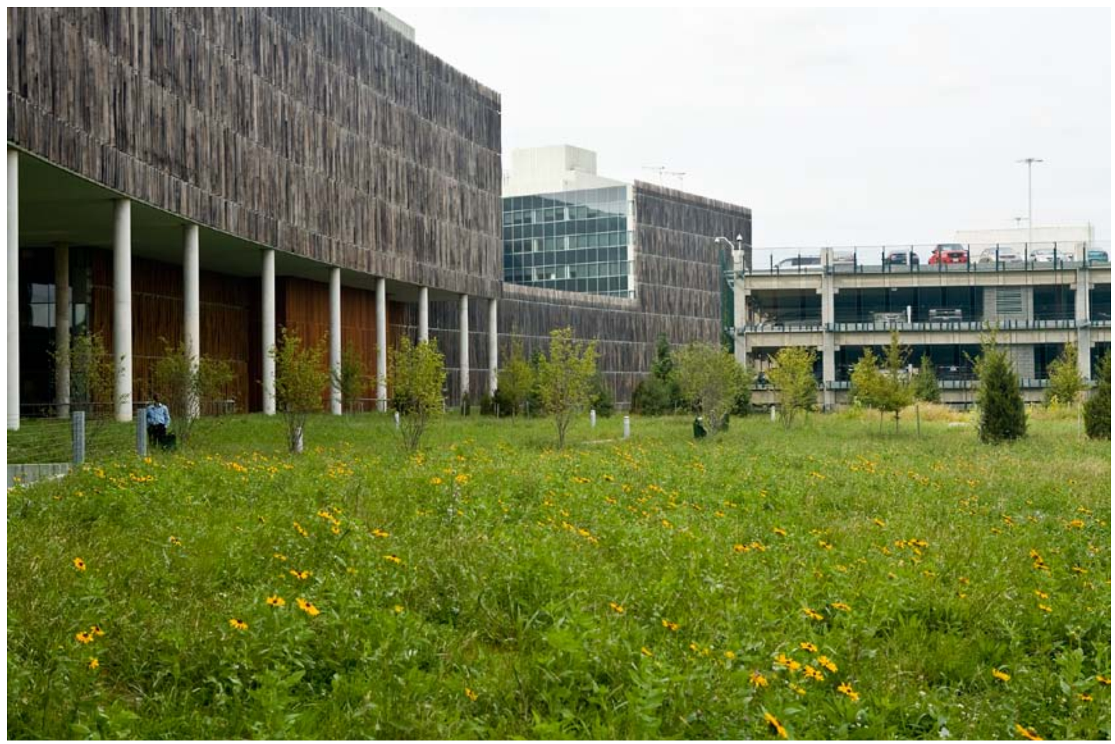
developed unique architectural identities and the highest performing sustainability concepts by rigorously designing for ecology and biodiversity in very urban contexts.

The system was developed in response to the need for a quantitative measurement protocol for biodiversity as a part of sustainable communities planning efforts using AECOM's Sustainable Systems Integration Model (SSIMTM). SSIMTM efforts address the multiple themes of sustainability -- transportation, energy, water, landscape, social, and so forth -- and include quantitative measurements of a variety of sustainability performance indicators such as greenhouse gas emissions, energy and water use, hydrologic indicators, etc. The landscape biodiversity planning and design system and associated Landscape Biodiversity Index (LBI) allows biodiversity to be measured in a quantitative way along with these other indicators. Such quantitative measurements allow projects to develop detailed and defensible estimates of sustainability performance in terms of both benefits and costs.

The system and LBI can assist in designing and comparing performance of alternative biodiversity strategies in landscape designs, biodiversity policies, or landscape master plans for neighbourhoods, communities, or municipalities. At the community planning level, the LBI helps determine the total amount and appropriate design of habitat to include on individual parcels, in the public realm, or in conservation areas to achieve a desired level of performance across an entire community. At the site design scale, the LBI can help prioritize specific plant species, landscape patterns or the structural design characteristics needed to achieve habitat and biodiversity objectives in landscape designs.

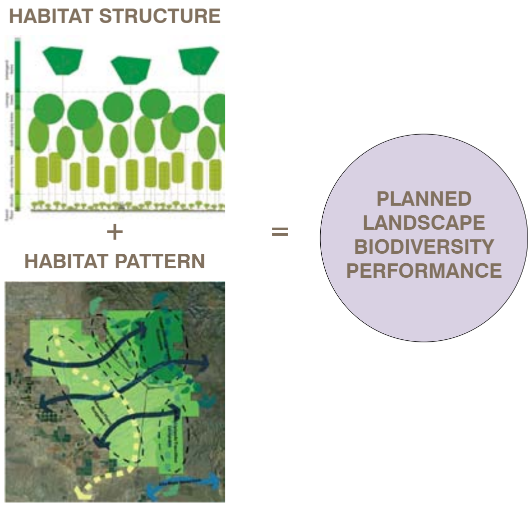
The system and index are "landscape based", focusing on the ecological and biodiversity characteristics of historic, existing, or planned landscapes as habitat for both flora and fauna. The system emphasizes biodiversity in terms of native biodiversity and ecosystems, although non-native biodiversity may also provide benefits in some situations. The system also emphasizes the role of landscape pattern in providing biodiversity supporting functions including dispersal, habitat connectivity, predator/pray relationships, migration, potential habitat sinks, and natural processes like seasonal flooding and succession.

In order to emphasize native biodiversity and local ecology, a key characteristic of the methodology is that it requires "calibration" according to specific project goals and local ecological characteristics. Depending on local priorities and characteristics, in addition to species richness or habitat value, biodiversity strategies can also be calibrated to emphasize



US Census Bureau, Washington DC

other important ecosystem services “co-benefits” such as carbon sequestration, water quality improvement, local climate control/ urban heat island mitigation, or other socio-cultural benefits.



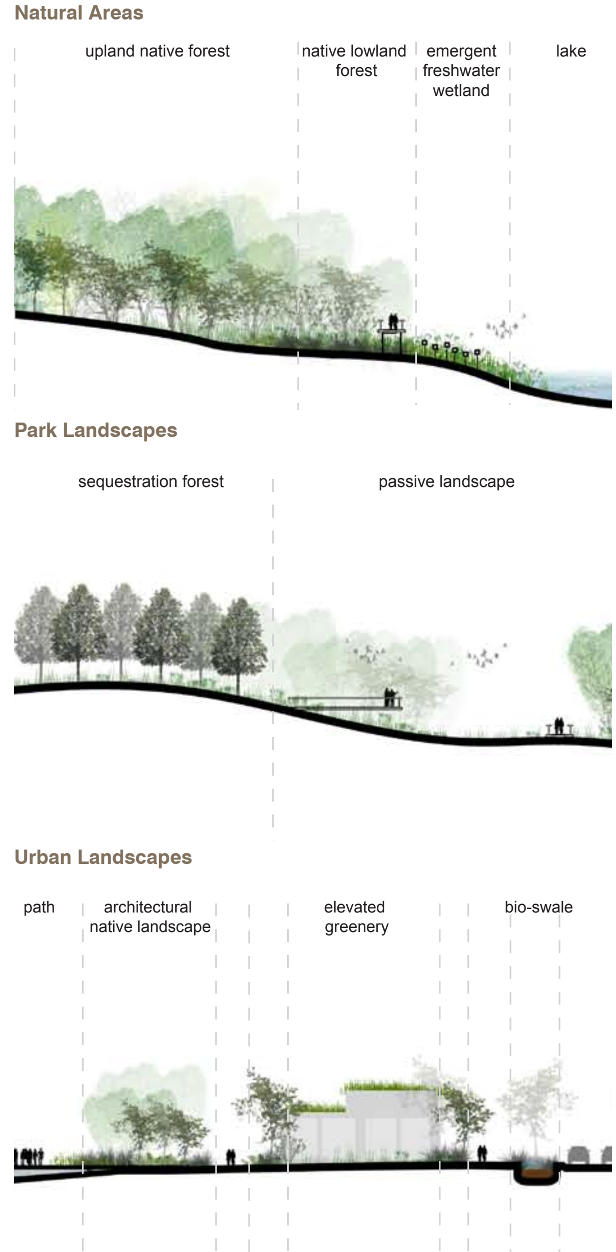
Assumptions

Some overarching assumptions of the system are that landscapes increase and sustain biodiversity by providing ecosystem characteristics for both flora and fauna that:

- provide habitat for cover, foraging, and other life history characteristics including key species interactions;
- facilitate species movement, migration, dispersal, succession, and establishment within and through a landscape;
- provide natural patterns and processes that species are adapted to including seasonal flooding, habitat structure, habitat adjacencies, shading and light; or
- reduce threats to wildlife survival including habitat sinks, invasive species, inappropriate land uses adjacent to habitat, and light pollution.

The system assess these characteristics within any type of landscape from natural to urban, and bridges landscape design themes including preservation, restoration of native ecosystems, non-native landscapes, or contemporary architectural landscapes that utilize native or non-native plants.

While the system may be used to target particular habitats, species, or overall biodiversity, it emphasizes plant species and landscape attributes as the primary units of measurement and assumed indicators of overall floral and faunal biodiversity. This is because landscape attributes can be consistently measured from existing condition,



This landscape biodiversity planning and design system considers all types of landscapes from natural to constructed

can be controlled during the design and planning process, and can be most easily measured and monitored after implementation. The system assumes two primary categories of landscape attributes as the key indicators of overall biodiversity potential:

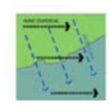
- Structural (vertical) attributes: habitat types, habitat structure, and plant species composition
- Pattern (horizontal) attributes: the total amount of habitat and the shape, size, and connectivity of habitat

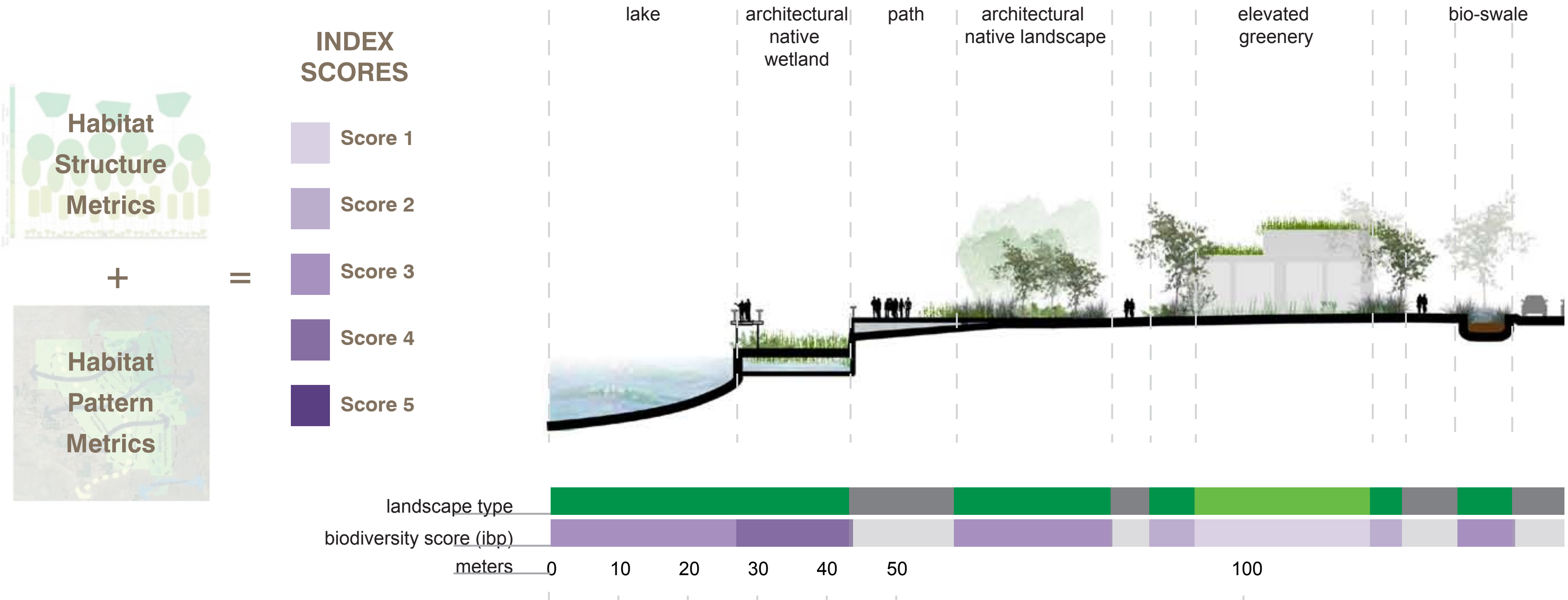
Additional attributes are “hybrids” and consider a combination of pattern and structural indicators. The attributes and indicators are described in the table on the following page. Projects may choose to measure all or a select number of indicators depending on project priorities.

The system is not designed to for measuring biodiversity in terms of maximizing total species richness, although that attribute may be emphasised, rather, it places value on how close a landscape resembles local native ecosystems; how well connected the landscape is to other landscapes and habitats; and/or the presence of an any culturally or environmentally important species or habitats. Therefore, an essential principle of the system is that biodiversity of a planned or preserved landscape is measured relative to a “local native ecosystem biodiversity benchmark”. By calibrating the system to the local ecosystems, it can be a useful tool to compare the native biodiversity value between project

The LBI is most suited for comparing alternatives for a single site. Regional calibration could allow effective use at the city or regional scale to compare projects within or between regions.

Overarching Landscape Ecology Indicators				
	Indicator Categories	**Sample Metrics**		**Assumption**
1	**Habitat Area**	% project area preserved		The total amount of landscape area is the foundation for biodiversity. More landscape area is assumed to indicate more potential for biodiversity, whether it is preserved, restored, or provided through cultural landscapes. The amount of preservation, outside of a planned development footprint, is often an early conservation in land use planning.
2		area of landscape within development		Landscape footprint within a development is often an important consideration that is closely related to many other community sustainability indicators and urban design considerations. Percent landscape area on parcels and within land uses is often required by codes and is also a foundation for potential biodiversity in more urban areas.
3	**Habitat Variety**	% area priority habitats avoided		Priority habitats, often guided by regulatory priorities, cultural preferences, or management practices, are often the most important biodiversity indicator considered.
4		% historic habitat types present		The variety of native habitat types, often relative to historical site conditions or other benchmarks, provide an indication of the overall level of biodiversity that may exist at the site.
5	**Habitat Quality**	% structural layers present in landscapes		Whether plants are native or non-native, the presence or absence of the vegetation and ecosystem structural layers, as compared to layers present in native ecosystems, is assumed to indicate value for native biodiversity. For example, in forests, layers could include canopy, sub-canopy, understory, and ground cover. Hydrological, physiographic, soil or other structural layers may also be considered. Layers may be emphasized that support target species.
6		# target plant species within structural layers		The existing or planned plant species composition, often relative to the species composition of structural layer in a native ecosystem benchmark, is assumed to indicate overall biodiversity. Plant species are emphasized because they can be controlled and measured in both existing and planned landscapes, whereas presence of faunal species cannot be measured as concretely in planned landscapes. Target species may be emphasized within layers.
7	**Habitat Patch/ Corridor Size and Shape**	habitat patch area		Larger patches have less edge relative to area, providing more interior habitat conditions for native biodiversity. Larger patches provide more area for natural processes such as succession, disturbance, dispersal, or continuous areas of natural habitat structure and larger populations of species, all important indicators of higher biodiversity.
8		habitat corridor width		Corridors provide movement and migration of species between patches. As corridors become wider they exhibit greater interior conditions and the ecological characteristics of a patch, allowing species adapted to interior habitat conditions to move and migrate.
9	**Habitat Connectivity**	distance gap between patch or corridor		Habitat patches or corridors that are closer in proximity to others are assumed to indicate higher biodiversity for both habitats. Visual continuity, species mobility characteristics, dispersal strategies, and adjacent land use character can also impact biodiversity benefits of habitat proximity. This indicator addresses the ability of species to move between habitat patches and between corridor segments.
10		network consistency		The biodiversity value of habitat areas can be increased or decreased depending on the quality of habitats in its broader network. In other words, a low quality habitat patch or corridor that is near a high quality patch or corridor is assumed to be more valuable than if the same patch or corridor were near a another low quality patch or corridor. This indicator also addresses the ability of species to move along networks of habitat "stepping stones" or corridors.

Additional Potential Landscape Ecology Metrics								
Structural Metrics	 priority species / habitats	 structural quality	 population size	 rarity	 cultural value / mgn't capability	 re-creatability	 endemism	SPP. species richness
Pattern Metrics	 ecosystem benchmark	 habitat type balance	 connectivity within habitat type	 connectivity across habitat type	 off-site connectivity	 ecotones preserved	 natural processess accomodated	 matrix interactions priorities



The LBI scoring system is applied to all landscape areas, regardless of landcover type. Scoring considers pattern and structural attributes that are calibrated for the project based on target local ecosystems or habitats.

alternatives; between different projects within an ecoregion; or possibly even across regions. To date, the system has been applied primarily to compare project alternatives for single project sites. Many of the indicators are based on the widely accepted principles of landscape ecology and conservation biology presented in *Landscape Ecology Principles in Landscape Architecture and Land-Use Planning* (Dramstad et al. 1996).

A Landscape Biodiversity Index (LBI) has been developed to systematically measure performance according to the indicators. Because this is a planning tool, and projects may not built at the time of assessment, the measurement is based on potential rather than actual biodiversity present, with the exception of baseline measurements of existing and historic site conditions which measure exiting landscape attributes.

Structural and pattern scoring criteria and performance metrics for indicators, described in detail in the following pages, are defined, or "calibrated", for the project area by the planning team based on measurements of existing ecosystems either performed through field measurements; based on project precedents; found in empirical literature; or based on expert opinion. LBI scores of 1 (lowest biodiversity potential) to 5 (highest biodiversity potential) are possible for each indicator and are weighted and assessed for each landscape area of a project. Since LBI scoring criteria and thresholds are based on specific, defined pattern and structural attributes, and are calibrated based on existing and target native ecosystems or species for a the project area, the approach can effectively compare biodiversity potential between plan scenarios.

The following pages describe the LBI metrics and general performance measurement protocols. While there are more nuanced details of project calibration, performance measurement, and alternative approaches to planning steps have not been included, the following tables outline the general performance metrics and scoring system. These aspects are more fully described in project documentation materials that may be available upon request. The metrics tables are

Attribute	Performance Measurement
Habitat Priorities 1	These indicators are used to value existing habitats for preservation or for prioritizing target habitat characteristics of planned landscapes. Priorities are established by the project team for each of the criteria. Priority categories are weighted and assigned to habitat types. Priorities are considered when establishing targets for habitat variety in the following attribute categories.

Indicators

target species, structural quality, rarity, cultural value, spp. richness, re-creatability, endemism

Metric

Criteria	Importance Weighting
target species	a%
structural quality	b%
rarity	c%
cultural value	d%
species richness	e%
re-creatability	f%
endemism	g%

Performance Thresholds

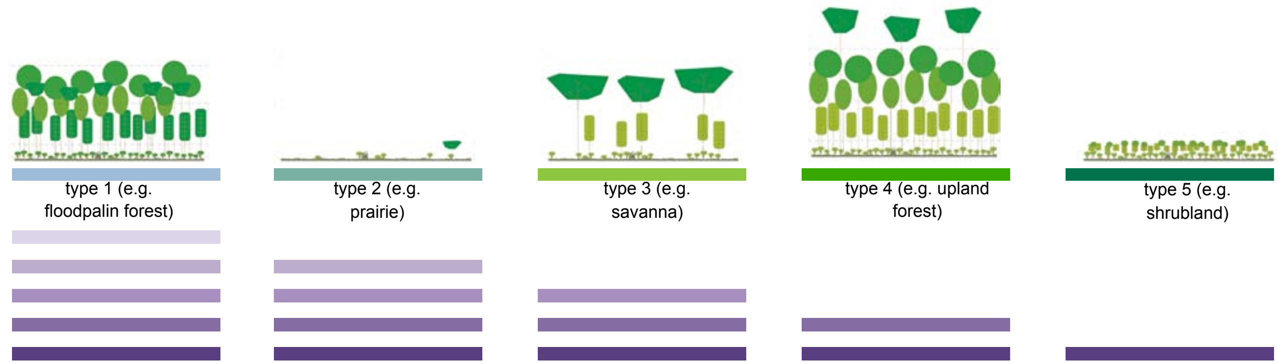
target species | structural quality | rarity | cultural value | re-creatability | endemism | species richness

Notes

Attribute	Performance Measurement
Habitat Variety **2**	The type and area of each habitat or ecosystem, either existing or planned, is measured. Historic, e.g. “pre-settlement”, habitat types that may no longer occur on the site may also be mapped and used as a benchmark. For scoring to be effective, all landscapes, even architectural landscapes or monocultures, must be placed into a “habitat type” category. The variety and area of habitats created or preserved relative to the benchmark occurrence is measured.

Indicators	Metric	Performance Thresholds
variety and area of habitat types	see criteria table below	see diagram below

Criteria	Importance Weighting
% target variety	1/5
% target variety	2/5
% target variety	3/5
% target variety	4/5
% target variety	5/5

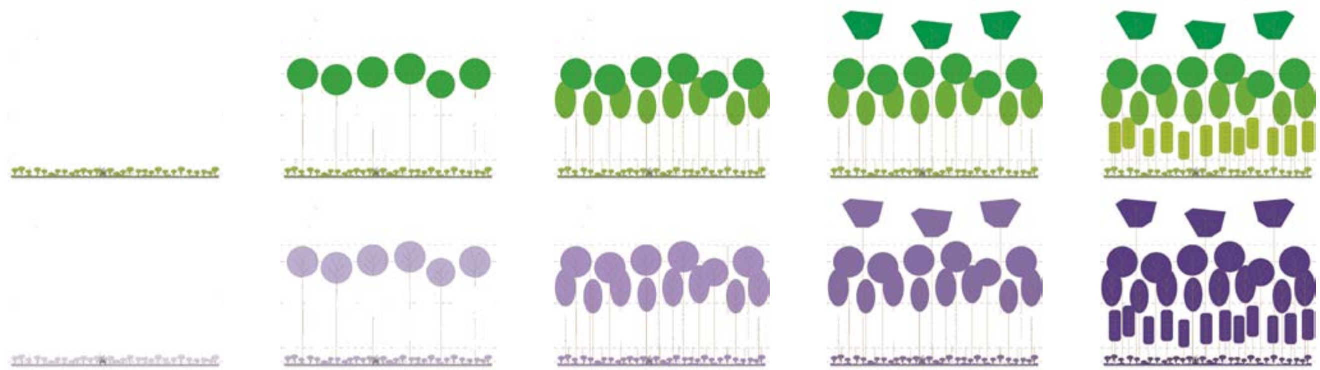


Notes

Attribute	Performance Measurement
Habitat Quality: Structural Layers **3**	The structure of landscapes, whether it be existing, planned, or historic, can be systematically measured. This attribute is primarily used to assess the structural diversity of designed or planned landscapes, but may also used assess the structural quality of existing landscapes and suitability for preservation. Structural measurements are compared to native ecosystem types that most closely resemble the landscape of interest. The percentage of structural layers present in the landscape is measured. Native ecosystem "benchmark" structural measurements may be determined by literature review or field measurements. Planned landscapes must be designed to a level of detail sufficient to assess these structural attributes or they must be specified in design guidelines. The systems may also be applied to wetland or water body types.

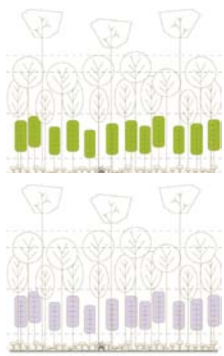
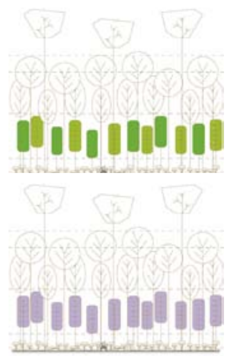
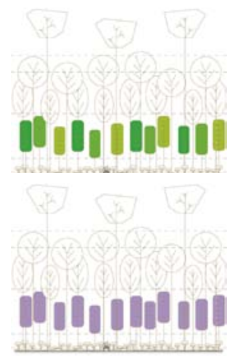
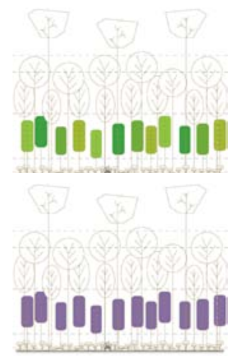
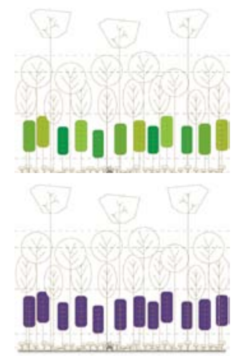
Indicators	Metrics	Performance Thresholds				
presence of structural layers in habitat types	(see table below)	<e%	e%-f%	f%-g%	g%-h%	h%-100%

Vegetation Structure : type 4 - dryland forest example	
canopy	yes/no
sub-canopy	yes/no
understory	yes/no
shrub layer	yes/no
croundcover	yes/no
intact soil structure	yes/no
key natural process	yes/no



Notes

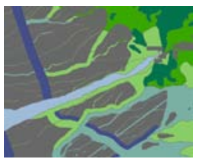
Attribute	Performance Measurement
Habitat Quality: Plant Species Composition **4**	The species composition of structural layers in the landscape of interest is measured for plant species composition relative to the native ecosystem benchmark for the structural layer. Plant species are the preferred indicator to measure as opposed to faunal species because plant species can be more easily controlled and measured in plans for future landscapes.

Indicators	Metrics	Performance Thresholds				
		<a%	a-b%	b-c%	c-d%	d-100%
plant species composition within structural layers	see table below					

Plant Species Composition: Understory Layer - Type 4	
>a%	of plant species composition
a-b%	of plant species composition
b-c%	of plant species composition
c-d%	of plant species composition
d-100%	of plant species composition

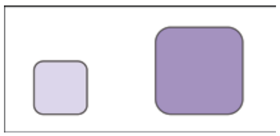
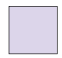
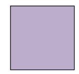
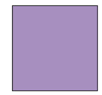
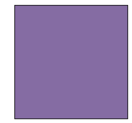
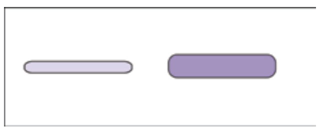
Notes

Attribute	Performance Measurement
Habitat Area 5	The total area of each structural score category is measured across the parcels of the project area for the existing, planned, or historic benchmark condition. Preserved landscapes are measured separately from planned new landscapes.

Indicators	Metrics	Performance Thresholds					
precent preserved or created landscape area	% project area preserved vs developed 	preservation / open spacearea LBI score					
	% area of landscape within developement area 	development area LBI score	  % landscaped area	  % landscaped area	  % landscaped area	  % landscaped area	  % landscaped area

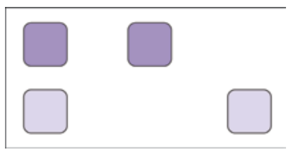
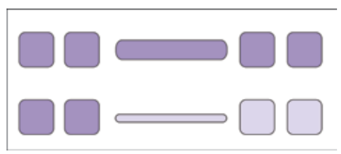
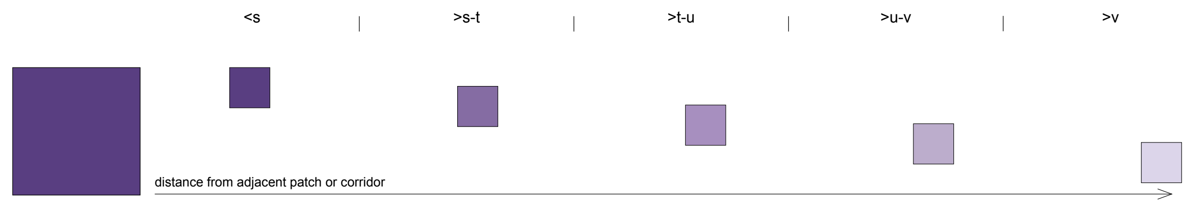
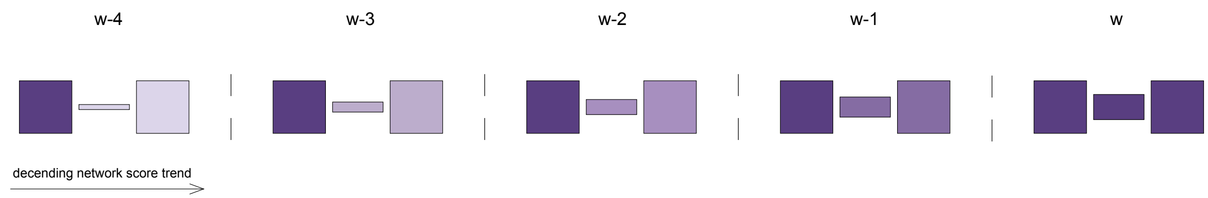
Notes

Attribute	Performance Measurement
Habitat Shape and Size **6&7**	Habitat Shape: Patches are assumed to be less than 2x wide as long and include a higher proportion of interior conditions. Corridors are assumed to be more than 2 times longer than they are wide and provide a higher ratio of edge conditions compared to interior conditions. (Specifically, patch width at narrowest point is no less than the square root of ½ of the width at the widest point.) Habitat Size: Size criteria and thresholds are calibrated based on local ecological characteristics, requirements of target species, or "keystone" habitat variables such as canopy height or canopy tree diameter. The size threshold relationships indicated below are often used, however they may be adjusted based on specific site conditions or available empirical literature.

Indicators	Metrics	Performance Thresholds				
habitat patch size; habitat corridor width	patch size 	$<w^2$ meters 	w^2-x^2 meters 	x^2-y^2 meters 	y^2-z^2 meters 	$>z^2$ meters 
	corridor width 	$< w/\sqrt{2}$ meters 	$w/\sqrt{2}$ to $x/\sqrt{2}$ meters 	$x/\sqrt{2}$ to $y/\sqrt{2}$ meters 	$y/\sqrt{2}$ to $z/\sqrt{2}$ meters 	$> z/\sqrt{2}$ meters 

Notes

Attribute	Performance Measurement
Habitat Connectivity **8&9**	Spacing thresholds may be based on data from empirical literature. Spacing thresholds can also be based on assumed widths of sidewalks, roads, and other features that will likely bisect habitat areas. Visual continuity, species mobility characteristics, dispersal strategies, and adjacent land use character can also become the basis for habitat separation performance. Network consistency performance scores are measured by considering the score of adjacent patches or corridors. Cumulative low scores of the nearest adjacent areas reduces the value of the area of interest in terms of it's "network", "stepping stone", or "linkage" value.

Indicators	Metrics	Performance Thresholds
spacing between patch or corridor; network consistency (quality of habitat along a network of habitat areas)	patch or corridor spacing  network consistency 	 

Notes

Attribute	Performance Measurement
Ecosystem Type Pattern **10**	The spatial pattern of habitat types is also considered when prioritizing habitat locations. The presence of ecotones along the boundaries between ecosystem or habitat types; the inclusion of corridors or patches that transect across multiple ecosystem/habitat types; and ensuring that the layout of habitat types provides broader connectivity within the regional patch-corridor matrix is also considered. Additionally, the character of the surrounding land use matrix, and its effects such as light, noise, pets, roadways, etc., are important in locating the habitat network. The level of occurrence of these indicators is measured and importance is weighted based on project priorities.

Indicators

habitat type connectivity, adjacent land use, ecotones, off-site connections

Metrics

Criteria: Type Pattern	% achieved
habitat type diversity	b%
connectivity w/in type	c%
connectivity cross type	d%
off-site connectivity	e%
ecotones preserved/ connected	e%
target landscape process flows	f%
adjacent land use suitibility	g%
total type-pattern achievement	weighted average %

Performance Thresholds


ecosystem benchmark

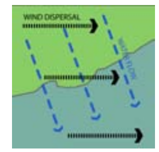

habitat type diversity

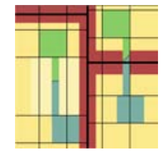

connectivity within habitat type


connectivity across type


off-site connectivity


ecotones preserved


natural processes accomodated


matrix interactions weighed

Notes

	Sample Landscape Biodiversity Index (LBI) Scoring Threshold Metrics (thresholds calibrated based on ecological context)					
Indicator Importance Weight?	**LBI Indicators**	Score 1	Score 2	Score 3	Score 4	Score 5
weight	1&2: Habitat type variety/priority score	>a% of target variety/priority	a%-b% of target variety/ priority	b%-c% of target variety/ priority	c%-d% of target variety/ priority	d%-100% of target variety/ priority
weight	3: Habitat structural layers	>e% of structural layers present	e%-f% of structural layers present	f%-g% of structural layers present	g%-h% of structural layers present	h%-100% of structural layers present
weight	4: Plant species composition	>i% of target species	i%-j% of target species	j%-k% of target species	k%-l% of target species	l%-100% of target species
weight	6: Patch size	$<w^2$ meters	w^2-x^2 meters	x^2-y^2 meters	y^2-z^2 meters	$>z^2$ meters
weight	7: Corridor width	$< w/\sqrt{2}$ meters	$w/\sqrt{2}$ to $x/\sqrt{2}$ meters	$x/\sqrt{2}$ to $y/\sqrt{2}$ meters	$y/\sqrt{2}$ to $z/\sqrt{2}$ meters	$> z/\sqrt{2}$ meters
weight	8: Patch/corridor spacing	<s meters	s-t meters	t-u meters	u-v meters	>v meters
weight	9: Network consistency	adjacent habitat area score is 1 and weighted average of structure and pattern indicator scores is 1	adjacent habitat area score is 2 & weighted average of structure and pattern indicator scores 2 or adjacent habitat area score is 1 and weighted average of structure and pattern indicator scores is 3	adjacent habitat area score is 3 & above cumulative is 3 or adjacent habitat area score is 1 and above cumulative is 4 or adjacent habitat area score is 2 and weighted average of structure and pattern indicator scores is 5	adjacent habitat area score is 4 & above cumulative is 4 or adjacent habitat area score is 3 and weighted average of structure and pattern indicator scores is 5	adjacent habitat area score is 5 & weighted average of structure and pattern indicator scores is 5
weight	10: Ecosystem pattern achievement	weighted average % of metrics <m%	weighted average % of metrics = m%-n%	weighted average % of metrics = n%-o%	weighted average % of metrics = o%-p%	weighted average % of metrics = q%-100%
summary	5: Total area score	indicator weighted average of scored areas/total project area	indicator weighted average of scored areas/total project area	indicator weighted average of scored areas/total project area	indicator weighted average of scored areas/total project area	indicator weighted average of scored areas/total project area

This is a sample of the scoring rules used in the LBI. Scenario measurement and scoring is assessed using a combination of GIS and Excel-based tools. Other scoring rule categories used in the LBI include rules for larger community and regional open space.

followed by general description of the system application process for projects.

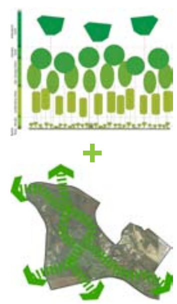
Application

Applying the landscape biodiversity planning system includes the following analysis and planning steps. While this discussion focuses on performance measurement, it ideally includes a parallel design process to ensure that performance is maximized and the most efficient and appropriate strategy is implemented.

Step 1) Site Assessment

The process begins by building an understanding and inventory of local biodiversity and ecosystems. Both existing and historic ecosystems, sometimes know as "pre-settlement" ecosystems, are evaluated. Considering climate change, it may also be appropriate to consider future change to local ecosystems and species range shifts. These ecosystem and habitat "benchmarks" provide a framework for preservation, restoration, landscape design strategies, and performance measurement. Local landscape ecosystem maps, structural profiles, and species richness levels as show on the adjacent page are valuable tools for project benchmarking and

1) Site Assessment of site conditions and local ecosystem attributes

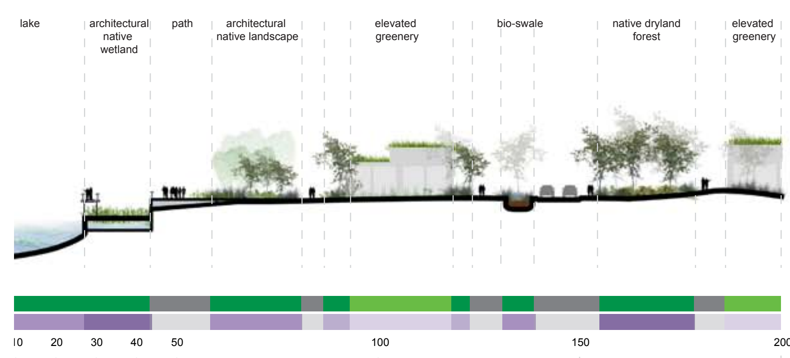


2) Calibrate LBI scoring system based on local ecosystem attributes and project goals

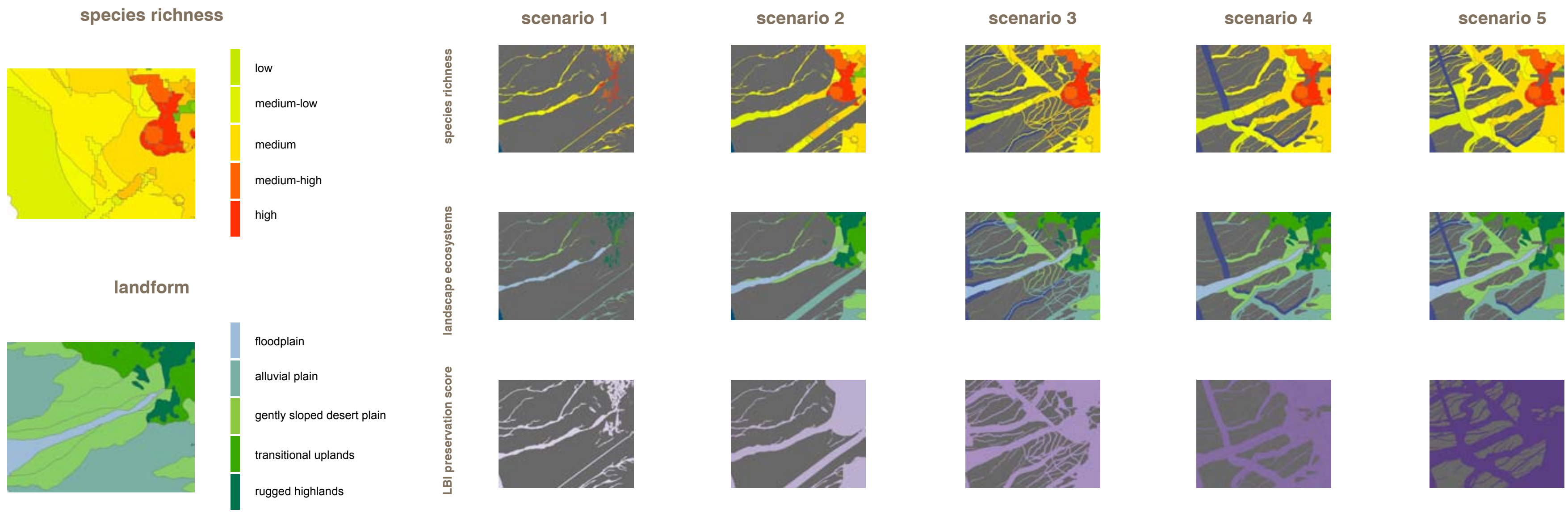
3) Measure existing, historic or other relevant benchmark LBI scores

4) Measure alternative master plan scenarios for how well they preserve existing biodiversity and establish new habitats.

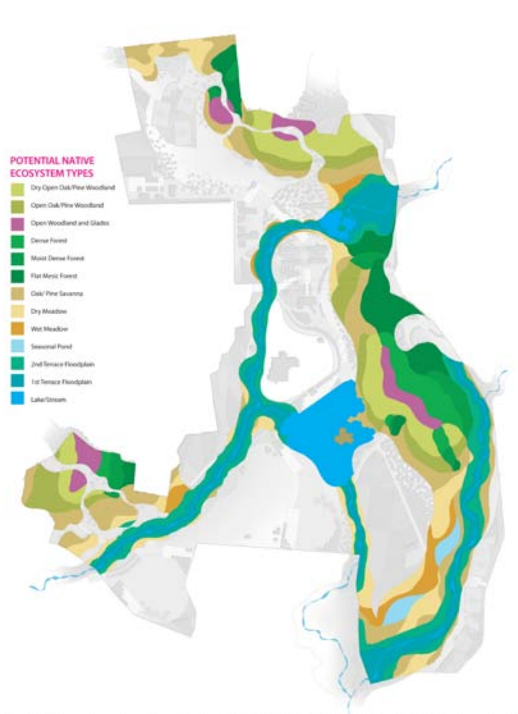
5) If multi parcel planning project, measure LBI score of design guideline strategies for development parcels and public realm.

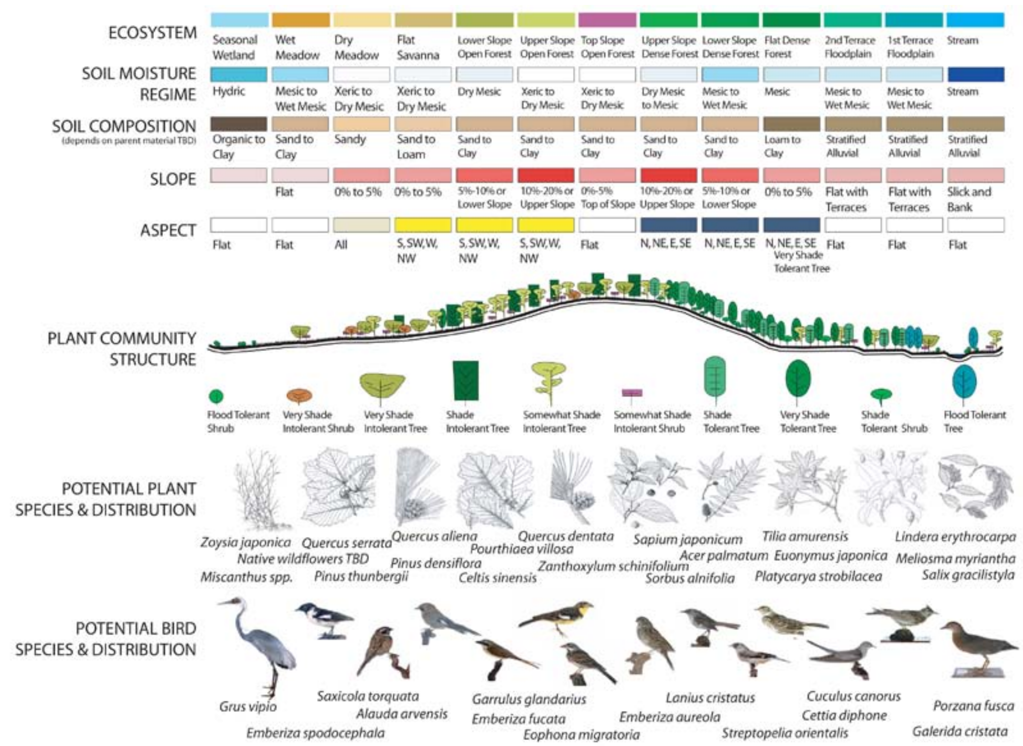


6) If specific site design is created, measure actual scores of landscape design and preservation solutions.



Baseline ecosystem attributes such as species richness, landforms or landscape ecosystems are benchmarks for applying the system. The above sub-regional scale diagrams and conceptual LBI scores for open space scenarios were adapted from analysis done for Superstition Vistas Regional Growth Scenarios, AZ, USA. Gray areas indicate development footprints of growth scenarios. (source: http://www.superstition-vistas.org/wp-content/uploads/Environment_EDAW_2009.pdf).





Ecosystem map and structural profiles for the Yongsan Park Ideas Competition, Seoul, Korea

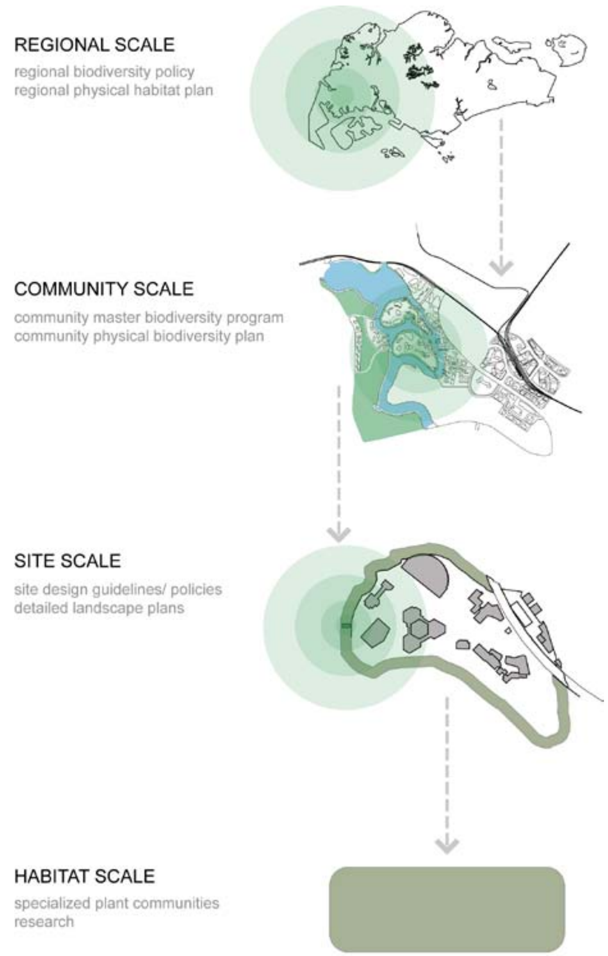
LBI "calibration". More basic levels of inventory and mapping may also be appropriate depending on the level of information available and project priorities. Ecosystem mapping is performed at multiple spatial scales, from regional to local, in order to understand the nested hierarchy of processes and patterns occurring across the site and influencing biodiversity. Priority species, habitats, or ecosystems including culturally significant features are also identified. These maps and profiles become the basis for design strategies and model calibration.

Step 2) LBI Model Calibration

Based on the structural and pattern attributes of the local ecosystems, habitats and target species, the LBI scoring system is "calibrated" for the project by determining scoring "thresholds" (scores 1 through 5) for the metrics listed on the previous pages. All or a select number of indicators may be assessed for projects depending on the level of effort that the project desires to support. Performance thresholds can be based on empirical research, local best practices, or may be developed specifically for a site based on expert opinion. Because empirical research is often rare for many target habitats and regions, thresholds can be based on assumed "keystone" structural, pattern, or process attributes of local ecosystems or land use forms. For example, corridor width thresholds could be based on a native forest tree crown width and height (as was done for the Jurong Lake and Portland applications); edge effect distances may be known for some target species; a natural process such flood regimes and natural floodplain terracing structure; or even typical widths of habitat connectivity "barriers" including roads or sidewalks. Using the "keystone habitat attribute" of forest canopy tree crown radius of 6 meters, as was done at Jurong Lake, pattern indicators thresholds based on multiples of 6 were used to indicate the number of "trees wide" habitat patches or corridors were and the amount of interior vs. edge conditions for biodiversity.

Different sets of thresholds for each indicator may also be developed for major land use categories. For example, different design constraints, ecological functions, implementation practices, or property rights may occur in conservation areas, pubic realm and parks, or on private parcels and score thresholds may be adjusted accordingly. For example, major open space areas tend to provide larger more contiguous habitats and higher functioning ecosystems, providing a more significant contribution to regional biodiversity. On private parcels, habitats may be smaller, more fragmented, and more architectural in character, and scoring may be adjusted accordingly. Some value may also be added for smaller habitats in developed areas that may be of higher socio-cultural value because of improved interaction with nature may result in increased conservation behaviour.

The diagrams on the following pages describe some of the LBI scoring thresholds that were used for the Jurong Lake application.



Calibrating the LBI for a project area requires assessment of the ecological role that the area plays within the broader region, especially considering habitat connectivity, regional rarity of ecosystems, and community access to nature.

Step 3) Existing Condition LBI Baseline Measurement

A goal of many projects is to create a plan that achieves improved biodiversity and ecosystem function from the baseline existing condition. This baseline LBI score, or other benchmarks including the historic native ecosystem condition, or a business as usual scenario are typically used as benchmarks by which achievement of performance goals are measured. Therefore, one "key performance indicator" of projects tends to be:

Key Performance Indicator:

- Percent change in the overall LBI for onsite habitats compared to the historic natural (pre-settlement), existing site, or business as usual master plan condition.

The first step in calibrating the LBI and establishing biodiversity performance targets includes a relative biodiversity valuation process for the existing condition (i.e. measurement of the baseline LBI score) to determine priority areas for preservation, to frame goals for biodiversity enhancement, and to measure project improvement.

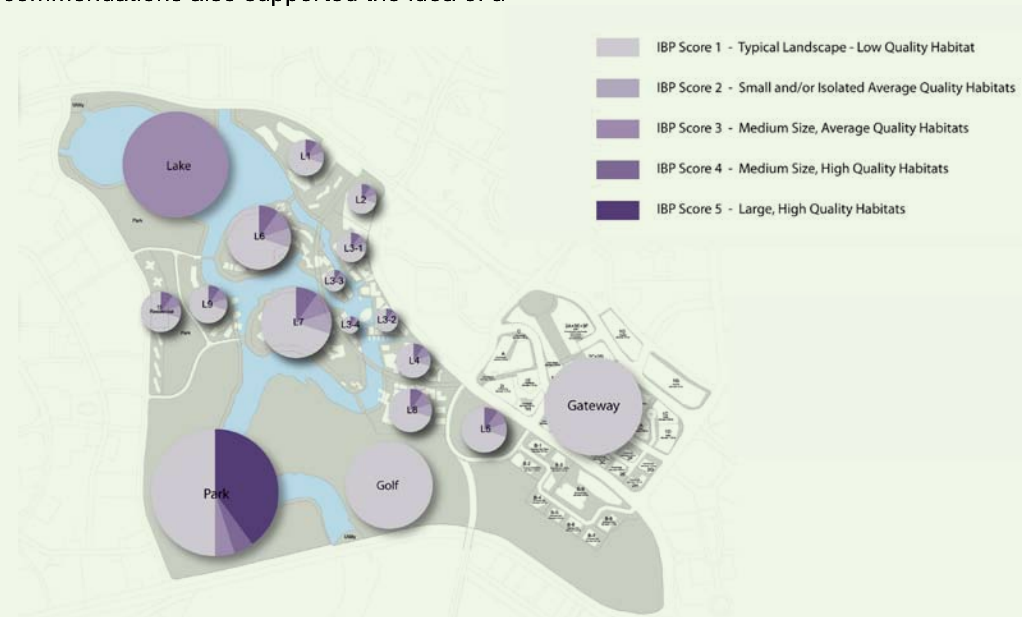
The existing condition benchmark analysis involves performing an inventory of all areas of the site and scoring each area based on the scoring criteria included on the previous pages. The baseline LBI score for a site provides an indication of its existing relative value to biodiversity. Generally, urban sites with little or no valuable habitat will have LBI scores of between 0 and 1, whereas a natural site in a wilderness location could achieve a

LBI Case Study:

Jurong Lake District, Singapore

The Jurong Lake District in Singapore was the initial project where the LBI was developed and applied (at the time the LBI was called the Index of Biodiversity Potential - IBP). The LBI was part of an AECOM led comprehensive sustainability planning effort for the District. The 300+ ha site included a small amount of existing wetland and secondary forest habitats and was envisioned by the client to be a global exemplar for sustainable development. The LBI process supported development of the overall master plan and park scenarios, a biodiversity target of a 25% improvement from the existing condition, and parcel-level LBI design guidelines for landscapes to be designed by future developers. The recommendations also supported the idea of a broader biodiversity network within Singapore, with Jurong Lake acting as a key urban biodiversity hotspot.

The recommendations included guidelines for habitat area allocations on parcels, target habitat types, plant lists, and contemporary landscape architectural habitat enhancements at ground level and on green roofs. Providing habitat on the project's green roofs and through an elevated "eco-grid", similar to New York's "high line", was also considered, but these measures were found to be logistically unfeasible and more costly compared to ground-level habitat investments. The project also includes a major urban park with very high levels of biodiversity and multiple ecosystem services.



Index of Biodiversity Potential: Recommended Landscape Area Scores by Parcel*

*alternative score profile possible (i.e. if higher IBP scores are achieved, less land area may be allocated to habitat) score of 5. While the assessment of the existing condition is dependent on how the planning team defines scoring criteria, it is useful as a baseline for plan alternatives; however, if the protocol and criteria were standardized across a municipality or region, the LBI process can effectively compare the performance among different projects.

In this and the following steps, LBI scores for areas of the plan may be mapped through a combination of on-site measurements, GIS, aerial photo analysis, and Excel-based calculations.

Step 4) LBI Scoring of Plan Alternatives

Once the LBI score is measured for the existing site condition, plan alternatives are created and impacts or preservation of existing condition LBI score areas are measured. Design typologies for new landscapes, that may include architectural strategies or ecological restoration, are developed, their spatial extent is planned, and LBI performance is measured for one or several scenarios. Often, a "business as usual" scenario is developed as a benchmark to demonstrate the improvement in performance of other more ecological robust scenarios. Areas of landscape typologies may be planned at a general level across land use types, parcels, or districts of a planning area in this early stage of master planning (e.g. at a basic level, the overall land area planned for coverage of each type of landscape, or at a more detailed level, the spatial layout of landscape types across parcels may be performed at this stage).

Step 5) Parcel/Land Use Category LBI Score Targets and Guidelines (if applicable)

Detailed landscape planning for individual parcels or land use categories may be performed, or guidelines for landscapes may be created. At Jurong Lake, rather than performing detailed parcel landscape design, parcel guidelines requireing total amounts of landscape coverage and target LBI scores were determined, and the LBI metrics were used as design guidlines that future developers can follow during detailed design. Such guidelines could play a similar role in municipal biodiversity policies or codes.

Step 6) Detailed measurement of landscape design solutions

If detailed landscape design is performed, LBI measurement of the design can be performed as is show in the Portland Integrating Habitats project on the following pages. Measurements are made using a combination of GIS and hand measurements.

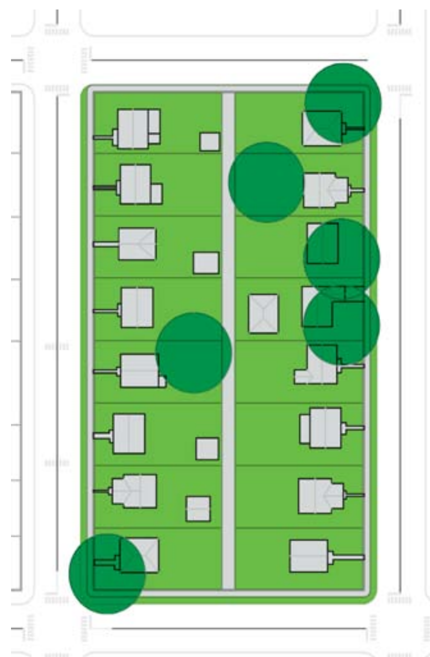
Native plant landscape at Millenium Park, Chicago IL

Existing Site Condition

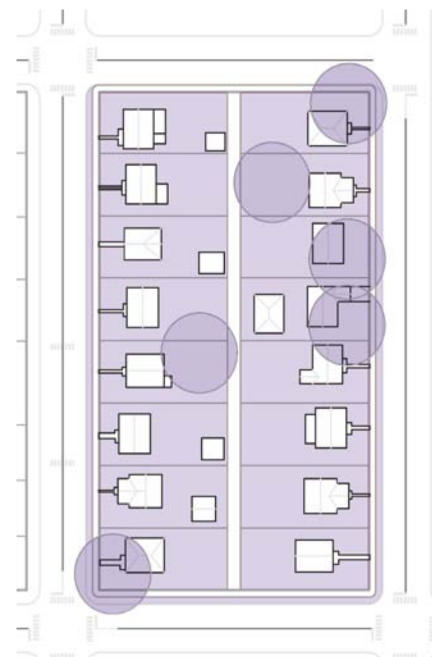
In 2008, Portland Metro (Portland, OR, USA) held the “Integrating Habitats” design competition. Participants created habitat design strategies for a number of typical land uses across the City. The AECOM team examined a typical city block and developed the strategy on the following page. LBI measurements were performed to evaluate performance between the existing condition (below) and final concept (next page).

Existing Condition LBI Score: 0.89/5

Landscape Types	LBI Scores
Hardscape	Score 1
General Landscape	Score 2
Primary Habitat	Score 3
	Score 4
	Score 5



Landscape Types



LBI Scores

The AECOM entry, “Growing Together,” took the People’s Choice award and second place overall. The LBI assessment indicated more than a 100% improvement in biodiversity potential from the existing condition. Despite more than doubling the human population density. A key lesson of this case study is that biodiversity enhancement and density increases can be accomplished simultaneously. Integrating habitats into urban areas may become more important as the world’s population becomes more urban and overall cultural connections with nature widen.

“Growing Together”: Portland Metro Integrating Habitats Competition Entry

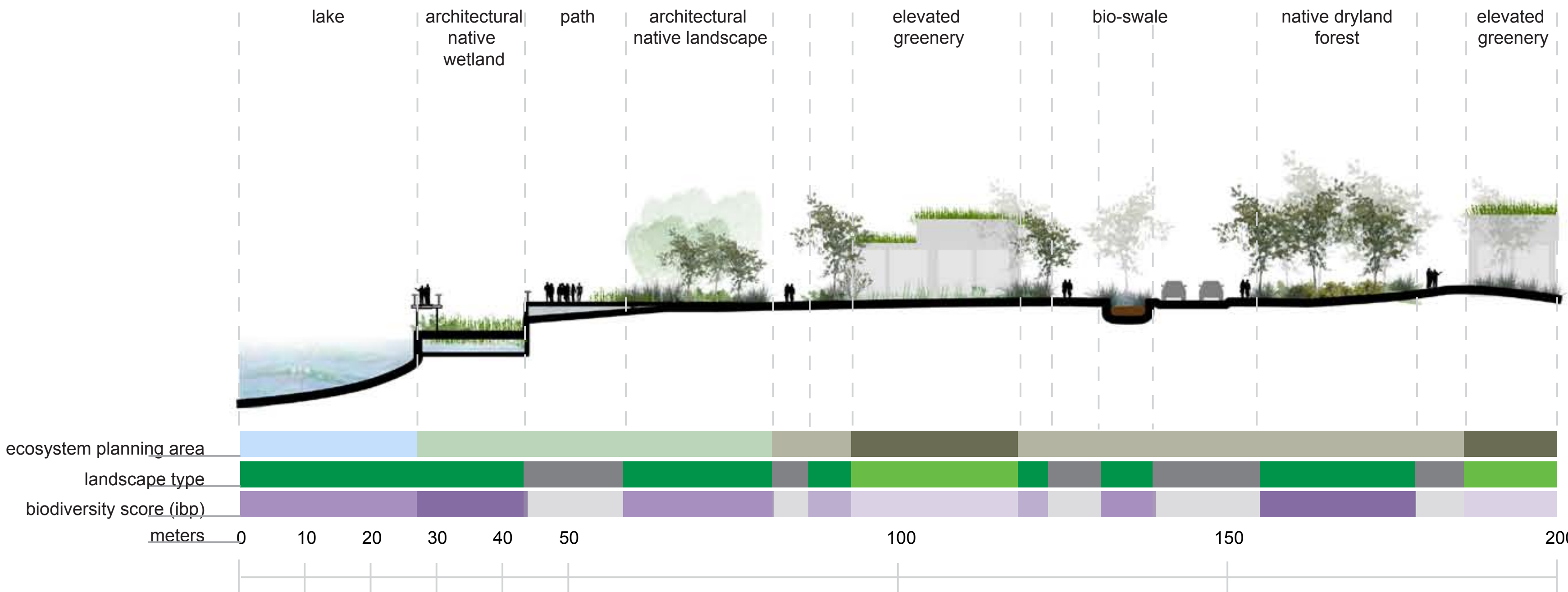
Final Concept LBI Score: 1.93/5

Landscape Types	LBI Scores
Hardscape	Score 1
General Landscape	Score 2
Primary Habitat	Score 3
	Score 4
	Score 5

Landscape Types

LBI Scores

developed space



ecosystem planning area

- Lakeside: Elevated Greenery
- Lakeside: Landscape
- Major Open Space
- Lake

landscape type

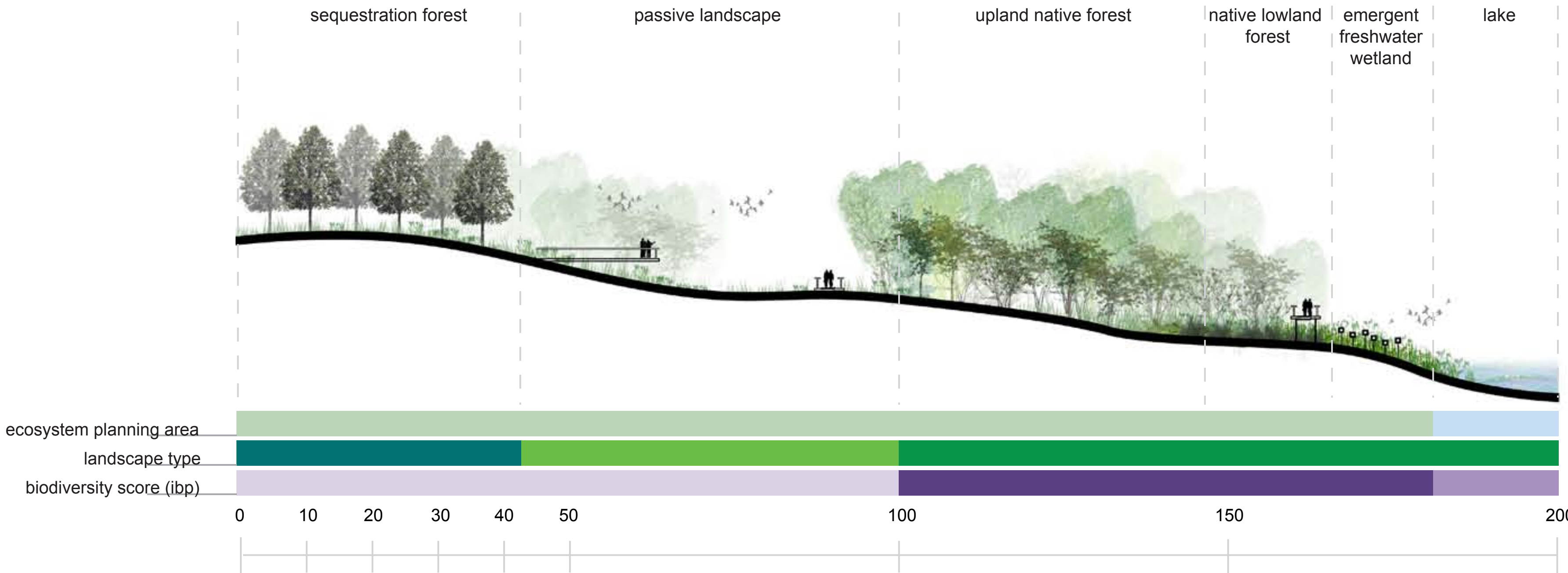
- Landscape Area: Habitat
- Landscape Area: Typical Landscape
- Landscape Area: Community Agriculture
- Landscape Area: High Carbon Sequestration Forest
- Hardscape

biodiversity score (ibp)

- IBP Score 1
- IBP Score 2
- IBP Score 3
- IBP Score 4
- IBP Score 5

Conceptual section diagrams of landscape types and LBI scores for developed landscape and open space (next page) planning areas

major open space



Step 7) Implementation and Verification

Following construction, landscapes can be measured to ensure that performance metrics have been achieved. Overall biodiversity measurements could then be performed and achievement verified.

Discussion

We are excited to promote wider application of the system and LBI for planning and measuring project biodiversity performance. To our knowledge, no other projects have attempted to quantitatively assess biodiversity strategies at this level. Currently, many of the metrics, thresholds, and assumed performance benefits are not yet supported by focused scientific studies, but instead are based on sound landscape ecology principles; relevant supporting science when possible; our experience on projects and project analogs done by others; and measurements of local native ecosystems.

Rapidly accelerating habitat loss, habitat fragmentation, and climate change are combining to drive a paradigm shift in biodiversity conservation strategies across the globe. Changes to ecosystems, especially changes to biota, hydrology, temperature, and storm patterns, are some of the direct impacts that many communities and biodiversity will face. Smarter community and regional land use design strategies that maintain and restore more robust habitat diversity and connectivity can help sustain biodiversity and ecosystem services as they are increasingly impacted by climate and land use change. This system and other new strategies for ecological infrastructure are helping to “future proof” communities for emerging environmental challenges and create more vibrant built and natural environments.

Precedent Biodiversity Planning Approaches

Tools to measure and evaluate biodiversity within planning and design projects are critical for targeting and evaluating landscape options that may optimize biodiversity performance. AECOM's research into the current availability of biodiversity planning tools within development contexts yielded few precedents. The majority of research conducted has been within the realm of landscape ecology and conservation biology, and has focused largely on conservation in areas void of development or on specific protected species, rather than for comprehensive biodiversity or ecosystem preservation. Urban biodiversity tools tend to provide qualitative, policy guidance rather than specific guidelines or metrics for assessing design performance.

For valuable examples of how comprehensive biodiversity performance may be considered and measured see:

Natural Capital Project

Matrix Matters: Biodiversity Research for Rural Landscape Mosaics

UK Forestry Commission

Biodiversity in Fragmented Landscapes

Evaluating Biodiversity in Fragmented

Landscapes: Applications of Landscape Ecology Tools

ASLA Sustainable Sites Initiative

Living Building Challenge

Convention on Biological Diversity

International Association for Landscape Ecology

California Natural Communities Conservation Planning

Landscape Ecology Principles in Landscape Architecture and Land Use Planning

Portland Metro Nature in Neighbourhoods

Singapore Index on Cities' Biodiversity

The Singapore Index on Cities Biodiversity (Singapore Index) is a tremendous example of a municipal to national-scale biodiversity planning and performance assessment framework. The Singapore Index focuses on evaluating existing ecological conditions as the basis for biodiversity performance targets, and policy level activities within cities and towns. The approach can also be used as a high-level design and planning framework for targeting broad-scale landscape structural guidelines and habitat connectivity.

The Singapore Index was an important consideration in developing the LBI. However, we found that the Index was not suitable to quantify and compare biodiversity more specific design scenarios on smaller project sites. Therefore, one of our goals in developing the LBI was to create an approach for biodiversity design oriented projects that may fit within a broader regional or municipal framework, such as the Singapore Index.

For additional information see:

http://www.cbd.int/authorities/gettinginvolved/cbi.shtml

This document was prepared by Isaac Brown at AECOM in San Francisco, CA with contributions from Shaun O'Rourke (Boston Architectural College - Urban Landscape Lab); David Gallacher and The Soe (AECOM Singapore); Claire Bonham-Carter and Chiaki Nakajima (AECOM San Francisco). Special thanks to Gary Grant from Green Roof Consultancy Limited (2012 London Olympics), Michael Boland (The Presidio Trust), Mike Sands (Prairie Crossing), and the Singapore Urban Redevelopment Authority and the National Parks Board for their generous contributions to this document.

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Cover Images: (Front) Echinacea pallida; Stapleton Central Park + Greenways, Denver, CO; US Census Bureau, Washington DC; National Museum of the American Indian, Washington, DC — (Back) Back Cover Images: ; US Census Bureau, Washington DC; Kunshan Ma An Shan Road Landscape Design, Kunshan, China; Jinji Lake Waterfront Redevelopment + Landscape Master Plan, Suzhou, China; The Children's Hospital at Fitzsimons, Aurora, CO