Natural Infrastructure

A Climate-Smart Solution

NORTHWEST BIO CARBON INITIATIVE

NWBiocarbon.org

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Executive Summary

In May 2013, carbon dioxide in the Earth's atmosphere reached 400 parts per million for the first time in roughly two million years. The buildup of carbon pollution is disrupting the heat energy balance of the planet, affecting the climate systems of the Earth. As evidence of accelerating climate change mounts, humanity has reached an era of climate consequences that requires us to address three crucial climate imperatives:

1. **Dramatically cut back on burning the fossil fuels** that are the major source of carbon pollution;
2. **Remove as much of the carbon pollution as possible** that has accumulated in the atmosphere over the past several decades; and
3. **Build resilience in infrastructure and natural systems** to protect vulnerable communities from future climate impacts.

Natural Infrastructure: A Climate-Smart Solution explores the role that natural infrastructure can play in addressing all three of these climate action imperatives. Focusing primarily on Oregon and Washington, this paper describes natural infrastructure; explores how it addresses the three climate imperatives; describes its multipurpose benefits; and discusses how to scale it up by taking a comprehensive approach and building the business case for investing in natural infrastructure. The paper also includes a supplement profiling successful Northwest natural infrastructure projects and programs.

A daylighted stream in Portland, OR connects an upstream forested wetland with a downstream rain garden and directs flow below the surface for groundwater recharge.

Natural infrastructure uses natural elements—soils and vegetation, including trees—to supplement and complement hard (or gray) infrastructure, such as pipes, pumps, treatment plants, and other often expensive structures and facilities. Cutting-edge natural infrastructure pioneers in Oregon and Washington are demonstrating how investing in natural systems can help avert the need to expand hard infrastructure and extend the viable lifespan of current systems—saving ratepayers money—while also delivering a rich array of co-benefits.

Natural infrastructure is a climate-smart solution because it reduces the need for energy created by burning fossil fuels; increases carbon storage in biological systems; and improves resilience in the face of climate impacts.

While our understanding of natural infrastructure's climate benefits is nascent as this is an emerging field in need of greater research attention, this paper gathers a variety of studies that suggest significant climate benefits from natural infrastructure, as follows:

Energy Benefits: Natural infrastructure projects can conserve energy in several ways, helping reduce reliance on fossil fuels used to produce our energy supplies.

- Philadelphia's Green Cities, Clean Waters maintains that managing half the city's stormwater through natural infrastructure will save 370 million kilowatt hours, 700 million BTUs, and $34 million, cutting carbon dioxide emissions by 1.1 million tons over 40 years.
- A University of Washington study has found that adding 15-30% compost to soils increased moisture retention and resulted in a 50% reduction in stormwater runoff, which reduces the need for energy to pump and treat stormwater.
- Applying natural infrastructure practices throughout Los Angeles County is projected to improve groundwater recharge and reduce the need to import water from distant locations by as much water as is needed for more than half a million people. The energy savings from averting the need to pump this water from far away would be equivalent to the electricity used by 20,000 to 64,000 households.
- Houston's 663 million trees are providing cooling that reduces the need for air conditioning valued at $131 million annually, while San Francisco's urban forest canopy saves an estimated $27 million in natural gas costs and $305 million in electricity.

Biocarbon Benefits: Natural infrastructure projects protect, enhance, and expand carbon-storing vegetative cover and healthy soils, which pull carbon dioxide out of the atmosphere and grow the stored pool of the

Earth's biocarbon. Quantifying natural infrastructure's biocarbon benefits remains an emerging field, with the dynamics of soil carbon particularly worthy of greater attention.

- A wastewater utility's program to restore streamside habitat along 35 miles of the Tualatin River watershed will remove an estimated 135,000 tons of carbon dioxide from the atmosphere in the coming century.
- Portland's Grey to Green initiative has planted nearly 30,000 trees, completed over 800 green streets, and helped develop nearly 400 green roofs. An Ecotrust study that examined the biocarbon storage potential of Portland's urban forests and streamside habitats found that natural infrastructure could double the biocarbon stored each year to over 485,000 tons of carbon dioxide per year.
- King County's Wastewater Treatment Division is using biosolids left after processing waste to enrich soil in the county, building soil carbon and reducing use of synthetic fertilizers, with a net benefit of 51,700 tons of carbon saved per year.
- The paper highlights studies of the carbon storage benefits of urban forests and trees in several cities including Houston, Chicago, San Francisco, Sacramento, and Seattle.

Climate Resilience Benefits: Natural infrastructure strategies not only reduce the carbon pollution we are adding to the atmosphere and absorb carbon pollution we added in the past, but can also enhance our communities' resilience in the face of changing climate.

- Increasing the forest and vegetative cover and building healthy soils will improve water retention and infiltration, helping to reduce the risk of flooding.
- Natural infrastructure can have an important temperature-moderating effect. A Toronto study estimates that covering half of the city's flat downtown roofs with irrigated green roofs could cool the city by 3.5 degrees F.
- A Manchester, England study found that increasing tree cover by 10% would keep the city's temperatures stable even as the broader climate warms under future climate change scenarios, while a loss of 10% in tree cover in the city would magnify future increases in temperatures by 12 degrees F.
- Natural infrastructure will help native birds, mammals, fish, and amphibians cope with climate change.
- Restoration of coastal habitat may help reduce the risk to coastal areas during storms that are anticipated to grow more intense, while improving habitat that is vital to sustain marine ecosystems and fisheries.


Urban stormwater as art

Multipurpose Public Benefits: Communities in Oregon and Washington have been pioneers in natural infrastructure, helping demonstrate that natural infrastructure offers a variety of important public benefits. These benefits range from stormwater and flood management to protection of water supplies, climate control, improved habitat for a variety of native species, and enhanced beauty and comfort of urban community spaces. To date, most natural infrastructure projects have been in response to specific regulatory requirements yet the package of economic, social, and environmental benefits, if communicated effectively, can be highly attractive to the public.

Scaling Up Natural Infrastructure: Oregon and Washington's natural infrastructure early-adopters have demonstrated that investing in bolstering natural systems can reduce the costs and increase the effectiveness of traditional infrastructure, while also delivering a rich array of co-benefits. What is needed to scale up these strategies are:

- **Stormwater Solutions for All Communities:** Funding for capacity-building and technical assistance for small- and medium-sized communities is needed and is justified in light of natural infrastructure's valuable savings and co-benefits.
- **A Comprehensive Approach:** To maximize natural infrastructure's benefits, communities need to move from single objective, single agency programs to develop comprehensive strategies. Comprehensive natural infrastructure approaches bring together various agencies, as well as multiple sectors, around a coordinated plan to meet numerous objectives and deliver a variety of co-benefits.
- **Establishing the Business Case for Natural Infrastructure:** It is essential that the co-benefits of natural infrastructure investments be rigorously and credibly calculated and made transparent, alongside the costs for the hard infrastructure that these investments reduce or make unnecessary.

Natural infrastructure clearly has a crucial role to play in addressing the three climate imperatives, but the magnitude of its benefits is not well studied, quantified, or understood, so additional research is required to fully establish the role that natural infrastructure can play as a climate-smart solution.

The natural infrastructure community must continue to develop the business case to quantify the economic value of the full range of benefits of natural infrastructure investments. This is key to providing the public and decision makers with a clear picture of just how economically attractive these investments are and of the variety of public challenges they help address.

The Northwest is a pioneer of natural infrastructure innovation, boasting a growing portfolio of exciting projects and programs, a number of which this paper profiles in the supplement. By scaling up natural infrastructure strategies, our region can powerfully demonstrate an important new climate-smart solution.

A rain garden in Portland, Oregon treats storm water from adjacent development and right-of-way, helping to filter pollutants as well as slowing and reducing the volume of stormwater flows

Introduction

Over the past quarter century, carbon pollution in the Earth's atmosphere built up well beyond concentrations that scientists consider safe, heralding the era of global climate consequences. The physics of the problem are relatively straightforward: excess carbon dioxide, which in May 2013 reached 400 parts per million for the first time in roughly two million years,[1] disrupts the heat balance of the Earth's atmosphere because the additional greenhouse gases retain more of the sun's energy and allow less to escape back into space, thereby adding warmth to the atmosphere.

The consequences for humanity and the world's economies are exceptionally serious and hardly simple. It is increasingly clear from global extreme weather events that climate consequences are unfolding in waves of devastating drought and storms in the U.S., costing billions of dollars in damages; extraordinary wildfires, heat waves, and flooding throughout the world; unexpectedly rapid melting of Arctic sea ice; and increasing acidity of our oceans.

We must take meaningful action to address climate change and that effort will require coordinated action to accomplish three critical climate imperatives:

1. Dramatically cut back on burning the fossil fuels that are the major source of carbon pollution;
2. Remove as much of the carbon pollution as possible that has accumulated in the atmosphere over the past several decades; and
3. Build resilience in infrastructure and natural systems to protect vulnerable communities from future climate impacts.

Natural Infrastructure: A Climate-Smart Solution explores the role that green or natural* infrastructure can play in addressing all three climate action imperatives. The paper begins with a discussion of what natural infrastructure is; explores how natural infrastructure addresses the three climate imperatives; describes the multipurpose public benefits of natural infrastructure; and explains how to scale up natural infrastructure by taking a comprehensive approach and building the business case for investing in natural infrastructure. In the supplement, we include examples of natural infrastructure strategies throughout the Northwest that demonstrate how natural infrastructure works to address the three climate imperatives, while delivering a range of co-benefits.

Natural infrastructure stormwater solution

* The terms natural infrastructure and green infrastructure are often used interchangeably. For this paper, we chose to use the term natural infrastructure to focus clearly on investment in natural systems and features, rather than on a more inclusive suite of 'green' environmentally-sound strategies that can include, by some definitions, the technologies and facilities to provide renewable energy production, end-use efficiency, and non-motorized transport. Our use of natural infrastructure in this paper means investments to protect, enhance, and expand areas across the landscape with carbon-storing vegetative cover and healthy soils. These include natural areas relatively free of human constructs, as well as engineered natural features in urban areas such as green roofs, green streets, bioswales, and the like.

Cost-Saving Solution with Rich Co-Benefits

Natural infrastructure uses natural elements—soils and vegetation, including trees—to supplement and complement hard (or gray) infrastructure, such as pipes, pumps, treatment plants, and other often expensive manmade structures and facilities. Leading-edge communities are deploying natural infrastructure to cost-effectively manage stormwater, reduce flooding, cool through shading, recharge groundwater, and enhance habitat for native fish, wildlife, and plants. These efforts are proving that natural infrastructure can provide cost-effective services that reduce or even avoid expenditures on hard infrastructure.

These communities are also finding that natural infrastructure comes with a rich assortment of valuable and important co-benefits, from cleaner water and air to greater access for people to natural beauty and recreation. Natural infrastructure can often cost-effectively complement a city's hard infrastructure systems, enabling costly expansions of the system of pipes, pumps, and water treatment facilities to be "right-sized," or scaled down, with a net savings to the community.

For example, Northwest cities, led by Seattle and Portland, are integrating natural infrastructure into their stormwater management systems. They are finding that investing in protecting and restoring natural areas, as well as engineered features, such as green streets, green roofs, and bioswales that use vegetation and soils to absorb rain water that would otherwise flow over hard surfaces, helps reduce stormwater runoff that can overwhelm a city's drainage system in extreme downpours. These same natural features offer valuable co-benefits, from helping cleanse rainwater of pollutants picked up from our city streets to helping cool summertime temperatures and making urban spaces more attractive.

What is Biocarbon? So how do we remove carbon pollution that is already in the atmosphere? Good old photosynthesis, plants absorbing carbon dioxide to create biocarbon. **Biocarbon strategies** mobilize nature to pull more carbon from the atmosphere, fixing it in soils, trees, and other plants.

Climate Benefits of Natural Infrastructure

Importantly, natural infrastructure also helps with the three climate solution imperatives: reduce the use of fossil fuel energy, increase storage of carbon in biological systems, and improve our resilience in the face of extreme weather:

- Natural infrastructure **often saves energy, reducing the need to burn fossil fuels**.
- Bolstering and augmenting natural systems **increases the carbon storage capacity** of a region's soils, plants, and trees, thereby pulling more carbon pollution from the air.
- Natural infrastructure enhances our communities' **ability to cope with and recover from some extreme weather events and climate impacts** that will continue to grow more powerful and frequent, even as we work to bring carbon dioxide back down to safe levels.


Tanner Springs Park, Portland, OR

As extreme weather events have heightened concern about global climate change, interest in adaptation strategies has understandably surged. It is important to acknowledge upfront, however, that without stabilizing and reducing carbon dioxide concentrations in the air, carbon dioxide levels will climb inexorably toward tipping points where the scale of change will overwhelm our ability to adapt. Natural infrastructure has a crucial role to play because it uses nature to both address the cause of climate change and build resilience.

Natural infrastructure projects are excellent examples of "adaptive mitigation" – a term coined by Brian Stone in his 2012 book, *The City and the Coming Climate: Climate Change in the Places We Live*. Adaptive mitigation strategies reduce carbon in the atmosphere while building greater resilience into community infrastructure in the face of changing climate.

Our understanding of the climate benefits of natural infrastructure is nascent and will grow in sophistication with new research that emerges going forward. In this section, we highlight a variety of studies that begin to paint a picture of how natural infrastructure reduces carbon pollution, by saving energy and storing more carbon in soils and vegetation, while also enhancing our ability to cope with the climate changes that are coming.

ENERGY BENEFITS

Natural infrastructure can save energy, which reduces reliance on fossil fuel energy such as coal and natural gas, which in turn reduces carbon dioxide emissions into the atmosphere. Examples of the energy-saving benefits of natural infrastructure include:

- Natural spaces and green features make cities more attractive places to live, drawing more people to live in cities, and improving the quality of life of local inhabitants. People living in cities on average use significantly less energy than people living in suburbs or rural areas. By some estimates, city dwellers may produce 60% less carbon dioxide emissions than their suburban counterparts.[2] Natural infrastructure clearly increases the attractiveness of living in cities and will draw more people. The potential magnitude of this climate benefit is not well studied nor quantified so we do not have specific studies to share here.

- A significant share (an estimated 13%) of our nation's electricity is consumed directly for water-related energy uses.[3] To help reduce the need for water-related energy, natural infrastructure projects can:
    - Recycle and reuse cleaned-up wastewater to irrigate local landscaping and to recharge aquifers, reducing the amount of potable water that must be pumped and piped into our communities from far away, which saves energy.
    - Deploy carbon-rich organic soil amendments, such as compost and biosolids, that enhance the soil's water retention capacity and shrink the amount of irrigation water needed to sustain landscaping features, which saves energy.
    - Reduce stormwater runoff, which means less stormwater is pumped through pipes and subjected to wastewater treatment, both of which are energy-intensive processes.

- Urban trees and green roofs can provide shading and evaporative cooling for our buildings and reduce wind speeds, which can save energy by reducing air conditioning loads in summer and, during cold and windy times, by protecting buildings from winds that increase heating demand.

Recognizing that the study of the energy-saving benefits of natural infrastructure is in its infancy and demands much more rigorous and systematic attention, we offer these examples of studies that shed light on the climate benefits of natural infrastructure:

> **Portland's Grey to Green initiative** estimates that if the program's goals for green roofs, green streets, and urban trees are achieved, the amount of stormwater runoff needing to be pumped and processed will be reduced enough to save about 275,000 kilowatt hours a year, a figure equivalent to roughly the electricity consumed by 25 average American homes.[4]
>
> David McDonald of **Seattle Public Utilities** reports that field trials conducted by the University of Washington found that adding 15-30% compost to soil by volume on reclamation sites resulted in a whopping 50% reduction in stormwater runoff because of enhanced soil structure and improved moisture-holding capacity. If widely deployed, using compost-rich soils in natural infrastructure projects will help reduce stormwater runoff, further reducing energy required to pump and treat stormwater through the traditional hard infrastructure systems.[5]
>
> The **City of Los Angeles** estimates that 'low-impact development' practices applied throughout L.A. County would promote recharge of the community's vital aquifer resource, because natural infrastructure better absorbs and infiltrates rainwater into the ground. By bolstering groundwater recharge, the County could reduce water imports by an amount equivalent to the consumption of 450,000 to 900,000 people. This would save energy by reducing the amount of water the County pumps from distant locations, conserving as much electricity as is used by 20,000 to 64,000 households.[6]

Several cities have looked at the energy-savings benefits of their tree canopies and of programs to expand tree cover, including:

> **Philadelphia's** *Green Cities, Clean Waters* program projects that managing half of the city's stormwater runoff through natural infrastructure will result in electricity savings of 370 million kilowatt hours and natural gas savings of 700 million BTUs over the 40-year period of the project, saving $34 million. These energy savings would reduce carbon dioxide emissions by 1.1 million tons over the project period, which has a monetary value of $21 million.[7]
>
> In the greater **Houston** area, 663 million trees are providing energy savings and carbon emissions reductions valued at $131 million annually, primarily due to their cooling function in the summer. Another study found that annual residential energy savings due to tree shade is around $26 million.[8] Houston's very hot summers and high air conditioning use, which cost homeowners on average $714 per home annually, help explain why these savings are especially significant.[9]
>
> For the nine-county **San Francisco** Bay Area, the urban forest canopy provides an estimated $27 million in savings of natural gas costs and over $305 million in electricity cost savings.[10]
>
> A study in the **Sacramento** area found net annual energy savings from a tree planting program totaled $10 per tree. A projected 7% increase in tree canopy cover is expected to decrease neighborhood air temperature and result in a doubling of these savings.[11]

BIOCARBON BENEFITS

Natural infrastructure projects protect, enhance, and expand carbon-storing vegetative cover and healthy soils, which pull carbon dioxide out of the atmosphere and grow the stored pool of the Earth's biocarbon.

To date, natural infrastructure projects have been financed as *cost-effective infrastructure* investments, for example, reducing overall costs for a city's wastewater management system. It is important to note that in these cases, the climate benefits are a bonus, making the cost per ton of carbon saved by natural infrastructure projects essentially less than zero.

Soil scientist Kate Kurtz holding compost

Quantifying natural infrastructure's biocarbon benefits remains an emerging field, and is neither standard practice nor a fully mature science. To illustrate the point: studies estimating the carbon fixed by such projects often treat soil processes as a black box, when soils actually represent the single largest land-based carbon pool on the planet. While carbon storage in soils is clearly a significant portion of the total biocarbon benefits to be realized by natural infrastructure projects, many or most current studies ignore carbon stored in soil.

Relatedly, organic soil amendments such as compost or biosolids can significantly enhance the survival rate and growth of plantings and increase soil carbon.[12] In addition, inoculating tree and plant roots before planting with appropriate mycorrhizae (beneficial fungi that provide plants nutrients from the soil) has proven promising in agriculture and wildland restoration settings.[13] Yet estimates of the carbon benefits of natural infrastructure projects have not calculated the carbon benefits with or without such soil amendments.

Recognizing that research needs to be scaled up, let's examine some indicators of the biocarbon benefits of natural infrastructure investment.

Nationally, urban forests and trees currently store about 640 million tonnes* of carbon (with a monetary value calculated at $50.5 billion), and add 25 million tonnes of carbon storage per year[14] (valued at $2 billion). Adopting a more inclusive definition of the boundaries for "urban forests" significantly increased the carbon benefit and dollar value by roughly 100% and 300% respectively.** This 2013 estimate did not incorporate below-ground carbon storage in its analysis, but cited another study that found approximately 1.9 billion tonnes

*Editor's note: The studies discussed in this section measured carbon in metric tonnes or tons. One metric tonne equals 2,204.6 pounds, whereas one ton equals 2,000 pounds. We did not convert the measurements to a common unit, but offer the data in the units as reported in the studies.
**Alaska's unusually large community boundaries accounted for 17% of the US urban/community area.

of carbon stored in urban soils in the US, or about three times as much carbon stored within the soil layers than above ground in the trees.[15]


Upper Tualatin rivershed

An Ecotrust analysis of the **Clean Water Services (CWS)** program to restore streamside habitat along 35 miles of the Tualatin River watershed calculated that over 100 years the program will remove about 135,000 tons of carbon dioxide from the atmosphere. In addition, by investing in natural infrastructure, CWS avoided the need to build a cooling facility for the water it discharges into the river, saving the community about $100 million while also avoiding the energy consumption (and carbon emissions) required to run the chilling machinery.[16]

Portland's Grey to Green initiative uses a variety of natural infrastructure elements to provide improved stormwater management, enhancing the community's natural systems. Since 2008, the City has planted nearly 30,000 street and yard trees, completed over 800 new "green streets"[17] facilities, and helped facilitate the creation of nearly 400 green roofs. The City pegs the total biocarbon storage at 8,800 tons per year if all Grey to Green goals were achieved in the city.

A separate Ecotrust study calculated the biocarbon storage potential of **Portland's urban forests**, combined with streamside habitats across the greater Portland metropolitan region's parks and open spaces. The study found that natural infrastructure strategies could double the amount of biocarbon stored each year in the area studied, to over 485,000 tons of carbon dioxide per year in 2050.[18]

Loop trucks

King County's Wastewater Treatment Division (WTD) manages three large wastewater treatment plants that process sewage generated by 1.5 million people over a 420 square-mile area. After various treatment processes, the material enters an anaerobic digester, where the methane is harvested to generate renewable energy. The solids left after the processing are a carbon-rich soil amendment, commonly called biosolids, which WTD applies to area forests, farms, landscapes, and yards. Factoring in both the carbon cost of the diesel fuel burned to transport and apply the biosolids, and the carbon benefits of the renewable energy, of carbon accumulation in the soil, and of replacing synthetic fertilizers with biosolids, the County calculates a net benefit of 51,700 tons of carbon dioxide in 2012.

Several other cities have conducted studies that looked at the biocarbon benefits of their urban forests and programs to expand the forest canopy in their communities:*

- In the greater **Houston** area, 663 million trees are estimated to store a total of 39 million tons of carbon (valued at $721 million) and to be increasing the carbon they store by 1.6 million tons of carbon annually (valued at $29 million).[19]
- **Chicago** looked at a much smaller area in which 3.5 million trees currently store over 700,000 tons of carbon (valued at $14.8 million) and add 25,000 tons of carbon per year (valued at $500,000 annually).[20]
- A study of trees in San Francisco found that its 670,000 trees store almost 200,000 tons of carbon (valued at $3.6 million) and remove 5,200 tons of carbon annually ($95,000).[21]
- In **Sacramento**, a study encompassing urban and suburban areas found 6 million urban trees currently store 8 million tons of carbon dioxide, adding 238,000 tons of carbon dioxide sequestered annually. Perhaps surprisingly, the study found city areas storing about four times as much carbon per hectare than suburban areas, due to larger trees and more trees per acre.[22]
- A study in **Seattle** found carbon storage in forest biomass across the city amounts to almost 2 million metric tons of carbon dioxide (valued at $11 million), with an additional 141,000 metric tons added to the biocarbon storage bank in 2011 (valued at $770,000).[23]

*The cities that conducted the studies in this section did not use the same formulas for calculating carbon value per tree stored and sequestered per year, so the estimates of biocarbon benefits vary among them.

CLIMATE RESILIENCE BENEFITS

The best climate science now indicates that the point of dangerous human interference with Earth's climate system has been exceeded. Serious climate changes are now underway and will intensify, impacting our communities and economy in a variety of ways. Many communities are starting to think about how to build resilience into their infrastructure and economy to withstand or bounce back from climate shifts and extreme weather.

It turns out that natural infrastructure strategies can not only reduce the carbon pollution we are adding to the atmosphere and absorb carbon pollution we added in the past, but also enhance our communities' climate resilience.

Climate changes that we are seeing now and can expect to intensify in coming years will vary by location, with changes differing between Neah Bay and Coos Bay, Spokane and Seattle, Beaverton and Burns. But in general expected impacts in our region include:

- Bigger rainstorms and rain-on-snow events that cause flooding.
- Higher temperatures and shifting precipitation patterns that can trigger long summer droughts or disrupt normal accumulation of the Northwest's "white gold" (our mountain snowpack), both of which will increase conflict over water among cities, farms, hydropower, and fish.
- Shifting temperature and water regimes that stress ecosystems across forests, wetlands, streams, and estuaries, increasing the odds of major wildfires, impacting sensitive species, and favoring pest invasions.
- More frequent heat waves that intensify the "urban heat island effect," which can cause serious discomfort and danger for vulnerable populations who lack mechanical cooling.
- Rising seas that threaten productive coastal ecosystems and farmlands, as well as coastal cities and towns, with storm surges and property damage, backup of sewage systems, and saltwater contamination of aquifers.

With climate disruption underway and the urgent need to plan for the impacts we can expect will occur, it is useful to learn that natural infrastructure investment can help communities better cope with expected climate change. Increasing the forest and vegetative cover and building healthy soils, for example, will improve water retention and infiltration, helping to reduce the risk of flooding.

Our cities, with their predominance of concrete, pavement and structures, which absorb and radiate heat, already experience higher temperatures than surrounding areas–a phenomenon known as the "urban heat island effect." With hotter temperatures and greater risk of prolonged summer drought more likely in the future, natural infrastructure can have an important moderating effect. In comparisons of city centers with surrounding suburban areas that have greater tree and vegetation coverage, temperature differences of more than 9°F have been observed.[24]

A study in Toronto estimated that covering half the city's flat roofs downtown with irrigated green roofs could cool the city by 3.5 degrees F.[25] In Manchester, England researchers looked at the impact of urban tree cover on temperatures under future climate scenarios. They estimated that, with current tree cover, temperatures in the city would increase 6 degrees F by 2080 in a high emissions scenario, and by at least 12 degrees F if tree coverage was reduced by 10%. Increasing tree cover by 10%, on the other hand, would maintain temperatures in the city at the 1961-1990 baseline level for most of the climate change scenarios modeled.[26]

Natural infrastructure will help native birds, mammals, fish, and amphibians coping with climate changes as well. More extensive tree cover and vegetation will expand areas where these species can nest, find shelter and food, and move about. Even green roofs can help: one study of green roofs in London found abundant invertebrates, 10% of which were classified as "nationally rare and scarce" species.[27] Cold water fish species, such as salmon, will face even greater challenges as temperatures rise, but restoring trees and other natural vegetation along streams, rivers and lakes will create shade and help cool the waters.


White-crowned sparrow

Restoration of coastal habitats can, in some cases, help reduce the risk to coastal communities during storms that are expected to grow more intense. At the same time, coastal restoration projects improve habitat that is vital to sustaining rich marine ecosystems and the nurseries for many fish and shellfish species that are important to the coastal economy.[28]

Multipurpose Public Benefits

Communities in Oregon and Washington have been pioneers in natural infrastructure, successfully implementing a variety of cutting-edge projects that have advanced the practice and helped prove that natural infrastructure offers multiple public benefits (see supplement titled "Innovative Natural Infrastructure Projects and Programs"). The need to respond to specific regulatory requirements has been the driver for many of these projects. In many cases these projects have successfully proved an entirely new approach to satisfying that singular objective of regulators that simultaneously delivers a variety of public co-benefits that address other local regulatory and public challenges.

Portland neighborhood curb extension

Nancy Rottle, an Associate Professor of Landscape Architecture at the University of Washington, says a hallmark of natural infrastructure is multi-functional performance. “Where traditional infrastructure typically addresses a single system with a singular function, natural infrastructure most often serves multiple functions and provides more than one ecological service.” By serving multiple functions, Rottle adds, natural infrastructure strategies not only offer cost-effective solutions for environmental issues, “but also provide the amenities that people enjoy and want to support.”[29]

While our regulatory systems are reasonably effective at enforcing improvements on single metrics, they are not yet adept at encouraging systemic solutions that deliver progress on several regulatory metrics spanning regulating agencies. For any given natural infrastructure project, the list of regulatory concerns benefited may include several of the following:

- Protection of water supplies
- The amount and quality of stormwater
- Flood risk
- Coastal storm surge risk
- Pollutant load and temperature of water discharged into streams and rivers
- Habitat quality for protected fish, wildlife, and plants
- Brownfields recovery
- Recovery and beneficial use of organic wastes
- Moderation of the urban heat island effect

Communities can design natural infrastructure strategies that recognize their multi-benefits, only some of which respond to regulatory issues. One example Professor Rottle offers is increasing urban tree cover. Urban forests deliver climate control by providing shade for buildings, people, and streams; benefit wildlife habitat for birds and other species; reduce stormwater runoff and erosion by intercepting rainfall and evapotranspiring* it; improve air quality by removing particulates; filter polluted stormwater run-off; and enhance the beauty and comfort of urban community spaces.

Urban tree canopy in Portland, OR

The public benefits of natural infrastructure can deliver a package of economic, social, and environmental benefits that, if communicated effectively, can be highly attractive to the public. Part of communicating the benefits effectively is demonstrating why natural infrastructure strategies are smart economic investments. The natural infrastructure community must continue to develop its business case to quantify the economic value of the full range of rich co-benefits in order to provide the public and decision makers a clear picture of just how economically attractive these investments are.

Scaling Up Natural Infrastructure

Natural infrastructure pioneers in Oregon and Washington are demonstrating how investing in bolstering natural systems can reduce the costs and increase the effectiveness of traditional infrastructure. Natural infrastructure can help avert the need to expand hard infrastructure, extending the viable lifespan of current systems—saving ratepayers money—while also delivering a rich array of co-benefits.

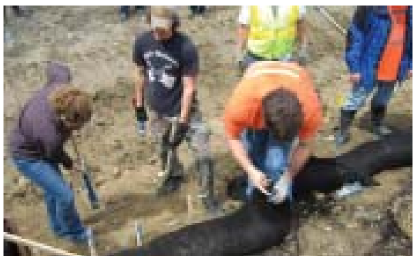
*Evapotranspiration is the process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants. http://dictionary.reference.com/browse/evapotranspiration

Natural infrastructure is clearly a smart, but underutilized and underdeveloped, public investment. How do we take natural infrastructure to the next level and scale it up to its full potential? Emerging recommendations to scale up natural infrastructure include:

STORMWATER SOLUTIONS FOR ALL COMMUNITIES

While major cities like Seattle and Portland have made huge strides in integrating natural approaches into their strategies for managing stormwater, many smaller jurisdictions have little or no experience with green stormwater infrastructure approaches. Part of the challenge for smaller governments is a lack of technical capacity on staff. Funding for capacity-building and technical assistance is needed—and is justified in light of the valuable savings and co-benefits that natural infrastructure offers.

Washington State has made notable progress in this respect, implementing funding programs to promote natural stormwater infrastructure demonstration projects and developing stormwater manuals for the west and east sides of the state. Washington has also reviewed the development codes of most Puget Sound cities to remove barriers to natural stormwater infrastructure.


Erosion control training for builders in Washington

In addition, Washington is at the forefront of recognizing the value of healthy soils for stormwater management, among other benefits. The state has established state Best Management Practices (BMPs) that create incentives for builders to make full use of compost. (We recognize that emerging concerns about metals and nutrient overloads in compost must be addressed to ensure that the continued growth of this important sector is not waylaid.)

The state's BMPs allow builders to save money by reducing the size of retention ponds required to handle water runoff. A complementary Building Soil guidelines manual (www.buildingsoil.org) helps builders implement the BMPs. In addition to the benefits for salmon and for the climate, builders are realizing additional economic benefits by using compost to meet the BMPs, including:

- Better plant survival/health/growth/appearance of landscape plantings
- Lower water bills and easier care due to better soil water retention, which means less irrigation
- Reduced need for chemicals

COMPREHENSIVE APPROACH

To date, natural infrastructure projects and programs have been designed primarily as responses to specific regulatory drivers, chiefly requirements on: a) cities to avoid spilling untreated sewage and wastewater when rainstorms overwhelm the capacity of their treatment plants, and b) wastewater utilities to undo the harm caused to fish when the treatment process discharges heated water into rivers and streams.

But to fully realize natural infrastructure's potential, communities must begin to develop ***comprehensive strategies,*** bringing together various agencies, as well as multiple sectors, around a coordinated plan to meet numerous objectives and deliver a variety of co-benefits. Such strategies will integrate entire urban regions and use the full natural infrastructure toolbox. They will incentivize retrofitting existing infrastructure and not just impact new development and redevelopment.

A comprehensive approach to natural infrastructure can help address a variety of federal regulatory issues, from Clean Water Act permits and plans to floodplain development, impacts on species listed under the Endangered Species Act and their critical habitat (including salmon), Natural Resources Damages Act actions, and clean up of contaminated brownfields and Superfund sites.

A coordinated, multi-agency response will inevitably unearth smart strategies that help address several challenges much more cost-effectively and efficiently than siloed, parallel-track processes. Federal policy needs to encourage and incentivize comprehensive natural infrastructure approaches that can deliver benefits across a range of regulatory fronts.

Our investments in acquisition and restoration of natural resources are another area where a variety of generally siloed and fractured efforts are looking at separate problems, rather than at common solutions. Comprehensive natural infrastructure plans can bring these efforts together, linking programs to protect and re-vegetate riparian (streamside) areas with salmon recovery investments, biodiversity corridor development, flood reduction activity, and climate action planning.

State policies need to encourage natural infrastructure innovation. For example, states can facilitate greater use of engineered wetland systems in the wastewater treatment process, establish clear priority for the use of composts and biosolids to build healthy soils, and support the full development of ecosystem services trading programs.


Duwamish Urban Waters Initiative

An example of what is possible is the Urban Waters Federal Partnership, which brings together a dozen federal agencies, bridging the silos to effectively coordinate and target federal resources, all aimed at transforming degraded urban waterways into clean, healthy and treasured centerpieces of community life. The Urban Waters program recently added the Green-Duwamish River in Seattle as a project location, the first in the Northwest. The local Green-Duwamish partners will be undertaking an 'ecosystem services evaluation' of the watershed to calculate the full range of economic and social benefits of natural systems that will serve as a basis for comparing different natural infrastructure restoration options.[30]

THE BUSINESS CASE FOR NATURAL INFRASTRUCTURE

California has begun to make natural infrastructure investments based on specific climate benefits. The state's Global Warming Solutions Act enables California's large polluters, if they are unable to meet targets for reducing carbon dioxide emissions on their own, to buy pollution credits at auction. Revenues, which could reach $60 billion by 2020, must be spent on actions that quantifiably reduce net emissions of carbon dioxide. California is beginning the process of reinvesting those revenues in transforming its energy and transportation systems to reduce emissions, but a portion of the funds will also be directed toward natural infrastructure.[31]

In Oregon and Washington, where carbon pricing markets that could fund climate strategies have not yet been established, natural infrastructure investments have been most often designed to help address a single regulatory obligation. The cost-benefit analyses developed to guide and justify these investments have been narrow in scope, e.g., what magnitude of green investment can reduce the hard infrastructure costs required to satisfy the regulatory objective at a net savings to ratepayers. These analyses show that investments in natural infrastructure that reduce rain runoff in big storm events can allow a scale-back of new investment in expensive pipes, pumps, treatment facilities, and other hard infrastructure. Significant savings can be quantified to make a compelling case to ratepayers for natural infrastructure deployment.

For example, the City of Portland's Tabor to the River program covers a 2.3 square mile area where the wastewater system collects both sanitary sewage and stormwater runoff from streets in the same pipes. With increases in pavement and other hard surfaces, and decreasing forest and vegetation coverage, the amount of stormwater going into the pipes is much greater than the system was designed to manage 100 years ago. In very heavy rains, the sewage can back up into the area's basements, flood streets, and overflow into the Willamette River.


Tabor to the River community-built rain garden

To address this serious problem, the Tabor to the River program is implementing several natural infrastructure strategies that complement—and substantially reduce the cost of—the needed improvements to the pipe infrastructure. The green strategies reduced overall costs from $144 million, if only traditional pipe solutions were deployed, down to $81 million.[32]

Natural infrastructure investments can be justified based on cost savings for specific systems, such as stormwater management or drinking water source protection. But the other benefits of natural infrastructure investments also need to be quantified in monetary terms. Natural features that control stormwater, for example, are also valuable for salmon recovery, flood management, outdoor recreation, public health, energy conservation, protecting biodiversity, biocarbon storage, and climate adaptation.

Conclusion

Natural infrastructure clearly has a crucial role to play in addressing the three climate imperatives to reduce use of fossil fuel-based energy, store biocarbon, and increase resilience. In addition, natural infrastructure investments offer a wide variety of valuable co-benefits to the public, cost-effectively helping conserve energy, protect water supplies, enhance biodiversity, and make cities more comfortable and attractive places to live. It is essential that the co-benefits of natural infrastructure investments be rigorously and credibly calculated and made transparent, alongside the avoided costs for hard infrastructure that these investments reduce or make unnecessary.

Great blue heron and children at Tanner Springs Park, Portland, OR

Developing the business case by quantifying the economic value of the full range of rich co-benefits will help provide the public and decision makers with a clear picture of just how economically attractive these investments are, as well as how beneficial they are to addressing climate change.

As we transition from the single-objective approach to the full integration of natural infrastructure into comprehensive plans for our communities, governments at all levels will need to bring together various agencies and leaders to align plans and strategies to more fully realize the potential and benefits of natural infrastructure solutions.

Funding for capacity-building and technical assistance is also needed for small- and medium-sized communities to help understand and implement natural infrastructure strategies. Natural infrastructure's significant savings and co-benefits justify the needed investment in research and capacity. Finally, natural infrastructure's ability to help with all three climate change imperatives—reducing carbon emissions, increasing biocarbon storage, and enhancing our climate resilience—gives new urgency to the need to scale up investment in comprehensive natural infrastructure solutions.

Innovative Natural Infrastructure Projects and Programs








NORTHWEST BIOCARBON INITIATIVE

NWBiocarbon.org

Innovative Natural Infrastructure Projects and Programs

The Northwest boasts a variety of innovative natural infrastructure projects and programs that are addressing the three climate imperatives to:

1. Reduce the need for energy created by burning fossil fuels
2. Increase carbon storage in biological systems
3. Improve resilience in the face of climate impacts

We have gathered several examples of natural infrastructure projects that address these imperatives and grouped them as follows: cooling wastewater treatment plant water; absorbing rainwater; cleansing stormwater; protecting drinking water and recharging groundwater; using organic waste to build healthy soil; and reducing floods and restoring salmon habitat through watershed restoration.

ABSORBING WATER IN RAIN STORMS

Seattle Community-Wide Green Stormwater Project

Seattle Community-Wide 'Green Stormwater' Project establishes natural infrastructure strategies as a critical part of the city of Seattle's drainage system, setting a 2025 implementation goal of managing 700 million gallons of stormwater annually though rain gardens, roadside swales, green roofs, pervious pavement, stormwater cisterns, rainwater harvesting and reuse. Mayor Mike McGinn issued Executive Order 2013-01[1] on March 6, 2013 directing this significant shift in Seattle's approach to stormwater management. This goal, which is a six-fold increase over current practice, translates into managing 1,000 "greened gallons" per Seattle resident annually with natural drainage approaches by 2025.

This rain garden in Portland, OR treats storm water from adjacent development and right-of-way, filtering pollutants as well as slowing and reducing volume of stormwater flows.

Portland Bioretention Facilities are being constructed in the southeast part of the city in roughly 500 locations. These small, dispersed facilities are intended to reduce sewer backups that occur with heavy rainfall, increase overall sewer capacity, and improve watershed health by infiltrating runoff and adding vegetation. The facilities include flat-bottom planters and V-shaped swales in a variety of configurations adapted to space constraints. They typically have 18 inches of bioretention soil (compost/mineral soil blend) to provide water treatment and infiltration, and support plants through the wet and dry seasons. Portland's bioretention soil blend is about one-third compost with a sandy soil. To ensure rapid infiltration, the mix has very little silt and clay.

WATER COOLING FOR WASTEWATER TREATMENT PLANTS

Upper Tualatin River

Clean Water Services (CWS), a wastewater utility with over 500,000 customers in Washington County, Oregon, joined with an innovative nonprofit, the Willamette Partnership,[2] in 2003 to make an unorthodox, climate-smart infrastructure decision that saved the community approximately $100 million. Required to cool down water that CWS discharges into the Tualatin River, the standard solution would have been to build an energy-intensive water chiller. Instead CWS invested in restoring riverside habitat along some 35 miles of the river, which cooled the river's water as much as a chiller would have at a fraction of the cost. It got the job done less expensively with huge benefits for wildlife, landowners, and climate by saving energy and boosting biocarbon storage in vegetation and soils.[3] The more than 1.6 million native trees and shrubs that CWS planted will pull an estimated 135,000 tons of carbon dioxide pollution from the atmosphere in the next 100 years.

The City of Medford's $7 million project[4] in the Rogue River Basin of southern Oregon will restore nearly 30 miles of streamside habitat, infuse millions of dollars in the local economy, and plant thousands of native plants that will pull carbon pollution from the air for decades. A water trading system designed to cool down clean wastewater that enters rivers and streams will restore the Rogue River while also avoiding the need for an expensive new facility to cool the effluent. Local restoration projects managed by The Freshwater Trust[5] are rigorously measured and verified by a neutral third party and credits are serialized and registered on a public register that the wastewater treatment facility can then purchase to meet its regulatory requirements. The projects are monitored annually for 20 years to ensure performance. Benefits abound: Medford's wastewater treatment plant complies with the law with a price tag that is under half of what a typical hard engineering solution would have cost; lease payments go to the landowners to allow restoration on their land; riparian plants are planted; habitat for fish and wildlife is improved; stream banks are stabilized; runoff from agriculture is reduced; and carbon dioxide is removed from the air and stored in the soils and plants. A 2010 University of Oregon study found that for every $1 million spent on restoration projects of this kind, approximately 20 jobs are created, with 80 cents of every project dollar staying in the local county.[6] President Obama cited[7] this Freshwater Trust project in a speech on March 22, 2012 as an example of "the kinds of ideas we need in this country that preserve our environment, protect our bottom line, and connect more Americans to the great outdoors."

Restoration work on the Rogue River Basin

CLEANING UP WASTEWATER

Albany-Millersburg's Talking Gardens Project is a public works project[8] that cools treated wastewater before entering the Willamette River. Higher temperature waterways had led to declines in coldwater fish such as salmon and trout, which prompted Oregon regulators to mandate new limits on the temperature and pollutant load of wastewater that public and private entities can discharge into the Willamette River. The cities of Albany and Millersburg partnered with a major metals manufacturer, ATI Wah Chang, which was required to relocate its point of discharge, to build a combined wastewater treatment wetland.


Railroad Wetland waterfall - Albany-Millersburg's Talking Water Garden

The project is naturally aerating and treating water by reducing pollutant levels, including the removal of 2,000 pounds per day of nitrogen and 40 pounds per day of phosphorous; promoting wildlife habitat in a former industrial area; creating a living laboratory that brings wetland science to life for K-12 and university students; and creating a new natural attraction for Albany-area visitors that integrates the history of the site and the Willamette River.

The wetland vegetation, covering over 30 acres, along with one acre of riparian forest and five acres of oak savannah, will remove tons of carbon dioxide from the atmosphere annually and store the carbon in soil, sediments, and plants for many decades. Waterfalls designed into the Talking Gardens help curb the production of methane, a significant greenhouse gas that can be generated by wetlands as organic matter breaks down in the absence of oxygen, thus helping ensure the project is a net win for the climate.

Another important co-benefit of this combined wastewater treatment system is reducing the nutrients that are deposited to the Willamette River and Columbia River Estuary.

PROTECTING DRINKING WATER AND RECHARGING GROUNDWATER


McKenzie River

McKenzie Watershed supplies drinking water for approximately 200,000 people in Western Oregon via a public utility, the Eugene Water and Electric Board (EWEB). With McKenzie Watershed partners, EWEB is developing an innovative Voluntary Incentives Program (VIP)[9] designed to finance needed restoration and conservation of riparian areas to protect drinking water quality. The program will pay landowners to keep their land in healthy condition. EWEB grounded its program by commissioning in an economic baseline[10] that estimated the annual economic value of the McKenzie Watershed, finding that its ecosystems provide between $248 million and $2.4 billion in benefits to the regional economy annually. If treated as an asset with a lifespan of 100 years, the watershed's asset value ranges between $6 billion and $58 billion at a 4% discount rate. Under the VIP, owners of land within a stewardship boundary that spans 6,500 acres of land that is highly valuable for protecting drinking water will qualify to receive annual payments if they meet specific stewardship standards.

In May of 2011, the City of Portland partnered[11] with Portland Metro and the Trust for Public Land to purchase a 146-acre natural area property in southwest Portland from **River View Cemetery.** Portland Parks and Recreation will manage the site as a natural area, working with the community to develop trails and a habitat management plan that will include restoration of native plants and removal of invasives like English ivy and blackberry. The site was a high priority natural infrastructure investment to control stormwater under the City's Grey to Green Initiative, featuring intact headwaters, a densely forested area, 2.2 miles of streams, and a source of cold, clean water for the Willamette River. The purchase also fits within Portland Park's Natural Area Acquisition Strategy, which aims to protect a healthy connected system of natural areas within the city consisting of green ribbons along major waterways and large natural area parks and preserves—part of a larger system of connected natural areas linking the Cascade foothills and the Coast Range, from the Tualatin to the Columbia River. Metro's complementary Natural Areas Program[12] protects water quality, wildlife habitat and outdoor recreation opportunities for future generations. "Metro's Natural Areas Program empowers every community to protect nature close to home," said Metro Council President Tom Hughes. "It's exciting to work with the City of Portland on a project that affects the landscape so dramatically."[13]


The River View property

HARVESTING ORGANIC WASTE TO BUILD HEALTHY SOILS


Compost

The Washington Organic Recycling Council launched its Soils for Salmon project[14] in 1999 to help builders and developers preserve native soil on building sites and restore soils disturbed by construction by using compost. During construction projects, native biocarbon-rich soils that store carbon in billions of soil organisms are regularly stripped and compacted, which causes soil to erode and dramatically increases stormwater runoff that damages streams and properties that are downstream from the construction area. Soils for Salmon began a "Building Soil" campaign[15] to help builders get the specific information they need to successfully comply with the state's soil management requirements. Best practices incentivized by the state include retaining and protecting native topsoil and vegetation; restoring disturbed soils by stockpiling and reusing good quality site soil; tilling 2-3 inches of compost into poor soil, or bringing in 8 inches of compost-amended topsoil; loosening compacted subsoil; mulching landscape beds after planting; and protecting restored soils from heavy equipment that can re-compact.


Vegetated and grassy swale

High Point Redevelopment Project[16] in Seattle combined street-side bioretention swales with compost-amended soils over the entire site comprising 34 city blocks. Swales ranged from broad ditches to shallow grassy planting strips with a more conventional appearance. Residents and maintenance staff were educated about grasscycling, mulching and minimizing pesticide use to maintain long-term soil health and protect water quality. Bioretention soils typically contain one-quarter to one-third (by volume) mature, stable compost with a local sandy soil for rapid infiltration, pollutant removal and vigorous plant growth.

Kate Kurtz, Biosolids Project Manager for **King County Wastewater Treatment Division** (WTD) likes to say that King County's biosolids are "an endlessly renewable resource." This will be true as long as 1.4 million or so people served by the County's wastewater treatment system[17] eat food and contribute their waste via toilets to the system. Cleaning up this wastewater is an energy-intensive process, but WTD is about 70% of the way toward its goal of becoming a carbon-neutral wastewater utility. The utility harvests methane gas generated by its digesters for both electricity and heat. It returns the biosolids residuals, or "Loop"[18] as the County calls it, to the land—a carbon-rich soil amendment boasting a full suite of macro- and micro-nutrients that healthy plants need. The carbon benefits of Loop are three dimensional: enhancing the growth of trees and other plants that store carbon; reducing the need for synthetic fertilizers that are fossil fuel-intensive to produce; and increasing the storage of carbon in our soils.


Seedling sprouts in healthy soil

RESTORING WATERSHEDS TO REDUCE FLOODING AND HELP SALMON

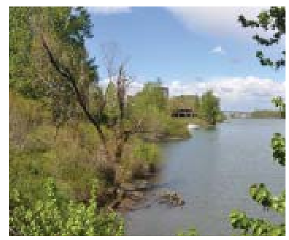
The **Whole Watershed Restoration Initiative** (WWRI) has reopened 466 miles of rivers and streams to salmon by restoring over 5,000 acres of natural habitat between 2008 and 2012, while generating significant family-wage jobs and undeniable biocarbon benefits. Several state and federal agencies pool restoration grant funds, and the Portland-based nonprofit Ecotrust[19] coordinates grants to local groups for on-the-ground restoration work. The idea is to achieve greater results faster by coordinating and concentrating the resources of multiple agencies. Restoration projects are job-creators—in construction, engineering, wildlife biology, and with a range of local businesses, from native plant nurseries to heavy equipment operators and rock and gravel quarries. An Ecotrust analysis found that natural infrastructure investments in 6,740 restoration projects across Oregon from 2001 to 2010 supported 4,600 to 6,400 jobs. Restoration work can't be outsourced—about 80% of the $411 million invested in these projects stayed within the county where the project took place, generating double the original investment in economic output.[20]


WWRI's Steve Dettman planting trees


Foster Floodplain Natural Area

For more than 70 years, various local, regional, state, and federal agencies have attempted to resolve recurring flooding problems in the Johnson Creek watershed, a 52-square-mile area linking the cities of Milwaukie, Portland, Gresham, and Happy Valley, as well as Clackamas and Multnomah Counties. In 2012, the City of Portland completed work to reclaim the **Foster Floodplain Natural Area,** restoring a 63-acre portion of Johnson Creek by transforming a flood-prone neighborhood into a beautiful natural area. Over 15 years, 60 families took advantage of the City's Willing Seller Acquisition Program,[21] which purchased land and helped move people out of the 100-year floodplain. In restoring the 63 acres of wetland and floodplain habitat, the City planted over 20,000 native trees, 70,000 native shrubs, nearly 5,000 wetland plants and 1,000 pounds of native grasses, forbs, and sedges.[22]









NORTHWEST BIO CARBON INITIATIVE

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Natural Infrastructure Paper

Cover: Visitors at Tanner Springs Park: Mike Houck

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4: A daylighted stream in Portland, OR connects an upstream forested wetland with a down stream rain garden and directs flow below the surface for groundwater recharge—City of Portland Bureau of Environmental Services
5: Urban stormwater as art—Mike Houck
6: A rain garden in Portland, OR treats storm water from adjacent development and right-of-way, helping to filter pollutants as well as slowing and reducing the volume of stormwater flows—City of Portland Bureau of Environmental Services
7: Natural Infrastructure stormwater solutions—City of Portland Bureau of Environmental Services
8: Tanner Creek Park from the Sitka, Portland, OR—Mike Houck
10: Soil scientist Katie Kurtz holding compost—King County Wastewater Treatment Division
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14: Erosion control training for builders in Washington—Washington State Building Soils program
15: Duwamish Urban Waters Partnership—Washington Department of Ecology
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Projects and Programs Supplement

Cover photos are taken from the list below:

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18: Upper Tualatin River—Clean Water Services
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20: McKenzie River—McKenzie Watershed Council
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20: Washington Organic Recycling Council—used with permission from SoilsforSalmon.org
21: Seedling sprouts in healthy soil—High Point Redevelopment Project—reprinted with permission from the Seattle Housing Authority
21: Vegetated and grassy swale—King County Wastewater Treatment Division
21: WWRI's Steve Detman planting trees—Sam Beebe, Ecotrust
21: Foster Floodplain Natural Area—City of Portland Bureau of Environmental Services
22: All photos by Mike Houck

Endnotes

Natural Infrastructure paper

[1]"400 PPM: What's Next for a Warming Planet," *Scientific American*, 9 May 2013. Web. <http://blogs.scientificamerican.com/observations/2013/05/09/400-ppm-carbon-dioxide-in-the-atmosphere-reaches-prehistoric-levels/>.

[2]"Does city living trim greenhouse gas emissions?" Sightline Daily, 14 Apr. 2009. Web. <http://daily.sightline.org/2009/04/14/does-city-living-trim-greenhouse-gas-emissions/>.

[3]"Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide," by Jeffrey Odefey, American Rivers, 12 Apr. 2012, <http://www.americanrivers.org/newsroom/blog/jodefey-20120412-green-in-the-bank-releasing.html>. See also: "Evaluating the energy consumed for water use in the United States," by Kelly T. Sanders and Michael E. Webber, IOP Science, Environmental Research Letters, Issue 3 (20 Sep. 2012) <http://iopscience.iop.org/1748-9326/7/3/034034>.

[4]*Portland's Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits*. Entrix, Inc., 2010.

[5]Green Stormwater Infrastructure Presentation, David Montgomery, December 2012, Slide 4 <http://www.ilsr.org/wp-content/uploads/2012/12/Green-Infrastructure-Soils-for-Salmon-for-Trash-Summit-Maryland-11-7-12.ppt>.

[6]"Green Infrastructure for Los Angeles: Addressing Urban Runoff and Water Supply through Low Impact Development," by Haan-Fawn Chau, 17 Apr. 2009. Web. <http://www.swrcb.ca.gov/water_issues/programs/climate/docs/resources/la_green_infrastructure.pdf>.

[7]A *Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds*, Stratus Consulting, 24 Aug. 2009 <http://www.michigan.gov/documents/dnr/TBL.AssessmentGreenVsTraditionalStormwaterMgt_293337_7.pdf>. See also: *Green City Clean Waters: the City of Philadelphia's Program for Combines Sewer Overflow Control Program Summary*, Amended 1 Jun. 2011, Philadelphia Water Department <http://www.phillywatersheds.org/doc/GCCW_AmendedJune2011_LOWRES-web.pdf>.

[8]"Urban Ecosystem Analysis for the Houston Gulf Coast, Calculating the Value of Nature," American Forests, December 2000. Web. <http://www.systemecology.com/4_Past_Projects/AF_Houston.pdf>.

[9]*Houston Green Urban Forest Effects Factsheet*, What is the Value of a Tree? Houston Area Urban Forestry Council, Web. <http://www.h-gac.com/community/qualityplaces/urbanforestry/publications/what_is_the_value_of_a_tree.pdf>.

[10]San Francisco Bay Area State of the Urban Forest Final Report, by J.R. Simpson and E.G. McPherson. Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station. 2007. <http://www.fs.fed.us/psw/programs/uesd/uep/products/2/psw_cufr719_SFBay.pdf>.

[11]"Atmospheric carbon dioxide reduction by Sacramento's urban forest" by E.G. McPherson, *Journal of Arboriculture*, 24(4): 215-223. 1998.

[12]"Recycled organics make splash in green infrastructure" by David McDonald, Shanti Colwell, and Henry Stevens, Climate Solutions Blog, 6 Feb, 2013. Web. <http://climatesolutions.org/cs-journal/recycled-organics-make-splash-in-green-infrastructure>.

[13]"Mycorrhizal Fungi-a big deal for biocarbon" by Wendy Peterman, 22 May 2013, Climate Solutions Web. <http://climatesolutions.org/cs-journal/gues-blog-mycorrhizal-fungi-a-biocarbon-big-deal>.

[14]Because 1 ton of carbon stored as biocarbon removes 3.67 tons of carbon dioxide, the carbon dioxide removed annually is about 82 million tonnes. For perspective, the State of Oregon's annual carbon dioxide emissions from fossil fuel burning (from all sources) in 2010 were about 40 million metric tons. <http://www.epa.gov/statelocalclimate/documents/pdf/CO2FFC_2010.pdf>.

[15]"Carbon storage and sequestration by trees in urban and community areas of the United States" by D.J. Nowak, E.J. Green, R.E. Hoehn, and E. Lapoint, 2013, *Environmental Pollution* 178: 229-236.

[16]"The Second Solution: Riparian Restoration—Clean Water Services," Solutions Story video, Climate Solutions. Web. <http://climatesolutions.org/programs/NBI/nbi-videos#green-infrastructure>.

[17]"Green Streets: Stormwater management for clean rivers" City of Portland Bureau of Environmental Services. Web. <http://www.portlandoregon.gov/bes/article/209685>.

[18]"Partners with Nature: Developing Scenarios for Ecosystem Services and Resilience in the Greater Portland Region," Brent Davies, Mike Mertens, Howard Silverman, Steve Dettman, Analisa Fenix, 15 Mar. 2012, Ecotrust. Web. <http://www.ecotrust.org/forests/Partners_with_Nature_3-23-12.pdf>.

[19]Houston Green Urban Forest Effects Factsheet, Houston Area Urban Forestry Council. Web. <http://www.h-gac.com/community/publications.aspx>. *What is the Value of a Tree?* Houston Area Urban Forestry Council <http://www.h-gac.com/community/qualityplaces/urbanforestry/publications/what_is_the_value_of_a_tree.pdf>. Urban Ecosystem Analysis for the Houston Gulf Coast Region, American Forests, 2000.

[20]*Chicago's Urban Forest Agenda*, City of Chicago, 2009. Web. <http://www.cityofchicago.org/city/en/progs/env/chicago_s_urban_forestagenda.html>. *The Value of Green Infrastructure*, Center for Neighborhood Technology, 2010. Web. <http://www.cnt.org/publications?issue=5>.

[21]Assessing Urban Forest Effects and Values: San Francisco's Urban Forest, by D.J. Nowak, R.E. Hoehn, D.E. Crane, J.C. Stevens, and J.T. Walton, USDA Forest Service, Northern Research Station Resources Bulletin NRS-8, 2007.

[22]"Atmospheric carbon dioxide reduction by Sacramento's urban forest" by E. G. McPherson, *Journal of Arboriculture*, 24(4): 215-223, 1998.

[23]"Our urban forest's carbon footprint," by Weston Brinkley and Lisa Ciecko, Climate Solutions blog, 23 May 2013, <http://climatesolutions.org/cs-journal/our-urban-forest2019s-carbon-footprint>.

[24]"Midwest community tree guide: benefits, costs, and strategic planting" McPherson, E. G., Simpson, J. R., Peper, P. J., Maco, S.E., Gardner, S. L., Cozad, S.K., Xiao, Q, USDA Forest Service General Technical Report, PSW-GTR-199, p. 16, 2006.

[25]"Performance of Green Roof Systems" by K. Liu and B. Bass. Toronto, Canada: National Research Council Canada, Report NO. NRCC-47705, 2005.

[26]"Adapting cities to climate change: The role of the green infrastructure" by Gill, S. E. Handley, J. F., Ennos, A. R. and Pauleit, S. Built Environment, vol 33 no 1, 2007.

[27]"Rare Invertebrates Colonizing Green Roofs in London," by Gyongyver Kada, Urban Habitats, December 2006. Web. <http://www.urbanhabitats.org/v04n01/invertebrates_full.html>.

[28]The Nature Conservancy Oceans and Coasts Restoration Work, <http://www.nature.org/ourinitiatives/habitats/oceanscoasts/howwework/nature-conservancy-coastal-restoration-work.xml>.

[29]Forthcoming paper: "Urban Green Infrastructure for Climate Benefit: Urban to Local," Nancy Rottle.

[30]"Restoring the Green-Duwamish Watershed: Conservation that Unites Urban and Rural Landscapes," The Urban Waters Federal Partnership <http://www.urbanwaters.gov/pdf/GreenDuwamishBackground.pdf>.

[31]"AB 32: Funding a greener, cleaner world while building jobs and a resilient, robust economy to boot" By Laurie Wayburn, Pacific Forest Trust, 29 Nov. 2012, Climate Solutions blog. Web. <http://climatesolutions.org/cs-journal/AB32>.

[32]Tabor to the River Program, City of Portland, Bureau of Environmental Services. Web. <http://www.portlandoregon.gov/bes/47591>.

Projects and Programs supplement

[1]City of Seattle Executive Order 2013-01 Citywide Green Stormwater Infrastructure Goal & Implementation Strategy, <http://www.seattle.gov/mayor/opengov/executiveorders/ExecOrder201301.pdf >.

[2]The Willamette Partnership, <http://willamettepartnership.org/>.

[3]The Second Solutions: Riparian Restoration, <http://climatesolutions.org/programs/NBI/urban-environment-stories-and-resources>.

[4]The City of Medford's Restoration Solution, <http://climatesolutions.org/cs-journal/the-city-of-medfords-restoration-solution>.

[5]The Freshwater Trust, <http://www.thefreshwatertrust.org/>.

[6]National Geographic, "Watershed Restoration, the New Job Growth Sector," Cathy P. Kellon, Ecotrust, September 26, 2013. <http://newswatch.nationalgeographic.com/2012/09/26/watershed-restoration-the-new-job-growth-sector/>.

[7]White House Conservation Conference, Washington, DC, 22 Mar 2012. Web. <http://www.youtube.com/watch?v=3I9btR-0YSU>.

[8]Cities of Albany-Millersburg Talking Water Garden, The Benefits of the Talking Water Garden, <http://twg.cityofalbany.net/benefits/>.

[9]Eugene Water and Electric Board's Voluntary Incentives Program, <http://www.eweb.org/sourceprotection/vip>.

[10]Earth Economics, Valuing the McKenzie Watershed, <http://www.eartheconomics.org/FileLibrary/file/21st%20Century%20Utility/EWEB%20factsheet_web.pdf>.

[11]Metro News, May 4, 2011, City of Portland, Metro Team Up to Protect River View Forest as Natural Area, <http://news.oregonmetro.gov/1/post.cfm/city-of-portland-metro-team-up-to-protect-river-view-forest-as-natural-area>.

[12]Metro, Natural Areas, Parks, and Trails, <http://www.oregonmetro.gov/index.cfm/go/by.web/id/24253>.

[13]City of Portland, Bureau of Environmental Services, "City to Purchase River View Forest," May 2, 2011, <http://www.portlandoregon.gov/bes/article/347614>.

[14]Soils for Salmon, <http://www.soilsforsalmon.org/>.

[15]Building Soil, <http://www.buildingsoil.org/index.htm>.

[16]City of Seattle High Point Redevelopment, <http://www.seattlehousing.org/redevelopment/high-point/>.

[17]King County Wastewater Treatment, <http://www.kingcounty.gov/environment/wtd.aspx>.

[18]King County Wastewater Treatment—Loop, <http://www.loopforyoursoil.com/>.

[19]Ecotrust <http://www.ecotrust.org/>.

[20]Ecotrust, Whole Watershed Restoration Initiative, <http://www.ecotrust.org/wwri/>.

[21]City of Portland, Bureau of Environmental Services, Willing Seller Program, <http://www.portlandoregon.gov/bes/article/106234>.

[22]City of Portland, Bureau of Environmental Services, Natural Area Information, <http://www.portlandoregon.gov/bes/article/286175>.

NOTES

Tanner Springs Park, Portland, OR. Photo by Mike Houck

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