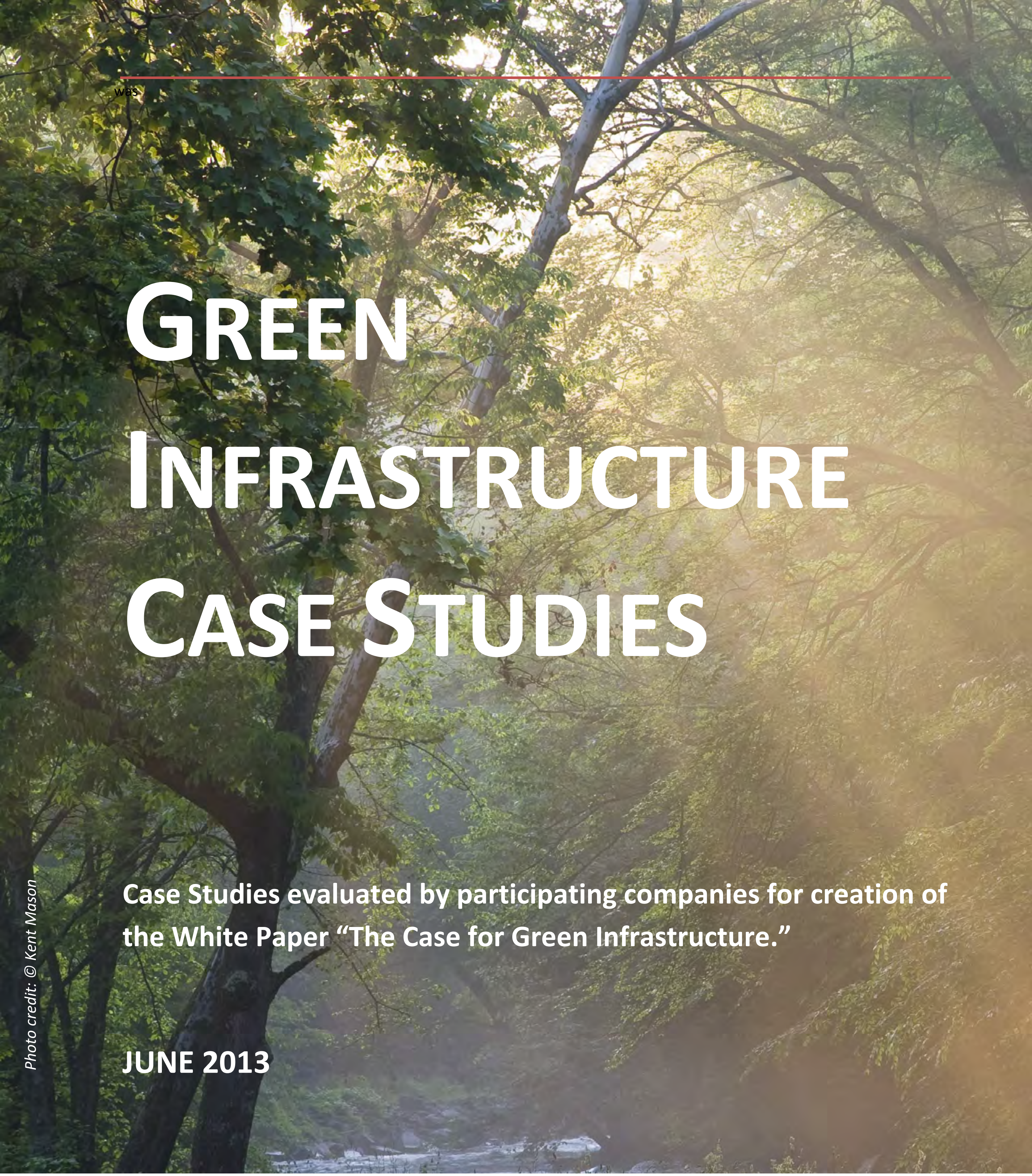
was



GREEN INFRASTRUCTURE CASE STUDIES

Case Studies evaluated by participating companies for creation of the White Paper "The Case for Green Infrastructure."

JUNE 2013

Photo credit: © Kent Mason

Dow · Swiss Re · Shell · Unilever · The Nature Conservancy — Protecting nature. Preserving life.

TABLE OF CONTENTS:

DOW: PHYTOREMEDIATION FOR GROUNDWATER DECONTAMINATION

Source/Organization: The Dow Chemical Company

Scale: Large –Dow Sarnia installation is roughly 2 acres with 1,300 trees within the fence line of the chemical complex site which is no longer in operation

Key stakeholder(s): Dow/Regulatory body

Project Phase: Fully implemented for 2 yrs

Geographical Location: Sarnia, Ontario, Canada

Sarnia Site, The Dow Chemical Company

PROJECT OVERVIEW

Phytoremediation is the engineered use of green plants to remove, contain, stabilize or destroy contaminants in the soil and groundwater. The uptake of groundwater by the plants can achieve containment of the groundwater and contamination (tree is basically acting as a solar pump). Engineered planted systems can degrade, extract and control the groundwater contamination. Dow has several field pilot demonstration projects in place and fully operational projects using phytoremediation to draw experience from.

One specific installation was completed at the Dow Sarnia facility. This large industrial complex contained several manufacturing units that operated for more than 60 years. The effort in ceasing operations included transitioning the existing traditional pump and treat groundwater treatment system. The traditional system consisted of pumping groundwater via carbon beds prior to transferring the recovered groundwater to an external water treatment facility.

The goal of phytoremediation was to replace this existing groundwater recovery and treatment system with a cost-effective, passive remediation system that fully complied with environmental requirements while minimizing the long-term cost of managing the site.

While still operating the pump and treat facility, the site was prepared by minimizing external infiltration and planting 1,300 trees (poplar and willows) on an area of roughly 2 acres to handle the uptake of the groundwater. As the trees grow along with site hydrology adaptation, some of the water still needs to be pumped and treated during this transition period. This technology does require on-going site maintenance such as sampling and analysis of ground water, hydrology testing to ensure ground water is contained, and tree management over the life of the project.

TECHNOLOGY MATURITY

Mature; a minimum of 4 growing seasons is necessary to prove the capability of the system. On-going pilot studies since 2005; Dow has over 15 sites in operation as pilots or full scale systems.

Investment/Costs/Time

- Although the initial project cost & short term maintenance costs for phytoremediation are significant, the NPV of the project is positive over the long term timeline associated with this type of project.

Project Management Considerations

- Use of this technology depends on site characteristics, source and extent of contamination.
- Best to have pilot study since this technology is highly dependent on site specific conditions and still considered a novel approach.
- Minimization of long term cost while meeting Dow and government regulations.
- Champion played an instrumental role in making this project a reality.
- Project selection criteria: capital expenditures/ ease of implementation/ease of operation/ carbon footprint.
- Maximize chance of success by partnering with a consultant holding key expertise.
- Technology requires significant time to be fully operational; can be considered for non-time critical remediation projects.
- If a regulatory body is involved, need a strong and mutually respectful relationship with regulators to implement green infrastructure.
- A different technical skill set is needed to be successful with green infrastructure projects.
- Long term project requiring multi-generational oversight.

Benefits

- No wastewater needing to be transported off site in trucks.
- No electricity required.
- Elimination of the carbon filtration system and expense related to its operation and disposal of spent carbon.
- No need for 24/7 hour operation (from an operation to a management activity).
- Significant reduction in maintenance costs compared to pump and treat.

Risks/Challenges

- Higher level of uncertainty at the onset of the project since dealing with a biological system, local geology, contaminants, site hydrology.
- Larger physical footprint than the gray alternative.
- Requires a period of growth to come to full operation.
- Try to limit interaction with biota since concerns with creating a wildlife habitat within a remediation site.
- Different set of challenges to deal with requiring different set of skills such as dealing with main disturbance (e.g. rabbits eating tree bark).
- Ensure that tight feedback and monitoring system in place to alleviate any environmental concern (e.g. leaves/pollen off the trees).

Resiliency Aspects

- Resilience is dependent on specific application, perspective and boundaries of project (How far upstream and downstream in process do you include? "Green" and "Gray" both resist shocks, but in different ways. Gray infrastructure can be more resilient in the face of an acute stress if that stress can specifically destroy the trees; it can be rebuilt and operational in a shorter time frame. "Green" may be more robust in response to certain stresses such as power loss and mechanical failure.
- Phytoremediation is multifunctional: can meet the needs of a traditional pump and treat system
- Criticality – if a quick solution has to be found – gray is the obvious choice. Green Infrastructure (phytoremediation) is a longer-term option because trees take time to grow.
- Innovation – working with variety of key research bodies to increase the number of tree species being used and tested for phytoremediation potential; recognizing a higher resiliency in having variety of plant species.
- Modular: easy to increase capacity but still needs time to grow.
- Higher level of remediation likely over the long haul since root systems can reach everywhere – not limited to system design as in the traditional gray system.
- Traditional remediation solutions are more replicable and less site dependent.

Key Learning

- The gray solution appears easier to control and manage but the long-term economic and environmental benefits of the green solution makes phytoremediation a technology that needs to be added to the portfolio of solutions when dealing with groundwater contamination.

Dow: Constructed Wetland for Waste Water Treatment

Source/Organization: Union Carbide Corporation, subsidiary of The Dow Chemical Company

Scale: Large –110 acres within the fence line of Union Carbide Corporation's Seadrift Operations

Key stakeholder(s): Union Carbide Corporation; The Dow Chemical Company; Regulatory body (TCEQ: Texas Commission on Environmental Quality); Dow "Near neighbors" Community

Project Phase: Fully operational (in operation for 15 years)

Geographical Location: North Seadrift, Texas, USA

Project Overview

Seadrift is a large industrial complex containing several manufacturing units involved in the production of plastic resins and other organic chemicals. Waste water from the facility and storm water captured in containment areas are routed through the wastewater treatment system. The original water treatment system consisted of primary/secondary (anaerobic/aerobic biological) treatment ponds and a shallow tertiary pond which is approximately 267 acres with water depth ranging from 1 to 4 feet. The tertiary pond is basically operated as a solar stabilization pond (no active mixing). Lower organic loads and long detention time within the aerobic section and tertiary pond resulted in ideal conditions for phytoplankton (floating algae bloom). This resulted in exceedance of the plant's discharge permit criteria (40 mg/l) for total suspended solids (TSS) and required extensive pH adjustments. This project was driven by the necessity to meet EPA Effluent Guidelines for OCPSF (organic chemicals, plastics and synthetic fibers; 40 CFR 414) facilities with regards to TSS.

Several alternative treatment options were investigated. A pilot-scale constructed wetland project was successfully completed on-site (roughly one year of data prior to launching the full scale project). The conversion of part of the tertiary pond into a constructed wetland was implemented in roughly 18 months and has been in full operation since then, meeting all discharge requirements for TSS, eliminating the algal bloom issues and additionally eliminating the need to adjust discharge pH (previously done around the clock).

Technology Maturity

Fully proven.

Investment/Costs/Time

- 1-2 years pilot study; small constructed wetland in operation in a sister plant in Mexico City.
- Fully operational 18 months after the contract was awarded.
- Initial capital investment $1.2 - 1.4 Million with maintenance/operation costs dramatically reduced.

Project Management Considerations

- Driver: reduce operational and maintenance cost while ensuring long-term compliance with EPA effluent guidelines (OCPSF).
- Upper management champion played an instrumental role in making this project a reality; data speaks for itself, therefore pilot study a good approach ("selling a swamp is not an easy task").
- Project selection criteria: capital expenditures/time to install/ease of implementation/ease of operation.

Benefits

- 100% compliant from day zero for over 15 years while eliminating the need to adjust pH.
- Low initial and operational capital required ($1.2 to 1.4 million as opposed to $40 million for gray alternative).
- Low energy and resource requirements with the corresponding environmental benefits – minimal equipment, no pumps, no additives, no oxygen system, no added water, no bio solids to handle or dispose.
- Operational support drastically different as a wetland requires minimal support from operations and maintenance, while the gray alternative requires 24/7 support.
- Construction and implementation time reduced.
- Co-benefits identified but not valued: positive impact on ecosystem (provides habitat for wildlife/educational opportunity and other soft benefits to Dow personnel and local community).

Risks/Challenges

- Potential new regulations (such as coliform bacteria).
- Criteria for application of this technology: compliance with applicable regulations, water quality, salinity and large physical footprint (this system would require 50 acres as opposed to 4 to 5 acres for gray alternative).
- Biotic stresses (nutria/alligators/bobcats, etc.) are the main disturbances that the system has to manage.
- There is always the potential risk that a threatened or endangered species might be found in the wetland. In the case of Seadrift, this is unlikely as none of the 46 threatened or endangered species listed by the State of Texas in the vicinity of the constructed wetland would be expected to occupy this habitat.

Resiliency Aspects

- Self- organizing process – the wetland does not look like what was built. Now a diversified biota from plants to micro-organisms increasing the built-in stability of the mini-ecosystem to respond to fluctuations. Biodiversity is much greater in the constructed wetland than the microbiology found in conventional waste water treatment plants.

- Innovation: looking to recycle the water to attain zero discharge.
- Building understanding and management practices of ecosystems dynamics (learn to switch from operate to manage mode and to leave it alone).

Key Learning

- A win in all aspects (no waste; no energy; no 24/7 operation; no landfill; safer; meets permit 100% of time at a fraction of the cost).
- Must expand the project boundaries to fully account for all benefits such as ecosystem services (life cycle costing).
- Green infrastructure projects require different technical skills than the traditional gray alternative
- Since green infrastructure solutions were not widely accepted when this was adopted, it required someone with passion to really drive and support the project. Upper management buy-in was a must.
- Need to have data to support a green infrastructure – this may point to needing more pilot-scale work in the general area of green infrastructure.
- The proper assessment of the “full value” of the green infrastructure may help in the alternative assessment process and push green infrastructure project over gray ones.

Dow/TNC: Air Pollution Mitigation via Reforestation

Source/Organization: The Dow Chemical Company and The Nature Conservancy

Scale: Local, regional

Key stakeholder(s): Dow plant management, Environmental Protection Agency (EPA), Texas Commission on Environmental Quality (TCEQ), conservation community

Project Phase: Research and evaluation stage

Geographical Location: Houston-Galveston-Brazoria (HGB) area near Dow's Freeport Texas Operations

The Nature Conservancy

Project Overview

This project will produce a methodology for the use of reforestation for air quality maintenance or enhancement instead of, or in addition to, reducing emissions through end-of-pipe control technology or changes in operations. Forests could be part of the solution by modifying the environment and removing pollutants from the air.

Dow Texas Operations is located in the U.S. Environmental Protection Agency (EPA)-designated Houston-Galveston-Brazoria (HGB) non-attainment area for ground-level ozone. The HGB region has been in violation of National Ambient Air Quality Standards (NAAQS) for ozone since the establishment of those standards in 1979. The HGB area failed to meet the revised 1997 NAAQS for ozone by the 2007 deadline, which has resulted in the mandatory imposition of Clean Air Act (CAA) penalty fees ($5,000/ton) on all large sources in the HGB area that exceed their allowed emission limits.

Technology Maturity

Early: research and pilot stage.

Investment/Costs/Time

- 2-4 years pilot study.
- Reforestation and other costs TBD.

Project Management Considerations

- Identify suitable planting sites and tree species that also yield conservation benefits
- Estimate removal of ozone and NO2 by the reforestation project to estimate total NOx credits the project could claim under the SIP.

- Estimate the cost-effectiveness of the proposed green infrastructure solution (reforestation for NOx control) to allow for comparison with alternative gray control methods. The analysis estimated NOx abatement by a hypothetical planted forest, and found it was cost-competitive with the evaluated next round of "gray" technology options that might be deployed should further NOx controls be needed.
- Identify and estimate the value of additional benefits green infrastructure options offer
- Need to get reforestation approved as an ozone precursor control strategy in ozone State Implementation Plan (SIP) (for the HGB area in this case).
- Work with appropriate federal and state regulators to increase likelihood of acceptance of and then ensure compliance with the proposed methodology.

Benefits

Anticipated:

- Reduced costs of additional ozone precursor abatement, if additional control efforts are deemed necessary to achieve compliance with National Ambient Air Quality Standards for ozone.
- Improved public services such as recreational opportunities for local residents and visitors and habitat for rare species.
- Air quality improvements which could lead to improved human and environmental health such as:
    - Carbon sequestration by the forest helps mitigates greenhouse gas emissions contributing to efforts to manage atmospheric concentrations of carbon and possibly creating value from pollution offsets or credits.
    - Reduced ground-level ozone formation (a smog-related pollutant) by mediating the urban heat island effect, leading to reduced energy use for space cooling, resulting in reduced pollutant emissions from power plants.

Risks/Challenges

- Reforestation still needs to be approved by agencies as a strategy for air quality compliance. This requires that emission reductions be quantifiable, additional, enforceable and permanent. This requires verification of approaches, validation of the complex models involved and a thorough risk assessment analysis.
- Trees naturally emit volatile organic compounds (VOCs), which may lead to increased formation of ozone. This can be avoided if reforestation projects are sited in areas where ozone formation is NOx-limited.
- Emissions from tree maintenance activities can also contribute to air pollution, so reforestation projects must be planned to minimize maintenance needs. This is achieved by designing such projects to be self-sustaining early on, using ecologically appropriate species, and planting forests rather than street or neighborhood trees.
- If ex-post verification of estimated pollution removal reveals that actual removal is less than originally estimated, offset quantities would be reduced and the cost-effectiveness of reforestation as a control strategy would be less than originally estimated, and possibly may fall below that of conventional control approaches.

Resiliency Aspects

- Adding another option to the solution set increases flexibility while potentially reducing marginal costs.
- Stronger collaboration links with regulators increase social and governmental participation and thereby societal resiliency.
- Forests damaged by extreme weather events or fire require more time to replace than gray solutions.
- Gray solutions are susceptible to events such as power loss and mechanical failure.

Key Learning

- This proposal deals with a novel GI solution requiring by testing and by in from a multitude of stakeholders and will therefore require a long period of study.
- Early stage – to be determined later in pilot, implementation, integration phases.
- Using reforestation for ozone abatement has broad relevance: a high share of the total area of ozone non-attainment and maintenance in the US is NOx-limited and thus may be suitable for ozone removal through reforestation.

SHELL: PRODUCED WATER TREATMENT USING REED BEDS

Source/Organization: Petroleum Development Oman LLC (PDO): joint venture with The Shell Petroleum Company Ltd and the Government of Oman (majority)

Scale: Large – world's largest commercial wetland covering more than 360 ha and treats more than 95,000 m^3 of produced water per day

Key stakeholder(s): Government of Oman , BAUER Nimr LLC, Oman (a subsidiary of BAUER Resources GmbH in Germany).

Project Phase: The plant came online in late 2010.

Geographical Location: Nimr, Oman (Nimr is located inland in South West Oman)

PROJECT OVERVIEW

At the PDO Nimr oil fields, a tenth of the total production is crude oil. The remaining production, around 330,000 m³ per day, is water that is brought to the surface together with the oil. This water used to be disposed of by injection into a deep disposal well. To reduce the high costs of treating and re-injecting the produced water, PDO together with BAUER, developed a project proposal that would reduce or eliminate the power consumption and CO_2 emissions associated with the operation of equipment for deep well disposal. The solution was a four-tier gravity-based wetland design.

As gravity pulls the water downhill, the reeds act as filters, removing oil from the water. The oil is eaten by microbes that naturally feed on hydrocarbons underground. Locally grown Phragmites Australis plants are used for the purification of produced water. The composition of the produced water from the Nimr oilfield is brackish; with total dissolved solids (TDS) ranging between 7,000 mg/l and 8,000 mg/l, and the oil in water content varies between 100 to 500 mg/l. The plant layout includes a pipeline, which enters the NWTP system and leads to an oil/water separator. The water is then distributed into a wetland facility where it is channeled through four wetland terraces by gravity feed. Finally, evaporation ponds are used to recover the salt while the biomass is land filled. Alternative uses of the water and biomass that could offer a variety of environmental and socio-political benefits are being explored.

The constructed wetland is designed to treat 95,000 m³ per day (30% of the daily volume of water produced by the oilfield). The facility was constructed under a build-own-operate contract and as such, BAUER designed and built the facility and is now operating it for a 20-year period.

As with every effluent treatment plant, the subsoil must be properly sealed. In selecting suitable sealants, synthetic materials were rejected in favor of a natural product. The surrounding desert areas were searched for suitable clay until an appropriate sealant mixture was found.

A pilot study was used to evaluate and optimize reed bed efficiency. The reed beds have proven to be capable of efficiently, and cost effectively, handling the treatment of the produced water from the Nimr oilfields.

Technology Maturity

Proven; fully operational since late 2010.

Investment/Costs/Time

- The project required a pilot study of more than 2 years.
- The wetland was fully operational 2 years after the contract was awarded.

Project Management Considerations

- Project selection criteria: capital and operational cost reductions, lowering the carbon footprint.
- Construction time of the wetland was roughly half of the traditional, gray infrastructure.
- Pilot studies involved recording and determining temperature, evaporation and evapo-transpiration rates as these can highly influence the performance of the constructed wetland.
- Pilot studies also investigated throughput parameters like retention time and hydraulic load for winter and summer seasons.

Benefits

- Significant capital cost savings compared to the man-made produced water treatment and injection facility.
- The gravity-based wetland design requires close to zero energy for water treatment, thus reducing power consumption by approximately 98% (for the 30vol% of water treatment) due to the elimination of electric powered water treatment and injection equipment. Also, the new facility enables an additional crude oil recovery of 200 barrels per day.
- Satisfactory water treatment performance ever since the start of the wetland operation (December 2010). The oil content in the produced water is consistently reduced from 400 mg/l to less than 0.5 mg/l when leaving the wetland system.
- CO_2 emissions reduced by approximately 98% (for the 30vol% of water treatment) due to the elimination of electric powered water treatment and injection equipment.
- The wetlands provide habitat for fish and hundreds of species of migratory birds. Also, the wetlands offer potential for innovative customer value propositions that could provide a variety of socio-political benefits e.g. through by-product optimization (fresh water, biomass etc.).

Risks/Challenges

- Large required land footprint: more than 360 ha to treat 95,000 m^3/d of produced water
- Long pilot period (>2 years) required to de-risk the constructed wetland technology and find the optimum wetland design.
- Operational risk of the wetland: potential risk of not meeting the performance requirements due to external factors (e.g. seasonal temperature swings, biotic stresses).

Resiliency Aspects

- This system is modular and the capacity can be increased stepwise.
- Potential for achieving improved system resiliency by increasing biodiversity (using various types of reeds).
- The facility makes use of feedback loops for monitoring the health and efficacy of the wetland system.

Key Learning

- Climate data and local soil conditions are essential design parameters.
- A champion was required to push this project even with positive results from the pilot study.
- It's important to involve other key stakeholders in the project (e.g. universities).
- It's recommended to use a non-biased project evaluation process to select the best available solution.

SHELL: NATURAL RECLAMATION AND EROSION CONTROL FOR ONSHORE PIPELINES

Source/Organization: Shell Canada Limited

Scale: Large; several reclamation plots are located in the Deep Basin Ojay Project site. The Ojay pipeline has 8 reclamation research sites each approximately 20 meters wide by 100 meters long.

Key stakeholder(s): British Columbia government (Oil and Gas Commission), First Nation communities, ReClaimit Ltd (execution contractor)

Project Phase: Fully implemented, has been operational for 3 years; optimization studies on-going

Geographical Location: NE British Columbia, Canada

PROJECT OVERVIEW

Shell's projects often involve the construction of pipeline corridors in ecologically diverse areas on previously undeveloped lands called "Greenfield" development. The pipeline is routed along what is known as a "right of way."

When building a pipeline, the construction activities not only cover the civil works to lay the pipeline and build the pump/compressor stations, but also the reclamation work to return disturbed land to an equivalent land capability with minimal impact on the environment. There is heightened recognition and popularity of natural reclamation and soil erosion abatement techniques as these ancient techniques address the shortfalls related to man-made pipeline protection techniques, particularly in terms of reduced installation and maintenance costs.

The technique of using living plant materials to create structures that perform some soil related engineering function is referred to as soil "bioengineering." Often, soil bioengineering is used to treat sites where surface stability and erosion problems exist. Bioengineering solutions can be applied to a wide variety of sites disturbed by construction activities. These solutions use natural components of pioneering plant communities and thus align well with ecological restoration strategies.

It is preferred to use local plant species to construct soil bioengineering solutions for naturally disturbed sites. Some recent innovations in reclamation approaches include the use of Willows and other tree/shrub/plant species to control soil erosion and establish a re-naturalization path. In the past 15 years, Shell has proven success in Willow staking in several upstream projects. Poplars and Willows are highly valued for erosion control and efficient control of groundwater due to their rapid growth, high rooting capacity, extensive root systems and high water use.

Shell continues to investigate different reclamation methods, using direct seeding, nursery stock grown from native seed and possibly peat pucks (seed with nutrients), to better understand the feasibility of the technology as well as the costs and time involved in growing such solutions.

Pipeline projects involve many stakeholders with specific interests and concerns. The pipeline right of way often traverses lands with rights of use belonging to multiple indigenous communities. The indigenous communities are often concerned with the fragmentation of the land and its impacts on the local ecosystem. Therefore, all solutions are strictly reviewed with these local concerns in mind.

Technology Maturity

Proven, with improvements being developed.

Investment/Costs/Time

- Natural reclamation techniques have the added benefit of being significantly lower costs than concrete and metal piling methods.
- Timelines for implementation generally fit very well with the overall project timeline as pipeline construction and tree planting share a common seasonal criteria and the activities can therefore be executed within the same timeframe.

Project Management Considerations

- Natural reclamation does not provide a broad base solution, i.e. it is only applicable to certain sites.
- Project teams need to be willing to assess such alternative approaches.
- Natural reclamation solutions require different skill sets (horticulture, biology).
- Joining forces with external experts is critical for the success of these pilot studies.
- It is important to build relationships with all key stakeholders early on in the project.
- It is important to identify and mitigate local environmental risks (e.g., care was taken to maintain moose habitat in the harvested areas by leaving clumps of Willows standing).
- Timing is key for success of this solution (e.g. when to cut and plant Willows).
- It is important to secure manual labor for large scale projects.
- Reclamation is often a compliance-driven sustainability effort.

Benefits

- Lower overall environmental impact, potentially including CO_2 offsets.
- Solutions are known to be superior overtime compared to the more traditional stabilization methods.
- Hands on work can be structured as a team building/educational activity for Shell employees
- Job creation for local labor.
- The solution can be designed to be sensitive to the local environment (e.g. allow access to local wildlife).
- These green solutions do not require regular maintenance as compared to gray solutions that often require mechanical intervention, e.g. for the excavation of existing banks or transport of materials.
- Low operating and maintenance cost.

Risks/Challenges

- Not a one-stop solution, but very much site specific (dependent on soil types, moisture level, light, etc.).
- Requires a different skill set for the design and implementation phase.
- Time constraints: any project would need to be started as early in the winter as possible.
- Survivability of the planting sites is an important requirement to establish long-term success.

Resiliency Aspects

- The green solution self-repairs and improves performance over time as opposed to gray solutions that depreciate over time and require maintenance.
- Solutions are modular; it is easy to select the required planting density along the pipeline corridor.
- Solutions are multi-functional: they reduce loss and fragmentation of wildlife habitat, reduce soil compaction and improve land capability and productivity in agricultural, prairie and forested areas
- These types of natural re-vegetation systems reduce anthropogenic disturbances to local ecosystems.

Key Learning

- The Environmental agencies are very focused on achieving sustainable outcomes and are typically sympathetic to soft engineering solutions.

SHELL/TNC: COASTAL PIPLINE EROSION CONTROL USING OYSTER REEFS

SOURCE/ORGANIZATION: Shell Pipeline Company LP

Scale: Approximately one mile of shoreline in total, the pilot project will be designed with the intention to be replicated at other similar sites

Key partner(s): Shell Global Solutions International, The Nature Conservancy

Project Phase: Feasibility study on-going; final decision to proceed or not will be taken mid 2013, pending approval/acceptance of the design

Geographical Location: Ship Shoal, Louisiana, USA

PROJECT OVERVIEW

Attenuation of soil and marshland erosion around oil and gas pipelines located on or near shorelines is a chronic concern for Shell and other commercial operators in the Gulf of Mexico. Erosion is caused by waves from marine traffic, tidal currents, and acute weather events like hurricanes. Maintaining these pipelines currently requires an intensive and expensive monitoring and maintenance system. The traditional gray approach uses hardened structures that armor and stabilize the shoreline; rock reinforcement, wood and metal structures, sand or cement bags to slow erosion, particularly in high energy environments.

The main drawbacks of this existing system from the company's perspective are the costs and risks related to maintenance activities taking place around these hardened man-made structures. There is the ongoing risk of pipeline damages related to frequent boat traffic, as well as the loss of intertidal habitat.

To lower these costs and the overall risks to the pipeline, Shell and The Nature Conservancy have been exploring shoreline erosion control methods using natural infrastructure to further attenuate erosion from waves. The final project may encompass a hybrid solution using a combination of green and gray infrastructure.

TECHNOLOGY MATURITY

There is empirical evidence that supports that green infrastructure can be an effective measure against shoreline erosion and wave energy. The innovation lies in applying the concept of green infrastructure to more effectively protect pipelines from coastal erosion while offering multiple environmental and social benefits.

Investment/Costs/Time

A primary objective of this pilot project is to better understand the relative costs of using these methods and test the hypotheses that natural infrastructure is more cost effective than made-made infrastructure. Historically, green infrastructure installations, such as oyster reef breakwaters have cost approximately $1 million per mile versus $1.5-3 million per mile to install traditional gray rock barriers, though this is highly variable. GI solutions are expected to require lower initial capital costs and lower maintenance costs due to being inherently self-sustaining.

Project Management Considerations

The approach taken thus far has been to hold workshops and meetings to design this project as a joint effort between Shell Global Solutions International, Shell Pipeline Company LP and experts from The Nature Conservancy. The team organized a field visit and gathered location-specific data as part of the bid process to generate conceptual proposals for the Ship Shoal pipeline. Due to the importance of pipeline integrity, an internal risk analysis will be performed on the proposed solutions.

Selection criteria for the proposals are: installation/maintenance cost savings, efficiency in sediment accumulation for stabilization, innovative edge and the delivery of ecosystem services.

Benefits

- Creates a natural buffer to protect the shoreline and pipeline from erosion.
- Can preserve and/or create habitat for benthic, estuarine, shallow water, and intertidal organisms.
- Increases stability for pipelines.
- Improves local water quality.
- Lowers installation and maintenance costs compared to gray solutions.
- Offers potential for local job creation.
- Creates land behind the natural defenses (open water to marsh; marsh to land).
- Has potential for self-repairing (fixes cracks developed from potential storm) and self-organizing structure (oyster bed builds up with sea level rise).

Risks/Challenges

- It is important to understand the business case (green vs. gray).
- Shell's comfort level with long-term liability issues (public access to a newly created oyster bed is a concern).
- GI solutions will need to comply with company and industry standards and requirements.
- These novel approaches require receptiveness of both internal and external stakeholders.
- There may be a need to train new contractors who may not be familiar with designing and installing natural infrastructure.
- The greatest concern may be related to social stresses such as pressure from oyster fisherman who could harvest and potentially inhibit natural growth and effectiveness.

Resiliency Aspects

- GI solutions have the dynamic capacity to repair themselves and adapt to evolving chronic and acute stressors. For example, in response to rising water levels due to climate change, an oyster reef will grow to match the new water levels, unlike any gray infrastructure.
- GI solutions offer multi-functional benefits, such as oyster beds providing erosion control and other ecosystem services.

Key Learning

- The keys to success for these kinds of methods will be finding the appropriate project scale, managing any regulatory constraints, proving long-term benefits, proving effectiveness at sediment accumulation and wave attenuation thereby protecting the pipeline, and creating a replicable product and process.
- A successful pilot should resolve most of the institutional, regulatory and financial concerns.
- Key anticipated learnings relate to testing the hypotheses that green infrastructure can be a superior alternative to gray infrastructure in protecting pipelines in the Gulf of Mexico, and better understanding under what circumstances green infrastructure and/or a hybrid combination of green/gray infrastructure is a cost effective investment.

TNC: Cauca Valley Water Fund

Green infrastructure type: Water treatment using forest and land management

Source/Organization: The Nature Conservancy

Scale: Seven small watersheds

Key stakeholder(s): The water fund is overseen by the Cauca Valley's sugar cane producers association (ASOCANA), sugar cane growers association (PROCANA), each watershed's local environmental authority, Vallenpaz (a peace and justice organization) and The Nature Conservancy.

Project Phase: Established in 2009, projects and investments are underway

Geographical Location: Regional around Cali, Colombia; mostly Valle del Cauca Department

Project Overview

The East Cauca Valley Water Fund is one of the more recently established water funds in Latin America. Water Funds are a financial vehicle developed at TNC, where main water users put resources into the fund and then the fund chooses projects to invest directly in the watershed.

The funds focus on investing in three types of services: water quality, sediment retention, water quantity. Typical investments include: changing land use or intensity (such as less intensive agriculture and ranching); fencing, creating silvopastoral systems, forest enrichment and restoration, enhancing protected areas; land acquisitions; and restoring riparian areas, slopes, and corridors for biodiversity. (Ramos 2012)

A recent ecosystem services analysis of the Bogota Water Fund determined that ranching and agricultural lands produce 10% more sediments than areas under conservation. That sediment increase requires approximately $4 to 5 million in additional water treatment costs downstream for end users.

The East Cauca Valley Water Fund was established around the private sector as sugar cane producers and growers in the region entered into a voluntary payment scheme to finance green projects across seven watersheds. Based in the Valle region of Colombia, the fund establishes a payment for ecosystem services for the growers based on hectares and tons of sugar cane produced. The cane growers were motivated to invest by research predicting that, without direct intervention, within 10 years they would be forced to reduce their irrigation cycles from 5 to 4, potentially losing US $33 million per year. So far, the primary investments by the Fund have been in changing land use or intensity; fencing, silvopastoral systems, forest enrichment and restoration.

The gray alternatives to the kinds of projects supported by these water funds include: building more dams (water quantity), treatment plants (water quality) or new pipelines for water supply from other watersheds.

Technology Maturity

Science papers show that investments in watersheds improve water quality and sediment retention and improve or maintain base flows. Furthermore, the financial mechanism has proven to be efficient with the Quito Water Fund, Fondo para la Protection del Agua (FONAG, 11 years old, endowment of nearly $10 million). The Conservancy alone has 11 created funds with approximately 30 more in the pipeline; analysis of green vs. gray is pending.

Investment/Costs/Time

The East Cauca Valley Water Fund has committed to investing $10 million over the next 5 years (Tallis and Calvache 2011). For the mature Quito Water Fund (FONAG) approximately 2% of the water utility revenue is paid into the fund. Some of the utility fees go to the endowment while the rest goes directly to project implementation.

Establishing an endowment is important to make long term agreements on watershed, with farmers, etc. The Quito-FONAG Fund is currently investing $2 million and can leverage $2 to 4 million (FONAG 2010).

The disadvantage for green infrastructure is in the startup and initial financing capacity: the East Cauca Valley Water Fund currently has annual revenues of $1 to 2 million but the business plan states that $18 million is needed for many projects to achieve very significant regional outcomes, which will take 12 to 15 years to raise. The timeline for outcomes is also problematic as some of these projects will take 20 to 30 years to mature while stakeholders expect results within 10 years.

Project Management Considerations

The process developed by the water fund and The Conservancy for determining how investments should be made is as follows: (1) Choose Objectives: through negotiation; (2) Choose Activities: based on science and experience; (3) Allocate Budget: based on experience; (4) Conduct a Diagnostic Screen: ranking of projects; (5) Select Priority Areas: return on Investment; (6) Estimate Returns: using models; (7) Design Monitoring Program; (8) Implement Project. The fund uses the GIS-based InVEST model suite developed as part of the Natural Capital Project to identify priority areas for intervention. (Tallis and Calvache 2011) (Ramos 2012).

The entire process is managed by a board of directors (ideally 50% public/50% private governance) and guided by annual and long-term plans. Water funds identify watershed areas and projects that give the highest ROI for water quality, sediment retention, and/or water quantity. TNC and several Funds are also exploring water pollution as an additional key metric to target in the future.

Benefits

- Increased water supply.

- Flood risk management.
- Increased agricultural productivity.
- Reduced waste and nutrient production and improved treatment.
- Social benefits: environmental education, local entrepreneurship, commercialization of facilities.
- Water Fund approach is much faster in terms of planning and impact vs. gray options:
    - Gray is government-driven and can take upwards of 10+ years to commence projects.
    - Green can also be integrated into gray infrastructure and planning.
- Insurance costs (possible positive impact, needs research).
- Risk management changes/improvements for the private sector.
    - In Medellin, Colombia, several large industrial companies are exploring water fund-style projects to reduce their operational and reputational risk from dangerous bacteria blooms in their water supply

Risks/Challenges

- Governance issues; questions over who manages the fund, efficiency concerns
    - Necessary to build alliances with utilities and key users.
- Need local government stability and buy-in.
- Need sound conservation agreements with the local communities; Rule of law.
- Need to capitalize/begin projects quickly (2-3 years) but results can take time to materialize.

Resiliency Aspects

- The field needs more research and modeling to compare green versus gray techniques in terms of resilience before any definitive judgments can be made. However, initial results and most experts believe the green techniques will be more energy efficient and require less maintenance than the traditional gray approaches.
- Resilience and flexibility in response to the effects of climate change could further tip the scales in favor of more green approaches and Water Fund type projects.
- A Water Fund offers a more bottom up approach in contrast to Gray infrastructure (government planned) which empowers end users to invest in future, e.g. sugar cane growers.

Key Learning

- Green disadvantage is in the startup and initial financing capacity:
    - Water for Life currently has annual revenues of $1 to 2 million but business plan says $18 million is needed for many projects with the most significant outcomes, which will take 12 to 15 years to raise. Need to show results in 10 years instead of 20 to 30.
- It is essential to identify the beneficiaries and water users, but not necessary to engage all stakeholders early on (start with the big users first to build momentum).
- Getting the basic science in place is essential and more work must be done to quantify the benefits whenever possible, communicate them to stakeholders, and frame the benefits, goals, costs, etc. into a science-based business plan.

References

Calvache, Alejandro. "East Vauca Valley Water Fund." (The Nature Conservancy, Natural Capital Project) 2009.

FONAG. "FONAG (Fondo para la Protección del Agua): Rendicion de Cuentas." (FONAG) 2010.

Goldman, R.L., Benitez, S., Calvache, A., and Ramos, A. "Water funds: Protecting watersheds for nature and people." (The Nature Conservancy) 2010.

Padilla, Pedro H.M. "Fondo Agua por la Vida y la Sostenibilidad: Valle Geographico del Rio Cauca." (ASOCANA) 2011.

Ramos, A., Benitez, S., Calvache, A. "Fondos de Agua: Conservando la Infraestructura Verde: Guia de diseno, creacion y operacion." (The Nature Conservancy, Fundación Femsa, Banco Interamericano de Desarrollo) March 2012.

Tallis, Heather, and Alejandro Calvache. ""Improving Conservation Investment Returns for People and Nature in the East Cauca Valley, Colombia"." (Natural Capital Project, The Nature Conservancy) September 2011.

TNC: Integrated Reservoir-Floodplain Management

Source/Organization: The Nature Conservancy

Scale: Regional; application over the whole of a river basin

Key stakeholder(s): Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, TNC, University of California-Davis

Project Phase: Study complete, implementation being explored on the Mokelumne River (Californina) and Cedar River (Iowa). Full implementation phase requires governance/financial mechanisms/political leadership to occur.

Geographical Location: Examples: Savannah River in Georgia/South Carolina; Mokelumne River (California)

Project Overview

Most of the tens of thousands of large dams around the world are not designed for a single purpose, but instead must balance flood protection, water supply, hydroelectric power generation, and other demands. These demands on water management often compete. One of the most common trade-offs involves choosing between keeping reservoirs relatively empty to reduce downstream flood risk or keeping them relatively full to provide water for cities and farms, generate hydropower, and support recreation. This conflict can be reduced and overall social benefits increased by restoring the natural flood storage and conveyance that downstream floodplains provide, thereby enabling the reallocation of some reservoir flood storage to other purposes.

This project investigates the possible benefits of coupling reservoir operations with floodplain management. The study components include modeling scenarios of incremental reductions in reservoir flood storage (0-100%), calculating incremental flood damages associated with flood-storage changes and quantifying the cost to mitigate those damages via floodplain management, assessing the benefits associated with reallocating flood storage to other purposes (water supply, hydropower generation, recreation and environment), and developing business propositions including financial models highlighting the costs and benefits of reallocating reservoir flood storage in coordination with changes in downstream floodplain management. This study was performed on two very different case study rivers – the Savannah basin and the Mokelumne basin.

- Research the integration of the green and gray infrastructure for flood risk management and floodplain service provision.
- Proposed interventions: change allocation of reservoir storage; adjuste dam operations; change flood plain management, land uses, relocation, etc.; move and/or enhancing levees.
- Proposed reducing dam flood water storage by 25%, 50%, 75% and 100%.
- Taking some of the reservoir storage away from flood control (via floodplains) allows you to keep more of the reservoir water storage for water supply, recreation and other uses.

- Reallocating water storage away from flood control results in substantial social benefits in both basins, including a 25-50% reallocation in the Mokelumne that would provide water supply for an additional 450,000 people (a major issue in California). The same 25-50% reallocation in the Savannah River would allow for increased hydroelectric generation valued at more than $12 million per year and enhanced recreation worth $3 million per year.

Technology Maturity

Research and pilot phases; a decade-long collaboration on dam operations and supporting work on floodplain management and policy.

Investment/Costs/Time

- Significant: floodplain land use changes, land acquisitions or easements; policy changes for broad implementation; potentially Congressional lobbying.
- Savannah (Georgia/South Carolina, USA): Small changes in floodplain management enable the use of up to 50% of the existing flood storage to increase hydropower and recreation valued at nearly US $13 million per year with no increased flood risk and with additional benefits for water supply, recreation, the environment, and climate change resiliency.
- Mokelumne (California, USA): Modest shifts in floodplain management free 25% to 50% of upstream reservoir flood storage for public water supply—enough additional water for nearly 450,000 people—while maintaining flood protection, increasing hydropower generation, and improving habitat for declining salmon.

Project Management Considerations

- The knowledge and tools exist to support full implementation of this approach in river basins around the world.
- Analysis can be furthered by including considerations of dam maintenance, safety and ecosystem services recognized but still not valued, as well as more rigorous assessment of costs-benefits under climate change futures.
- Must overcome the hurdles of governance systems/financial mechanisms and political leadership. The policy changes to enable fuller implementation are not complicated, but the politics are a challenge around private land use issues. However, these are potentially overcome through use of incentive-based finance mechanisms rather than government “takings.” More feasible in areas where floodplain is mostly undeveloped lands or agriculture with fewer stakeholders.

Benefits

- Reduced flood risk and flood damages through mitigation of properties currently most at risk.
- Increased water supply (quality and quantity); current reservoir flood storage in the United States is a large enough volume to meet the annual water needs of 800+ million Americans, so reallocating even 10-20% of that volume is game-changing.
- Additional hydropower revenue.
- Increase revenue from additional recreational use.

Risks/Challenges

- High-levels of engagement with Army Corps of Engineers and potentially from Congress to authorize significant changes in reservoir plans, dam operations, and authority/funding for land acquisitions/easements, etc.
- Army Corps does not have authority over floodplain land uses.
- Social needs conflict on the landscape. Example: After a dam is constructed, communities develop along river banks in higher flood risk areas.
- Approach currently is not practical in areas with a high level of human development due to large investment required and complexity involved in relocating houses/businesses/farms.
- Requires strong political will from local leaders and community.
- Perverse incentives for certain kinds of agricultural production that impact floodplains (Farm Bill: crop insurance); these incentives could be shifted to be positive.
- Economic losses for land use changes (e.g., removal of farmland from use) and flood risk changes.
- National Flood Insurance Program (NFIP) needs to incorporate a risk-based approach; initial changes along these lines were made by Congress in NFIP this summer.
- Flooding continues to occur despite the continued large investment in gray infrastructure, warranting a change of approach (likely catalyst for change).

Resiliency Aspects

- Multi-functional: by reallocating reservoir storage, increase resiliency to water supply/energy from hydropower/flood control onto the floodplains. Enhances social and ecosystem health.
- Various downstream benefits from ecosystem services not yet valued.
- Unlike floodplains, current gray infrastructure is rigid and vulnerable to breaching during acute events or recurrent droughts, often with a breaking point (e.g., Army Corps designed Mississippi levees).
- Modular: restoration of floodplains can be built in modular form e.g., Floodplains can serve as a sustainable and controlled relief valve by opening up certain critical areas of levees. Preferential flooding (relief value) can benefit highly populated urban areas. This is exactly what the Corps did – by design – on the Mississippi in 2011.
- Improved operational flexibility to meet environmental flow targets and to adapt to more frequent and intense floods and droughts.
- Great example of hybrid solution: grey infrastructure(dam) already in place can be coupled with green infrastructure (floodplain restoration) to reach higher level of resilience.

Key Learning

Changing dam operations in coordination with floodplain management can increase social, economic, and environmental benefits, including improved water supply and water quality, increased hydropower, enhanced flood protection, restored environmental health, expanded recreational opportunities, and increased resiliency to the impacts of climate change.

TNC: MANAGING STORM WATER RUNOFF WITH WETLANDS

Source/Organization: The Nature Conservancy

Scale: Municipalities

Key stakeholder(s): Water Department, TNC, NRDC, EKO Asset Management Partners

Project Phase: Early implementation, extensive planning

Geographical Location: Philadelphia, Pennsylvania, USA

Tim Pierce at commons.Wikimedia.org

PROJECT OVERVIEW

Philadelphia has a sewer collection system that is 60 percent combined sewer and 40 percent municipal separate storm sewer system. The City is working to improve storm water management and alleviate pressure on this combined sewer system (CSS) through restoration and demonstration efforts, regulations and incentives for the private sector via a revised storm water billing system. Philadelphia is trying to institutionalize green infrastructure as standard practice via citywide policies, such as a parcel-based billing system for commercial properties, Green Plan Philadelphia, Green Roof Tax Credit and the Green Streets program. (EPA, 2010)

- Philadelphia is one of 200 cities that are not in EPA compliance on storm water overflow, whereby raw sewage goes into combined sewer systems and then into waterways.
- EPA fines are a strong regulatory and financial driver in US for cities to take action.
- Philadelphia forecasts expenditures of $10 billion to solve their storm water problem over the next decade using gray infrastructure; the same estimate using green infrastructure is $2 billion (Natural Resources Defense Council, 2013)
    - City leaders are committed to green Infrastructure solving a significant portion (20-30%) of this problem for less than costs of traditional gray infrastructure
- Examples of green infrastructure include rain barrels, bioswales, pervious pavement, wetland protection and restoration; and other means to increase infiltration or retain rain water to reduce peak flow.
- Philadelphia set a new water billing system for commercial and industrial properties based on the amount of impervious surface on properties; also owners can get a fee credit through implementation of storm water.
- PWD has allocated $1.67 billion, on an inflation-adjusted basis, over a 25-year period to green at least 9,564 acres across the city, pursuant to a consent order with the Pennsylvania Department of Environmental Protection (Natural Resources Defense Council, 2013).

Technology Maturity

Mature.

Investment/Costs/Time

- Revised storm water billing system based the amount of a commercial property's impervious cover and thereby the amount of runoff a property will generate.
- City offers a storm water fee discount for customers who reduce impervious cover using green infrastructure practices.
- There are multiple ways to finance green storm water management including public-private partnerships, offsite credit trading, etc. (Natural Resources Defense Council, 2013).

Project Management Considerations

- Metrics used: cost savings.
- Local political leadership is key.
- See *Creating Clean Water Cash Flows: Developing Private Markets for Green Stormwater Infrastructure in Philadelphia*, for detailed analysis and recommendations for investment in green infrastructure for stormwater management. http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/pennsylvania/pa-stormwater-report.pdf

Benefits

- Storm water runoff reduction resulting in water quality improvements, relief to aging gray infrastructure.
- Create habitat for wildlife; carbon sequestration; recreation dual use spaces (ex. baseball fields).
- New practices will reduce combined sewer overflow (CSO) by 25 billion gallons, and save the city as much as $8 billion over gray infrastructure alternatives.

Risks/Challenges

- Evaluation of green solutions takes longer, can be more expensive and complex; gray is a known, easier.
- Comfort level of regulators with these newer projects (Philadelphia fought for years for a consent decree). Regulators can be concerned over precedent and "slippery slope" problems.
- Financing challenge for both green and gray; green is generally cheaper.
- Green projects are more visible and potentially polarizing whereas the gray option is invisible; Alternatively, the green options can create community assets that benefit people.

Resiliency Aspects

- In general resilience of either approach is similar but adding green to existing gray CSS can provide buffer and add filtration benefits.
- Gray advantage: harder to add capacity to a wetland than it is to increase pipe size.
- Energy uses are comparable after construction; gray requires much energy more to build.

- Green produces less waste as wetlands can also filter and absorb waste.
- Maintenance is much less for green.
- Green filters most pollutants on site.
- Acute stress: A flood can overwhelm both. Green might be more flood-tolerant and will not lose all function like a burst pipe.

Key Learning

- Mayors have a large role to play in bringing GI to the table for municipalities.
- Financial incentives could be optimized by taxing impervious surfaces differently based on geography.
- Green co-benefits can be time consuming to evaluate and value.
- Green can complement gray infrastructure, buffer the worst storm surges.
- Green infrastructure represents cost advantage vs. building new CSS capacity.
- Different skill set is required to fully understand / need to educate the key stakeholders.

References

- EKO Asset Management Partners, NatLab, The Nature Conservancy, Natural Resources Defense Council. (2013, January). *Creating Clean Water Cash Flows: Developing Private Markets for Green Stormwater Inrastructure in Philadelphia.* Natural Resources Defense Council. Retrieved from http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/pennsylvania/pa-stormwater-report.pdf.

- EPA. (2010). *Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure.* EPA Office of Wetlands, Oceans and Watersheds. Washington, DC: U.S. Environmental Protection Agency. Retrieved from http://www.epa.gov/owow/NPS/lid/gi_case_studies_2010.pdf.

TNC: OYSTER REEF BUILDING AND RESTORATION FOR COASTAL PROTECTION

Source/Organization: The Nature Conservancy

Scale: Local. Miles of oyster reefs installed in the Gulf of Mexico

Key stakeholder(s): Natural Capital Project, donor organizations, local communities, enterprises

Project Phase: Several successful project sites, expanding in use as experience and technology evolve


The Nature Conservancy

Geographical Location: Gulf of Mexico, potentially other sites as well. Oysters are found around the world in temperate and tropical waters. They develop some of the greatest structures in places like the Gulf of Mexico, the Atlantic seaboard up to New York, as well as waters off China, Japan and in similar Southern Hemisphere oceans.

PROJECT OVERVIEW

Oyster reefs have lost an estimated 85% of their historic extent globally (Beck, 2011). This loss carries a high economic cost because of the wide range of benefits oyster reefs provide to humans. Growing research on reef restoration in the last decade suggests that such restoration is feasible on a large-scale, holding the prospect of recovery of ecosystem services and economic benefits. For a large reef restoration project in Mobile Bay, Alabama, for example, TNC conservatively estimated that 5,850 m of restored reefs:

- Produce over 3,100 kg of finfish and crab and 3,460 kg of oyster (meat) harvests per year.
- Reduce the height and energy at shoreline of the average and top 10% of waves by 53-91% and 76-99%, respectively.
- Remove up to 1,888 kg of nitrogen per year from surrounding nearshore waters.

Total net benefits (consumer and producer surplus) from fishery enhancement dominate overall benefits from the reefs along the currently undeveloped shores with an estimated $217,000-$225,000 per year and their net present value (NPV) exceeds restoration costs ($4.28M) in year 34.

For 50 and 100-yr lifetimes and counting only fishery benefits, the reefs have a combined social return on investment (ROI) of 1.3 and 1.8 and a NPV of $1.17M and $3.23M, respectively.

Given ambitious restoration plans, the ROI of reef restoration is expected to increase substantially due to knowledge gains and economies of scale. Especially along developed shorelines, the ROI of reef restoration may exceed that of single-purpose alternatives for coastal protection and fishery enhancement due to the multi-functionality of reefs (Koeger, 2012).

The Gulf of Mexico is the single best opportunity for large-scale restoration of oyster reefs and sustainable fisheries, even as there has been an 85% loss of oyster reef ecosystems around the world. Restoring oyster reefs can have positive benefits for storm surge protection and sea level rise, social and economic vulnerability and risk, and conservation.

- Proven value of wave attenuation, reducing the energy and height of waves.
- Gulf of Mexico: several miles of oyster reefs implemented as breakwater projects.
- Re(building) reefs is done on a base using bagged oyster shells (best option) and/or cement structures; this structure is then seeded with oysters.
- Storm surge protection benefits are immediate as this base, which is a hybrid or green and gray.
- Reefs are self-maintaining and can grow with sea-level change.

Technology Maturity

Proven, for wave attenuation/storm protection. Now looking to optimize co-benefits like habitat, conservation, biodiversity, etc. But these benefits may take more time to prove.

Investment/Costs/Time

- Timeline varies slightly by geography because growth rates vary by species/strain of oyster, water conditions, etc.
- In Gulf of Mexico, benefits appear immediately after first stages of project (sinking bagged shells or concrete).
- Cost: About $1 million per mile, which is comparable or cheaper than gray alternatives in initial costs, with much higher cost/benefit returns because of the associated co-benefits
    - Gray infrastructure is industry- and profit-supported. Even Army Corps of Engineers has a bias toward gray. Engineers understand gray choices.
    - Reef restorations are often conducted by non-profit organizations, volunteer efforts and smaller startup companies, which may be one reason costs are as significantly lower..

Project Management Considerations

- Project and identification materials and guidance: http://gulfmex.coastalresilience.org/.
- Depth of water, salinity (oysters somewhat tolerant of variations), historical and current oyster populations.

Benefits

- Protection from waves and erosion is very clear; stabilization of shorelines and even expansion of coasts. Storm surge protection and greater safety for people and property are highly likely given the engineering results from comparable structures (e.g., submerged breakwaters), but are not yet proven from direct evidence before and after storms (we simply have not had them in place for these events). The potential for lower insurance costs is also real.
- Additional fisheries production; more habitat produces more species and populations, including fish, crabs, shell fish.
- Shellfish filtration improves water quality.

- Changes in shoreline, such as increase in marsh abundance.
- Job creation for local workers, building/maintaining reefs.

Risks/Challenges

- People value oysters as a food source and harvesting slows progress.
- Growing oysters can smother sea grass habitat; possible conflict with other native habitat (in the Pacific NW). This is not an issue in the Gulf of Mexico.
- Shell fish industry is afraid of illegal harvesting in sub-optimal waters where oysters could be contaminated (fears are greatly exaggerated).

Resiliency Aspects

- Maintenance advantages (under study); still need to measure the repair/growth timeline and reduction in costs
    - Self-repair will be huge over time for both acute and chronic stresses.
    - Acute damage creates greater water flow around structure which causes faster oysters growth.
- Oyster reefs will naturally expand upward with sea level, likely adjusting to chronic stresses (climate change).
- Lower energy requirements.
- Very popular with community, which sees value in protection, improved fish habitat.

Key Learning

- No structure offers absolute protection, and there is a need to increase understanding of reefs and not overpromise on protection benefits.
- The case for oyster reef bed building and restoration is compelling. The Gulf of Mexico is the single best and maybe last place where oyster reef and fisheries can see value from new structures. Can build them big enough to be significant.
- Many reef projects are getting stimulus funding. Restoration creates jobs, so projects funded.
- Most projects had been reefs in front of natural areas. When these started showing results, then more Green projects for replacing submerged breakwaters ensued with greater interest from municipalities. Now most reef projects are situated in front of developed areas.

References

- Beck, M. W, R. D. Brumbaugh, L. Airoldi, L. D. Coen, C. Crawford, O. Defeo, G. J. Edgar, B. Hancock, M. Kay, H. Lenihan, M. W. Luckenbach, C. L. Toropova, G. Zhang, X. Guo. (2011). Oyster reefs at risk globally and recommendations for ecosystem revitalization. *Bioscience, 61*, 107-116.

- Kroeger, T. (2012). Oyster reef restoration in the northern Gulf of Mexico: Assessing economic rationales for large-scale restoration efforts. *TEEB 2012 Conference.* Leipzig.

LITERATURE: GREEN ROOFS FOR ENERGY SAVINGS

Lamiot at commons.Wikimdia.org

Source/Organization: (Kazmierczac, 2010) See below

Scale: City

Key stakeholder(s): City government, public, builders, university researchers, National Department of Environment and Energy. Various stakeholders were consulted when developing the green roof concept, and in establishing the first incentive program: local business association, horticultural association, Pro Natura Basel environmental organization, Department of Parks and Cemeteries, and the National Department of Environment, Forest and Landscapes

Project Phase: Implemented and ongoing

Geographical Location: City of Basel, Switzerland

PROJECT OVERVIEW

Basel, Switzerland has the largest area of green roofs per capita in the world. Green roof usage has been fostered by a combination of financial incentives and building regulations. Building regulations have required the use of vegetation on roofs since 2002. Energy saving was the initial driver, although biodiversity conservation has also become important, according to a report by Kazmierczak, et al.

Green roofs can reduce the energy required for heating and cooling buildings. Green roofs absorb and store large amounts of heat when wet. When dry, green roofs insulate the building, decreasing the flow of heat through the roof, thereby reducing the energy needed for cooling. In the winter, less heat from inside the building is lost through the roof. In summer, green roof vegetation reduces roof surface temperatures and ambient air temperatures.

Green roofs were first funded by the City of Basel for a two-year period in the mid-1990s to stimulate interest and awareness. Encouraged by the success of this project, funds were then allocated for a study which documented the biodiversity benefits of green roofs and led to the current initiative. It is now also recognized that green roofs provide a climate change adaptation function by limiting surface water runoff and reducing urban temperatures.

By 2010, approximately 23% of Basel's flat roofs were green, or around 700,000 m2. It is estimated that 30% of all flat roofs in Basel will be green by 2015 (Kazmierczak, 2010).

TECHNOLOGY MATURITY

Mature.

INVESTMENT/COSTS/TIME

Basel has promoted green roofs via a number of funding streams and policies:

- Incentive programs provided subsidies for green roof installation. The first incentive program ran between 1996 and 1997, focusing on the insulating properties of green roofs and their capacity to reduce energy consumption. This was followed by another incentive program in 2005 and 2006, which incorporated design specifications into the green roof guidelines.
- A grant for research into the biodiversity benefits of green roofs resulted in improved design specifications for green roofs in Basel.
- In 2002, an amendment to the City's Building and Construction Law was passed that stated that all new and renovated flat roofs must be green and conform to design guidelines.
- In 1996 and 1997, the City invested one million CHF in a green roof incentive program. Another one million CHF funded the green roof incentive program that ran between 2005 and 2006.
- The Zurich University of Applied Sciences received funding for research into the potential of green roofs to provide valuable habitat for invertebrates and birds (Kazmierczak, 2010).

Project Management Considerations

The development of the regulations was led by the Department of Building and Transport, and included an academic expert in green roofs. Implementation is carried out by contractors working in the field, and the owners of the buildings.

Benefits

- Municipal energy savings: between 3.1 and 4+ giga watt-hours per year across Basel.
- Building owner energy savings.
- Stimulus to local economy for building materials.
- Habitat creation for endangered invertebrate species.
- National and worldwide recognition for Basel.

Risks/Challenges

Implementing the regulations was straightforward, yet the quality of green roofs was initially not good enough to create significant biodiversity benefits. So a second campaign (2005-2006) was created which created specific requirements for quality of green roofs. Current challenges include building awareness among the architects, planners, builders, gardeners, etc. on the benefits of green roofs.

Resiliency Aspects

- Energy demand reduction with temperature mitigation.
- Reduce workload on city storm water gray infrastructure.
- Groundwater recharge and more efficient water capture and utilization.
- Requires different, less "concrete", maintenance regime.
- Positive effect to ameliorate social stresses, community cohesion.
- Potential to mitigate some impacts of climate change.
- Habitat and support for biodiversity.

Key Learning

Green roofs are a type of green adaptation to climate change that brings multifunctional benefits. While the original driver was purely energy-savings, the focus soon shifted to biodiversity, and then to the role of green roofs in adapting to climate change.

- It is essential to involve all stakeholders from the beginning of the initiative.
- Requires leadership by a committed individual dedicated to the initiative's success.
- The success of the Basel program was due to a comprehensive suite of mechanisms, from financial incentives to statutory regulations.

References

Kazmierczak, A. and Jeremy Carter (2010). Adaptation to Climate Change Using Green and Blue Infrastructure:A Database of Case Studies . Manchester: University of Manchester.

LITERATURE: STORM WATER MANAGEMENT IN SIX CITIES

Source/Organization: EPA, American Rivers, Center for Neighborhood Technology. See references below.

Scale: Local, city

Key stakeholder(s): ??

Project Phase: Under investigation, planned and partial implementation

Geographical Location: Multiple municipalities in North America

James M. Pease at commons.Wikimdia.org

PROJECT OVERVIEW

Aging stormwater/sewer infrastructure, combined with greater volumes and velocities of stormwater runoff, threaten waterways, water quality for many communities and municipalities. In these cities, this is being addressed via various, complementary techniques and technologies including:

- Green roofs, tree planting, swales, porous pavement, green streets, rain gardens, infiltration zones.
- Purchase of upstream land for infiltration.

Based on cases from Aurora, IL; Chicago, IL; Milwaukee, WI; New York, NY; Philadelphia, PA; Portland, OR, Seattle, WA:

- To divert 1 billion gallons of storm water from sewers (Aurora).
- To address climate change, flood risk, and public health stresses (Chicago).
- To reduce the occurrence of combined sewer overflows and reduce stress on aging gray infrastructure (Milwaukee).
- To manage 10% of the runoff from impervious surfaces via detention and infiltration (NYC).
- NPV of Green greatly exceeds Gray (Philadelphia).
- Bring GI to scale and attain quantifiable, replicable benefits (Philadelphia).
- Green infrastructure to manage 50% runoff from impervious surfaces (Seattle).

TECHNOLOGY MATURITY

Mature, albeit new, unfamiliar and developing.

INVESTMENT/COSTS/TIME

Varies widely depending on location and scope of projects – see individual city descriptions in references below.

PROJECT MANAGEMENT CONSIDERATIONS

Varies depending on location, scale, intent. Spanning city works projects, incenting businesses and homeowners. See individual city descriptions in references below.

Benefits

- $108,000 savings, 1.4 kWh / 1k metric tonnes CO_2 annually (Aurora).
- Various benefits from 400 green roofs (Chicago).
- Holding 1.3 billion gallons of storm water at a cost of $.017 per gallon for green vs. 315 million gallons @ $.31 per gallon for gray (Milwaukee).
- NPV of $2.8 billion for green vs. $122 million for gray (Philadelphia).
- New York City expects to save $1.5 billion over the next 20 years by using green infrastructure.
- 63,000 kWh savings (Portland).
- $100,000 savings per city block (Seattle).
- Flood control: safety, damages, costs.
- Clean Water Act (CWA) compliance, reductions in fines.
- Strengthened city economy.
- Reduced urban heat island; improve air quality; traffic moderation; neighborhood aesthetics.
- Bioremediation.
- Reduced bacteria and disease.
- Increased recreational space.

Risks/Challenges

- Municipal leadership required.
- Multiple stakeholder involvement.
- Overcoming engineering bias toward gray solutions.
- Funding.
- Changing building codes and zoning; EPA regulations.
- Demonstrating efficacy and efficiency.
- Education and outreach.

Resiliency Aspects

Discussion of resiliency does not enter into the literature for storm water management (which comprises a large portion of the literature on green infrastructure). We can surmise, however that resiliency is increased based on:

- Smaller, local water “treatment” site vs. large, central gray infrastructure treatment plant; lower energy consumption; repair-ability, less frequent breakdowns; daylighting vs. buried / inaccessible infrastructure.
- Lower operating costs; ease of adding capacity.
- Habitat and biodiversity support; water table recharge; small scale agriculture support.
- Avoiding or lowering susceptibility to catastrophic events.
- Reduced social stresses (from disease to aesthetics).

Key Learning

Green infrastructure is an approach that is increasingly considered by many municipalities for water quality protection, especially in implementations which combine green and gray systems. These hybrid solutions to storm water and combined sewer overflow challenges can occur at the regional, community and site scales, and the business case for green infrastructure can be compelling.

References

American Rivers, e. a. (2012). Banking on Green Infrastructure: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Comunity-Wide.

EPA. (2010). Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure. EPA Office of Wetlands, Oceans and Watersheds. Washington, DC: U.S. Environmental Protection Agency.

CNT. (2011). The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits. Chicago: Center for Neighborhood Technology.

LITERATURE: GREEN AERATION CORRIDORS FOR AIR QUALITY AND TEMPERATURE CONTROL

Source/Organization: (Kazmierczac, 2010) See below.

Scale: City

Key stakeholder(s): The Mayor of the City of Stuttgart, public, state and local environmental offices, state and local regulators.

Project Phase: Ongoing; launched in the 1990s

Geographical Location: Stuttgart, Germany

Ra Boe at commons.Wikimdia.org

PROJECT OVERVIEW

Stuttgart has been susceptible to poor air quality since the 1970s. Low wind speeds in the region and a demonstrated urban heat island effect contribute to the problem. In the 1990s, the city began to establish green aeration corridors between urban areas and the surrounding hills to create an air exchange and promote cool air flow into the city. Preservation and enhancement of open spaces and vegetation is the key measure, in locations that have a role in air movement and air exchange across the city.

Adjusting zoning regulations to preserve open space and increase vegetation was critical to the effort. The corridors are positioned to take advantage of natural wind patterns and vegetation to reduce problems of overheating and air pollution. The city also achieved an in-house climatic research capability to provide knowledge of local conditions and tactics to adjustment zoning regulations.

The main mechanism is the German Building Code, the legislative basis for the initiative. Regulations are divided according to different types of green infrastructure and climate-amelioration mechanisms:

- The acquisition, preservation and enhancement of Green Space: based on a landscape scale and open-space control plan; establishing benchmarks for "green" uses; avoidance of soil capping; green roofs and facades.
- Securing the Local Air Exchange: establishing contiguous corridors which supply cold and fresh air from the hills, wildlife habitat and encourage advantageous forms of development.

The zoning regulations discourage any construction that would obstruct air flow in key strategic areas, removal of trees over a certain size, and the promotion of green roofs, facades and other "urban greening" initiatives (Kazmierczak, 2010).

TECHNOLOGY MATURITY

Mature and under regular review and revision.

Investment/Costs/Time

Driven by municipal planning and regulations; financial support for urban greening initiatives.

Project Management Considerations

Planning and zoning changes aimed at preserving open space and increasing vegetation in urban areas are based on the German Building Code and other national, regional and local regulations. See *Adaptation to climate change using green and blue infrastructure: A database of case studies* referenced below.

Benefits

- Improved air quality.
- Lower city temperatures.
- Enhanced recreation and urban aesthetics.
- Public health improvements.
- Reduced demand for indoor climate controls (energy savings).
- Preservation and creation of wildlife habitat.

Risks/Challenges

Multiple projects must be brought together into a strategy, with attendant internal and external barriers including: uncertainty about future climate change and impacts, limited staff and lack of organizational capabilities related to climate adaptation, and financial resources.

Resiliency Aspects

- Chronic stresses: Reduced energy demand.
- Acute stresses: Alleviates impact of high heat days.
- Social stresses: Health benefits and "green psychology" value.
- Gray infrastructure (air conditioning, filters) remains an option, but nature is the first defense.

Key Learning

- The case demonstrates the advantages to a municipality of having in-house climatic research capacity to provide concrete knowledge of local conditions and remedies, as opposed to relying on an understanding derived from general principles. Cumulatively, over several decades, the city has used its planning and landscaping powers to engineer an entire system of urban wind circulation.
- Compilation of detailed information about the area's topography, climate and land use allows for precise planning for different areas, which together aim to improve air quality and mitigate the urban heat island effect.
- Constructive use of existing regulations (e.g. the German Building Code) provides a mandate for the implementation of planning recommendations to impact the local climate.
- Close collaboration between the Office for Environmental Protection (analysis of information, provision of recommendations) and the City Planning and Renewal team means that the

recommended green infrastructure solutions are being implemented through spatial planning and development control.

- Collaboration with and among key stakeholders is key, as is engaging the public to reach and maintain political buy-in.

References

Kazmierczak, A. (2010). Adaptation to Climate Change Using Green and Blue Infrastructure. Manchester: University of Manchester.

Literature: Mangrove Restoration for Coastal Protection

Source/Organization: Mangrove Reforestation and Disaster Preparedness Programme. (International Federation of Red Cross and Red Crescent Societies, 2011).

Scale: Village, region

Key stakeholder(s): Local communities, donors, NGOs, national governments, fishers and farmers

Project Phase: Ongoing, mid-stage

Geographical Location: Vietnam coastal communities


The Nature Conservancy

Project Overview

The Community-based Mangrove Reforestation and Disaster Preparedness Program (CBMRDP) has been implemented by the Vietnam Red Cross (VNRC) since 1994. The purpose is to reverse the trend of mangrove destruction and reforest the intertidal eco-systems. Mangrove afforestation has been shown by this program to be a highly efficient/effective way to achieve protective, direct economic and ecological benefits. More than 300,000 students, teachers, volunteers and local leaders trained in disaster preparedness. Around 350,000 residents are direct beneficiaries of storm protection, and indirect beneficiaries who are now better protected by mangroves and other trees are estimated to be around 2 million, according to the Red Cross Red Crescent report.

Technology Maturity

Mature.

Investment/Costs/Time

$8.88 million from 1994 to 2010. 9,462 hectare of forest (8,961 of them mangroves) have been created in 166 communes; about 100 km of dyke line have been protected.

Project Management Considerations

- Strong local ownership required.
- Requires commitment of Vietnam government.
- Requires funding from outside sources, combined with.
- Local expertise to gauge prospects for plant success.

Benefits

Significant impact toward disaster risk reduction and improvements to community livelihoods. Typhoon damages have been reduced by more than the cost of the program.

- Avoided risk up until 2025 up to $37 million in one commune, and the program's protective benefits by far exceed its costs in each of the communes studied.
- Dyke maintenance alone reduced by $7 million per year.
- Carbon sequestration: The mangroves planted by VNRC will have absorbed at least 16.3 million metric tons of CO_2 by 2025. At $20 per ton of CO_2, with discount rate of 7.23%, the Net Present Value exceeds $218million.
- Habitat preservation/restoration; biodiversity support.
- Increased yield from aqua culture by up to 789%, depending on location, providing more income for coastal communities; strong indications that the program was able to lift people out of poverty (firm causality can however not be established).
- Strong cost-benefit ratios, even if only 1 of 3 benefits is counted (protective/direct economic/ecological) (International Federation of Red Cross and Red Crescent Societies, 2011).

Risks/Challenges

- Community leader engagement and buy in. Strong local ownership required.
- Long term funding available.
- Formal, long-term protection of mangroves needed.
- Commitment of Vietnam government.
- Funding from outside sources.
- Requires suitable soil conditions, local expertise, research, a long-term focus, and an appropriate integration of local communities. Where planting conditions are less ideal, costs can be substantially higher.

Resiliency Aspects

A study will assess the extent to which the program has contributed to building more sustainable safety and resilience among the targeted communities during the period 1994-2010. Next-phase research will attempt to answer questions in more specific to resiliency:

- What has been the long-term impact of the program on disaster risk reduction and capacity building since 1994, in particular the impact on the coastal environment and socio-economic situation of poor people and targeted vulnerable groups to flood and typhoons?
- Did the household or community level of disaster preparedness change?
- Dow the mangroves improve the livelihood of residents?
- Has the improved awareness led to changed behavior for disaster risk management?

Key Learning

- Concretization of sea dykes may not be necessary in locations where the dyke is already protected by a wide, dense and mature mangrove forest.

- Planting mangroves vs. concretizing dykes is cheaper and also brings further benefits to the community and the environment.
- Mangrove afforestation can be an efficient and effective tool for disaster mitigation and enhanced livelihood as well as for the mitigation of climate change. However, some caution is urged to curb the growing interest in mangroves, especially as an instrument for climate change adaptation; planting mangroves is not easy (see Challenges above).
- Boosting sustainable disaster resilience requires a long-term, developmental approach (International Federation of Red Cross and Red Crescent Societies, 2011).

References

International Federation of Red Cross and Red Crescent Societies. (2011). Breaking the Waves: Impact analysis of coastal afforestation for disaster risk reduction in Viet Nam. Geneva: International Federation of Red Cross and Red Crescent Societies.