Water-Sensitive and Ecological Design: Hebei Province, China
Capstone Report

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Executive Summary

This report provides a 'handbook' approach to ecological and water-sensitive design in order to guide the incorporation of environmental resilience into the work of SPD (Beijing) International Urban Planning and Design Co., Ltd., a planning and design firm located in Beijing. SPD requested the development of an urban and landscape design strategy to incorporate with water sensitivity (scarcity and pollution) and ecological design for its projects in China. More specifically, our project and this handbook focus on their design work in Baihe township, Hebei province, where our team spent ten days on a charette alongside SPD's landscape designers. This project, and SPD's work more broadly, present a unique opportunity for the growing firm to provide innovative, dynamic, and sustainable urbanization approaches in one of the world's fastest-growing economies, and play a major role in establishing the inception of ecological design in China.

Our handbook analyzes and evaluates approaches to water-sensitive urban design with an emphasis on urban, agricultural, and industrial areas. Where relevant, we examine opportunities for ecological solutions through the lens of pollution at the air, water, and land levels. This report finds that while SPD requested a 'drop-in' solution approach to ecological and water-sensitive design, each site and its particular geological attributes, contamination status, positioning within a watershed and other characteristics must determine the specific design that is implemented. In the absence of a drop-in solution for ecological and water-sensitive design, we seek to provide frameworks, methods, and tools in order to optimize SPD's ability to best influence the physical environments in which it operates.

This project seeks to inform SPD's work while also acknowledging the inherent limits of a design firm to improve long-term environmental conditions given that design firms end their work often before construction of a site even begins. Given the fact that design firms generally do not remain involved at sites after the design has been implemented, we emphasized the importance of incorporating ecological expertise in situations where SPD plans to incorporate ecological and water-sensitive design. Limitations to our work included difficulties with communication across languages and over distance; a lack of alignment between the master's capstone project and SPD's own deadlines for the Baihe project; and our client's limited financial resources that have thus far limited their ability to incorporate ecological expertise among their staff. To this end, we provide recommendations for resources SPD should add to their practice to best implement technologies and concepts from this guidebook into their future designs.

Introduction

In 2007, *The New York Times* described China's rise as an economic power as having "no clear parallel in history," and that the subsequent pollution problems that have arisen along with per-capita GDP and industrial prowess have "shattered all precedents." "Environmental degradation is now so severe," the paper went on, "that pollution poses not only a major long-term burden on the Chinese public but also an acute political challenge to the ruling Communist Party."

Ten years later, this burden remains visible and nearly ubiquitous in China's air, across its landscape, and in its water. Just this month, a Chinese study was published that found 80 percent of China's shallow groundwater--the source used by farms, factories, and most rural households--is contaminated by industry and farming pollutants, and is therefore unfit for bathing or consumption.[1] China's development augments already challenging water resource dynamics, where its total water resources rank fourth worldwide, but per capita water resources are only one quarter of the world average.[2] Given this relatively limited supply of water alongside its vast human population, China's ability to manage its water resources, preserve the safety of its supply, and leverage it where most needed and conserve when possible will be a major determinant of its ability to continue its streak of economic success.

With China's history, current growth trajectory, and environmental challenges as a backdrop, our master's capstone project has sought to equip a young landscape design firm headquartered in China's capital with the resources, tools, and frameworks that are required to incorporate principles of ecological stewardship into its designs, with an emphasis on preserving and purifying water resources. First, we applied these principles during a ten-day design charette in Beijing and on-site in Hebei province. This charette gave our group of five the opportunity to work alongside SPD's designers in order to incorporate our water-sensitive and ecologically-focused design approaches into SPD's proposed plans for the town of Baihe and a smaller site along the Tang River, both of which had been requested by their client. This work culminated in a joint presentation on May 11 by our team and SPD to those government officials charged with selecting a firm to implement designs in Baihe. We learned this past fall that SPD's plans, which incorporated our ecological and water-sensitive design recommendations, had been selected by the government and awarded the contract.

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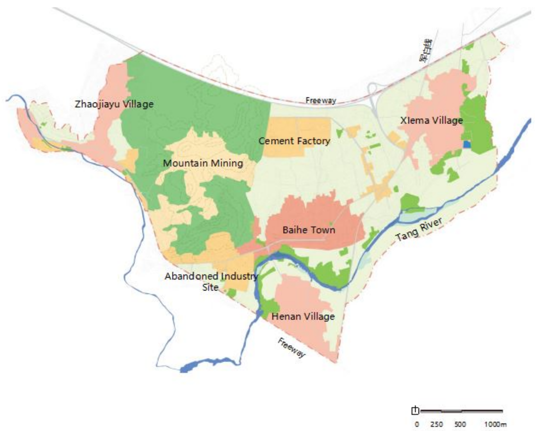
[1] Mandarin Chinese version may be found here: http://www.mwr.gov.cn/zwzc/hygb/dxsdtyb/201604/P020160405539942030096.pdf, translated summary in the following articles: Buckley, C. and Piao, V. "Rural Water, Not City Smog, May be China's Pollution Nightmare." *The New York Times*. April 11, 2016. http://www.nytimes.com/2016/04/12/world/asia/china-underground-water-pollution.html, "China Report Sounds Alarm on Groundwater Pollution." *The Associated Press* via *The New York Times*. April 12, 2016. http://www.nytimes.com/aponline/2016/04/11/world/asia/ap-as-china-water-pollution.html

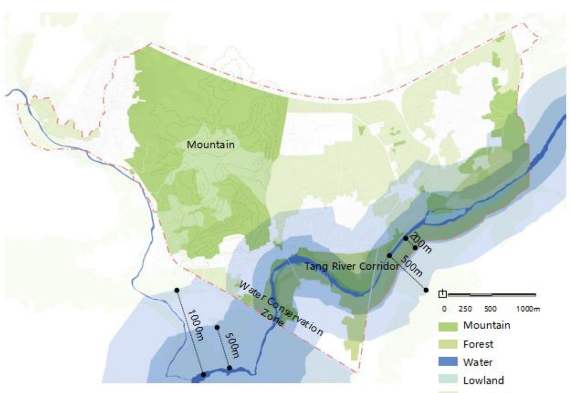
[2] This statistic is based on the years 2000-2011. "OECD FAO Agricultural Outlook 2013-2022." *Organization for Cooperation & Economic Development* and the *UN Food and Agriculture Organization*. 2013. http://www.oecd.org/berlin/OECD-FAO%20Highlights_FINAL_with_Covers%20(3).pdf

This paper provides an overview of our sixteen-month process, research, findings, and concluding recommendations for SPD. We provide frameworks for ecological and water-sensitive design that focus on agricultural, urban, and industrial areas. While we apply these frameworks to the Baihe site in particular, our goal is that the research and principles summarized here can be applied more widely, so that SPD can use these frameworks to inform their work overall. We hope that by applying the frameworks to the Baihe site--already a known quantity--it becomes easier to envision their on-the-ground application and the resulting dynamics that may arise in response.

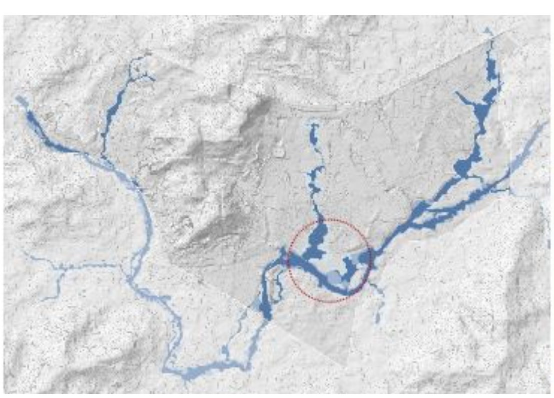
Regional Context



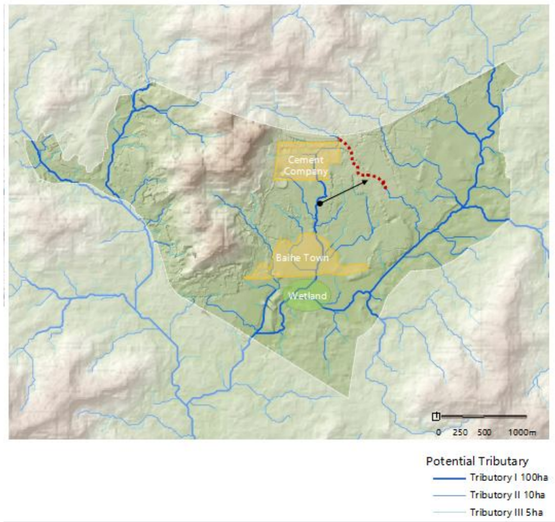
Baihe town is located along the edge of Tang river with a cement factory in the north, a mountain with mining industry in the west. It is surrounded by farmland in the east and south.



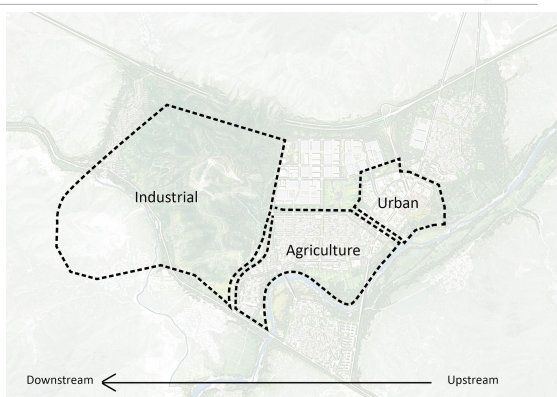
It is in a pretty flat area and right in the 1000 m river water conservation buffer zone. There is some forest and farmland between the town and river.



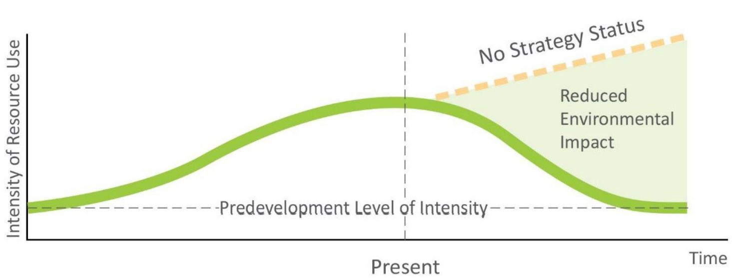
The water quality in our site is very important. Because the site is located in the upstream of drinking reservoir and surrounded by Tang tributary junctions.



Tributary map based on GIS topography analysis shows the potential floods flowing pattern in this area.



Based on what SPD proposed master plan for Baihe, we categorized it into three parts from upstream to downstream, that is urban, agri, and industry.



A design strategy to meet the development goal and also minimize the environmental impact caused by urbanization is developed based on the context analysis.

Urban Context

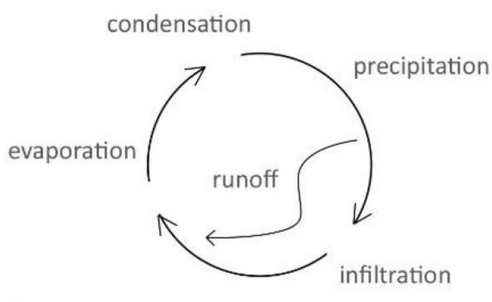
Urban Areas Impacts on Water Systems

From a bird's eye view, urbanization can be identified largely by the replacement of permeable surfaces with impermeable and high concentrations of humans and natural resource consumption. These circumstances alter the natural water cycle, drawdown the water table and pollute waterways leading to many layers of environmental and ecological impacts and degradation[3]. Urbanization causes pollution of waterways, flooding and erosion, drawdown of underground aquifers and increases heat island effect (HIE)[4]. All of these stress the environment leading to environmental and human health hazards.

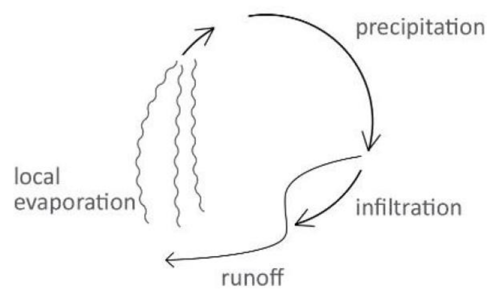
[3]Water Environment Federation, Alexandria, VA; and American Society of Civil Engineers, Reston, VA. "Urban Runoff Quality Management."WEF Manual of Practice No. 23; ASCE Manual and Report on Engineering Practice No. 87. 1998. Chapter 1.

[4] Barton, S. and Pineo, R. "Permeable vs. Impermeable Surfaces." University of Delaware College of Agriculture and Natural Resources, Bulletin #125. January 31, 2009. https://ag.udel.edu/udbg/sl/hydrology/Permeable_Impermeable_Surfaces.pdf

Concentrations of human beings becomes too great when pollution and waste are created faster than the environment can absorb them. The dramatic increase in impermeable surfaces in urban environments leads to urban runoff composed of sediment, nutrients, bacteria, toxins and metals[5]. Though modern stormwater and sewage systems are for the most part effective in draining surface water away from infrastructure, the water picks up toxins and pollutants that were not able to infiltrate into the ground and are carried through sewage systems to waterway. Additionally, this unnatural relocation of water alters underground water tables and, therefore, the native plants and animals that rely on them. Impermeable surfaces also create natural water slides for storm and waste water to flow and pick-up momentum; once stormwater does his non-paved surfaces, its velocity and amount greater than natural infiltration capacity leads to erosion. This all leads to a natural positive feedback loop of soil degradation leaving the ground less and less able to absorb water and restore natural aquifers that are vital to native plant, animal and human life.



existing water cycle of the area



future water cycle of the urbanized area

The natural water cycle is the lifeline for plants and animals that have evolved symbiotic relationships among themselves and their environment and are reliant on predictable precipitation patterns. Left to its own devices, precipitation falls from the atmosphere and is absorbed by permeable ground that replenishes underground aquifers which make up 30.1% of the earth's accessible fresh water[6]. This water is what native plants use to grow and become the food source for the first trophic level of animals as well as transfer water back into the atmosphere through transpiration[7] completing the most basic water cycle. When permeable surfaces are paved over water can no longer be absorbed into the ground. Decreased access to surface and ground water alters the plant and animal species that can exist in an ecosystem.

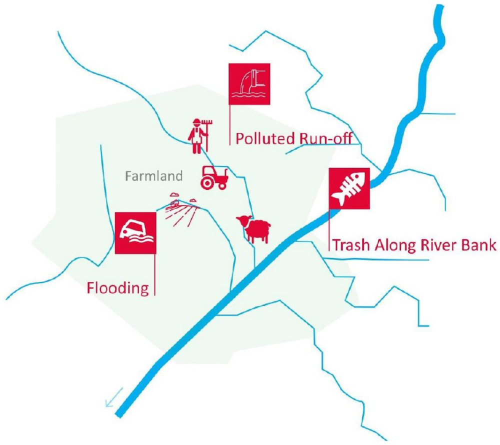
In addition to enabling the negative impacts of urban runoff, impermeable surfaces also trap heat whereas permeable surfaces and green space absorb heat and provide a cooling effect. Without the natural cooling effects of green space, heat is trapped leading to a possible

[5]Johnson, C.D. "Polluted Urban Runoff: A Source of Concern." University of Wisconsin-Extension. 1997. http://clean-water.uwex.edu/pubs/pdf/urban.pdf

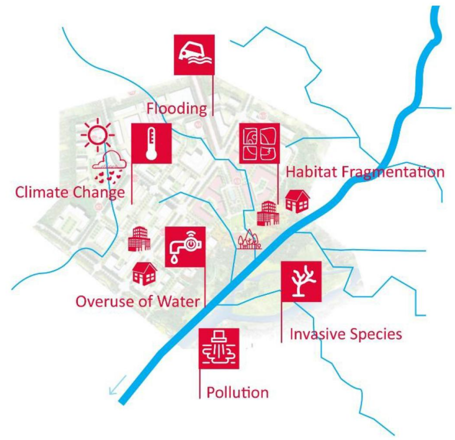
[6] United States Geological Society. "The Water Cycle". August 7, 2015. http://water.usgs.gov/edu/watercycle.html

[7] Gleick, P. H. (editor), Shiklomanov, Igor. "World fresh water resources" *Water in Crisis: A Guide to the World's Fresh Water Resources* (Oxford University Press, New York). 1993.

increase of 22 degrees fahrenheit in built urban areas versus less built rural areas[8]. Increased temperatures lead to increased demand for electricity to cool buildings. Production of this electricity provides even more pollution to be carried over impermeable surfaces by storm water to waterways. It's a dirty cycle that only gets worse as urbanization increases.



existing problems of the area

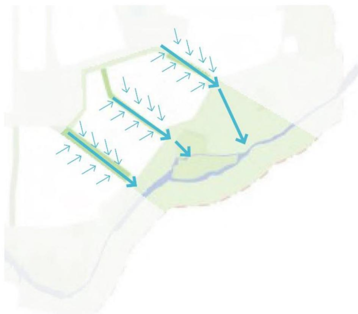


future threats of the urbanized area

In the context of Baihe, we saw vast amounts of impermeable surface without sewage systems, vast amounts of waste strewn in the streets, open latrine systems for most residents and a plan to realize massive seasonal increases of tourists and associated demand on resources. Economically, Baihe's main industry, cement, is being phased out and the city as a whole does not look to have a large tax base with which to implement intricate and expensive systems. Water sensitive urban design (WSUD) provides an alternative approach to urban design systems and technologies to limit the negative impacts of urbanization on water systems at various levels of complexity and price. This section will discuss three such technologies: rainwater gardens, green roof and permeable pavement chosen with consideration to complexity and required expertise, required upkeep, upfront costs and resiliency. Rainwater gardens are the most cost effective technology requiring the least maintenance; therefore more focus will be given to it in particular.

Urban Area Master Plan

[8] Akbari, H. Energy Saving Potentials and Air Quality Benefits of Urban Heat Island Mitigation (PDF). Lawrence Berkeley National Laboratory. 2005. https://www.epa.gov/heat-islands/heat-island-impacts.

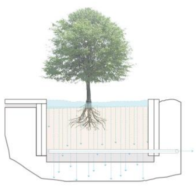


existing hydrology of the area

proposed hydrology of the area

The existing hydrology in SPD’s plan is pretty simple with three bio-swales following the existing tributary. Based on their plan, a more detailed and complicated storm water management system is created within each block to treat run-off on site and release the pressure on bio-swales to make it more resilient.

Rainwater Gardens



Rainwater gardens address a multitude of urban problems while functioning as an aesthetically pleasing landscape and matrix of habitats for native plants, animals and migrating species. This technology addresses all of the major urban problems of runoff and erosion caused by impermeable surfaces, diminishing groundwater and pollution of waterways.

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Runoff from impervious surfaces

Under circumstances with natural ground cover (i.e. 0% impermeable surfaces), on average 50% of precipitation will infiltrate into the ground watering plants and refilling aquifers, 10% will run off and 40% will return to the atmosphere through evapotranspiration. In low density residential (i.e. 10-20% impermeable surface) that ratio changes to 42:20:38. In medium and high density urban environments (30-50% and 75-100% impermeable surface) the ratio alters to a scary 35:30:35 and 15:55:30 respectively[9]. As these percentages show, the amount of impermeable to permeable surface has a huge impact on water infiltration, runoff and the microclimate.

Erosion caused by runoff is also a serious issue facing urban environments and the natural environments that border them. Without the ability for water to infiltrate the ground, it flows and gains velocity as it travels. Once it does reach ground or river beds it hits the soil with such force that it causes soil erosion. Erosion leads to nutrient transfer which has negative impacts not just in where nutrients are leached but also in where they are left. Non-point source pollutants that enter the waterways can harm marine life and the humans that rely on that life as a food source or livelihood[10].

Through observation and GIS, we characterized Baihe as a medium density urban environment. The following are insights from a site visit and most probable impacts on environmental and human health:

1) Lack of traditional stormwater conveyance systems and large impermeable areas
    - Impact: Stormwater could not infiltrate the ground and restore aquifers and either puddled (human health implications) or flowed with increasing velocity, picking up waste and toxins as runoff and not only polluting waterways but also causing erosion[11]
2) Open latrines, inadequate waste management system

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[9] Arnold, Chester L Jr; Gibbons, C James. *Impervious surface coverage: The emergence of a key environmental indicator.* American Planning Association. Journal of the American Planning Association; Spring, pg 243. 1996.

[10] .National Oceanic & Atmospheric Administration. "Watersheds, Flooding and Pollution." November 3, 2015. http://www.education.noaa.gov/Freshwater/Watersheds_Flooding_and_Pollution.html

[11] United States Geological Survey. "Runoff (Surface Water Runoff)". August 7, 2015. http://water.usgs.gov/edu/runoff.html

- Impact: Lack of a waste management system can lead to groundwater contamination, open latrines can easily flood and pollute waterways through runoff[12]

Diminishing groundwater

Groundwater is replenished in part by water soaking into the soil which is impossible in without permeable surfaces. As mentioned before, all life depends on having a water source. How quickly underground aquifers are replenished depends on multiple factors including but not limited to the type of soil which impacts the infiltration rate. Replenishing groundwater requires space in terms of precipitation per square foot. Rain gardens can decrease the amount of pollution that reaches waterways[13].

Technology Components

A main component of rain gardens is bioremediation. Bioremediation filters toxins from water and soil before water enters groundwater or waterways. Done properly, native plants are used in bioremediation efforts. Because they are native they require reduced maintenance, and are typically tolerant of soil, weather and hydrologic conditions. The root systems of many native plants also help to increase soil quality and permeability which leads to further water infiltration. An increase in green space and plants increases water returned to the atmosphere through transpiration thereby reducing the negative impact urban areas have on temperature and the natural water cycle.

Benefits

Rain gardens provide many immediate and systematic benefits. Immediately, by slowing flows of water they extend hydraulic lag time which allows more water to infiltrate into the ground restoring aquifers and reduces erosion. Because rain gardens act as a conduit for water infiltration in storm events, investing in this technology reduces investment in traditional stormwater conveyance systems. It is estimated that 800-2300 ft of rain garden can realize savings of $24,000[14]. With an estimated cost of $3-4/sq.ft., depending on soil quality, bioretention cells in the form of rain gardens would cost $100,000 versus $400,000 in traditional stormwater pond systems. In addition, depending on the scale of the rain garden, it may not require permits and, as a piece of residential landscape provides residents with visual benefits without burdening city maintenance budgets.

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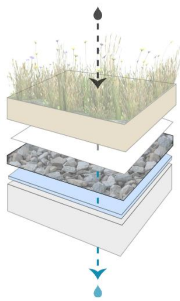
[12] Graham, J.P. Polizzotto, M.L. “Pit Latrines and Their Impacts on Groundwater Quality: A Systematic Review.” *Environmental Health Perspectives*. Volume 121, Issue 5. May 2013.

[13] S. Tang, et al. “Evaluating Retention Capacity of Infiltration Rain Gardens and Their Potential Effect on Urban Stormwater Management in the Sub-Humid Loess Region of China.” *Water Resource Management*. Volume 30, Issue 3, pg 983-1000. February, 2016.

[14] EPA Office of Water. *Storm Water Technology Fact Sheet: Bioretention*. EPA 832-F-99-012. 1999. http://www.lid-stormwater.net/bio_costs.htm

Risks and considerations
Bioremediation must balance amounts of toxins with filtration abilities. If not, toxins enter groundwater in concentrated amounts that will likely degrade human drinking water supplies. It is therefore crucial that toxin types and levels be known in order to provide adequate bioremediation. Another consideration is the impact that climate change has on the intensity and frequency of precipitation events. We are seeing 50- and 100-year storms happening more frequently which will require forward thinking planning.



Green Roofs

Green roofs have seen a surge in popularity in highly concentrated urban environments around the world and have benefited from creative and unique innovations. This technology is multifunctional, it reduces landfill waste by improving the lifespan of building materials and using waste as an input, reducing demand for electricity, mitigating urban heat island effect (UHI), increasing biodiversity and providing mental restoration for urbanites[15].

Reduces landfill waste[16]
By providing insulation in buildings, green roofs keep buildings more temperate therefore reduces the need to use the HVAC system. Reduced use increases the lifespan of large and small units. Upstream, this reduced use of the HVAC system equates to a reduction in energy use thereby reducing the amount of associated greenhouse gas emissions.

The urban environment is a built environment that is subject to normal wear and tear through use and exposure to various environmental forces. Green roofs protect roof membranes from the degrading effects of ultraviolet light, thereby extending the life of roof systems and reducing the need for frequent replacement. In addition, by buffering and absorbing precipitation, green roofs also reduce the direct impact of water against the membrane. The roof, siding and foundation all have weatherproofing. Weatherproofing usually involves a highly water resistant coating. By reducing the amount of water that interacts with the coating it reduces the amount of toxins that are transferred from coating to urban runoff.

Many innovations have and are occurring in the area of green roofs. Edible gardens that serve the same insulation, filtration and protection functions also provide local food and service as places of community interaction and involvement. Upcycled material is diverted from landfills to be used as growing medium for green roofs.

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[15] Green Roofs for Healthy Cities. "Green roofs offer many public, private, and design-based benefits." December 18, 2015. http://www.greenroofs.org/index.php/about/greenroofbenefits
[16] IBID

Benefits
As with rain gardens, green roofs not only reduce urban runoff and associated water pollution they also limit intrusions on the water cycle by providing groups of plants that transpire, and soil media that holds water, allowing it to evaporate. In summer, green roofs can retain 70-90% of precipitation and 25-40% in winter. To visualize, that means that a 4-20cm growing medium can hold 10-15cm of water. Also like rain gardens, green roofs help reduce stress on sewage systems and required investment.

The Urban Heat Island (UHI) is an increasing problem that compounds on itself and is largely caused by modification of land surfaces[17]. Dark surfaces absorb heat, specific building materials such as concrete and asphalt hold more energy during the day and release it slowly at night leading to warmer days and nights. Urban areas have far less vegetation and therefore do not benefit from the natural cooling effects evapotranspiration through vegetation and shade provided by trees and shrubs[18]. UHI also increases when greenery is lacking because less carbon dioxide is absorbed by plants. Increased concentrations of carbon dioxide and other greenhouse gas emissions leads to increased temperatures[19].

The negative impact of cities on the human psyche has been extensively documented. Constant stimulation requires our brains to constantly filter out distraction, this leads to mental fatigue. Experiencing nature helps to restore directed attention leading to higher levels of effectiveness and happiness[20].

Lastly, green roofs provide a green corridor for some wildlife, such as butterflies and birds, with the roofs acting as stepping stones between fragmented habitats (usually fragmented by human settlements). In one study, over 30 species were found thriving in a single green roof[21].

Technology Components
Material, management and expertise for green roofs is more complicated than other technologies. Materials include protection and retention fabric, granular mats and drainage plates and drainage channels, filter fabrics and plants. In addition, building support structures

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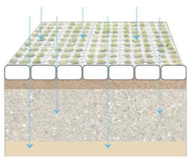
[17] United States Environmental Protection Agency. “Reducing Urban Heat Islands: Compendium of Strategies - Urban Heat Island Basics.” November 11, 2015. https://www.epa.gov/sites/production/files/2014-06/documents/basicscompendium.pdf
[18] U.S. Department of Energy. “Green Roofs.” August, 2004. DOE/EE-0298. https://www.nps.gov/tps/sustainability/greendocs/fta_green_roofs-sm.pdf
[19] Garrison, Noah. Horowitz, Cara. “How Green Roofs and Cool Roofs Can Reduce Energy Use, Address Climate Change, and Protect Water Resources in Southern California”. June 2012. https://www.nrdc.org/sites/default/files/GreenRoofsReport.pdf
[20] Kaplan, S. “The Restorative Benefits of Nature: Toward An Integrative Framework.” *Journal of Environmental Psychology* 15, 3: 169-182. 1995
[21] M.T. Fountain, S.P. Hopkin. Biodiversity of Collembola in urban soils and the use of Folsomia candida to assess soil ‘quality’. pp. 555–572. 2004. http://www.sciencedirect.com/science/article/pii/S2212609014000211

must be designed to hold the additional weight of a green roof. If an edible green roof is installed, even more knowledge and maintenance is required. At an estimated $10-25/sq.ft., it is more expensive than many other technologies[22]. Because of the financial and technical aspects of green roofs as well as unknown infrastructure integrity, we do not suggest Baihe use this technology on existing infrastructure but consider requirements for green roofs when designing specifications for future buildings.



Permeable Paving

Unlike impermeable pavement, permeable pavement is designed specifically to allow infiltration of water to the ground below by its unique base and substrate construction[23]. Permeable pavement is currently most suitable for areas with light traffic such as sidewalks, emergency roads, parking lots, bike paths, etc. As parking lots are often places with high toxins including oil, gas and heavy metal particles, this is a particularly important place to not allow for urban runoff. Border phytoremediation is an important addition to areas using impermeable pavement.

Reduces Urban Runoff, Filters Pollutants

Being permeable, this type of paving naturally reduces urban runoff by allowing precipitation to to filter through the pavement and into the soil. Not only does its porous design allow for this but its base and sub-base structure also filters out toxins before they enter the groundwater. Following the same idea behind hydroponic agriculture, micro-organisms live in the empty spaces of the base substrate levels and feed on the toxins and even metals that filter through leaving only water and carbon dioxide. Permeable pavement is a very useful part of a systematic approach to water sensitive design. When combined with a swale, only 10% of rainfall is converted to runoff versus 51% with traditional asphalt alone[24]

Promotes Environment for Greenery

Because permeable pavement allows for the infiltration of water over a large area, groundwater is more available over the entirety of the area thus allowing for greenery. If native species are used, even less maintenance and watering may be required. Plants will uptake carbon dioxide, provide shade and transpire thereby countering UHI. Plant roots can also help filter toxins and stabilize and enrich the soil further promoting precipitation infiltration.

Technology Components

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22 Bruening, Jorg. Green Roof LLC. “Green Roof System”. 2016. http://www.greenrooftechnology.com/greenroof-system

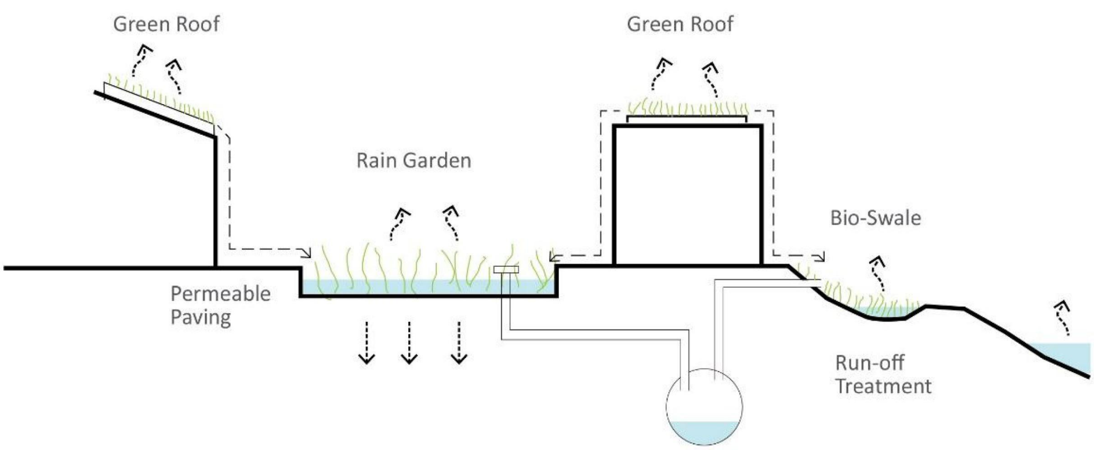
23 Interlocking Concrete Pavement Institute, “Sustainability Equals Preserving People, Planet and Profit”. 2015. http://www.icpi.org/sustainable

24 University of Maryland-Extension. “Permeable Pavement Fact Sheet Information for Howard County, Maryland Homeowners.” November 13, 2015. http://tinyurl.com/olrakkv

Depending on the type of permeable pavement being used, the cost will vary ranging from $1.50-10/sq.ft. versus $.50-1 for traditional pavement[25]. although exact materials and designs vary, all have a permeable base and sub-bases that not only allow for precipitation filtration but also filtration of toxins.

Risks and Considerations
Permeable pavement is considerably more expensive especially when taking into account an entire urban area. In addition, it is not suitable for heavy loads and therefore limits the activity it can support. Because it allows water and toxins to filter through proper building material that supports micro-organism activity must be used in order to keep pollutants from entering the groundwater. Effectiveness of water infiltration through permeable pavement into groundwater is impacted by the composition of the soil and its associated infiltration rate.

An Efficient and Resilient System



Water will be infiltrated from the green roof and could be collected in permeable paving or rain garden if it overflows. Rain garden can retain and filter rainwater on site and perform educational demonstration site for the community. An underground detention structure is

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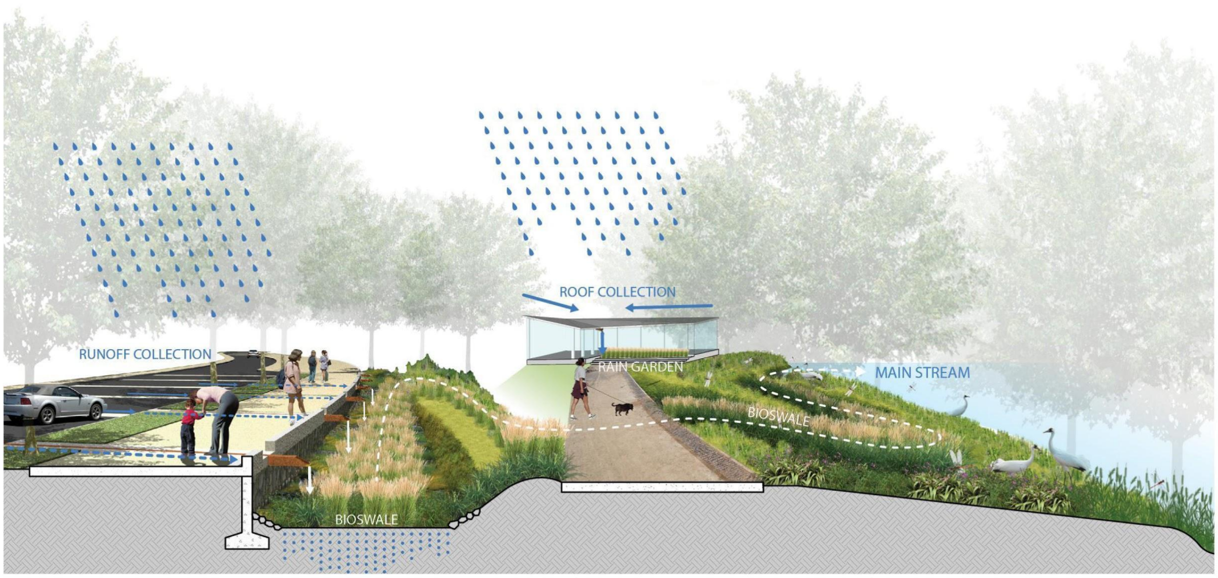
[25]"Permeable or Pervious Pavers Cost Comparison." March 13, 2016. http://www.paversearch.com/permeable-pavers-costs.htm

created in case rain garden overflows and it could help detain water and convey it to the bio-swale after the rain event, where rainwater will be treated before it flows to the river.



With such an integrated rainwater management system, we really focus on filtering toxins and keeping them out of waterways, refreshing underground aquifers, reducing soil erosion, creating appealing public space and providing educational opportunity for the community.

Industrial

The design proposal for the industrial site of Baihe focuses on limestone mine reclamation and native plant ecosystem regeneration. While the small town's economy relies on cement manufacturing and limestone quarrying, the pollution generated from the mines and factories is unhealthy for residents and the environment. Learning from post-industrial and eco-tourism case studies for ecological landscape design, this proposal focuses on generating a sustainable landscape based on water sensitive design, ecological restoration, environmental justice and environmental education. This proposal should be seen as a model for SPD when designing in similar areas where environmentally hazardous industry should be replaced and deforested sites should be reclaimed.

Cement industry in China

In the book *Making the Modern World: Materials and Dematerialization*[26] Vaclav Smil writes that China used more cement in the three years between 2011-2013 than the United States used during the entirety of the 20th century. This fact became a popular re-tweet from Bill Gates and blog subject in the United States after it was published, highlighting the astonishing consumption rate and rapid industrialization of China.

Three years of China's cement in downtown Chicago; Covering Hawaii (Allain, 2014)

As the primary ingredient in concrete and the second most consumed substance on the planet after water[27], cement consumption and production is integral to the urbanization and growth of new China. Concrete is the substance of China's new cities - buildings, bridges, roads, and dams, and it is what is paving over China, and decreasing the amount of agricultural and forested land in the country. After all, China was urbanizing quickly enough to consume 6.6

[26] Smil, V. "Making the Modern World: Materials and Dematerialization." Hoboken, NJ, USA: Wiley, 2013."
[27] Rubenstein, M. "Emissions from the Cement Industry." State of the Planet, Columbia University. May 2014. http://blogs.ei.columbia.edu/2012/05/09/emissions-from-the-cement-industry/

gigatons in three years, enough cement to cover all of the Big Island of Hawaii in a .25 meter thick parking lot.

Forests in China

The ecological restoration of a limestone mine to a “native” ecosystem is difficult to determine, because people have been altering the Chinese landscape for thousands of years. In the Taihang Mountains, where Baihe is located, forests have been almost completely destroyed by people since 2500 B.C.E. There are no native forests left, only secondary forests in some areas.[28] However it is clear that afforestation efforts are necessary. Since 1989, the national level plan known as Taihang Mountain Afforestation Action has been implemented to improve the forest coverage rate from 15% to 35% in three phases: 1986-2000, 2001-2010, and 2011-2050. With the completion of the second phase (2001-2010), forest coverage rate has increased 9.99%. This action also effectively improved ecological balance and protection of biodiversity, and directly created economic benefits for tourism and wood industry up to 11.4billion RMB. In the third phase of this action, the government would transfer the focus from afforestation to forest management which aims at preserving water and soil in the long term.[29]

Before the foundation of the People’s Republic of China in 1949, China had few remaining forests and consequently a poor base for forestry. At present, forests cover an area of 130 million ha, which is only 3–4% of the total forest area of the world. Rapid population growth, coupled with the development of agriculture, industry and construction, the over-exploitation of forest resources and subsequent cultivation on steep slopes have led to the deterioration of forest ecosystems and a reduction in biodiversity. As a result of these changes, China has faced a series of hazards and disasters including soil erosion, desertification and floods. At least 200 plant species have become extinct in China since the 1950s, and more than 61% of wildlife species have suffered severe habitat losses. As of 2004, 38% of China’s total land area was considered badly eroded.[30]

Forests are economically and ecologically beneficial for many reasons, including soil stabilization, flooding reduction, biodiversity and habitat for wildlife, CO_2 sequestration, timber generation, and human recreation.

Environmental impact of the cement industry

Urbanization and the rapid consumption of concrete has environmental impacts on its own - from decreasing the health of waterways, to increasing urban temperatures, to fragmenting habitat. However China produces much of the cement it consumes, and the mining and manufacturing of cement degrades large tracts of land and contributes to pollution. China has

[28] Xiao-lan, Y. et al. “Vegetation Changes of the Taihang Mountains Since the Last Glacial.” Institute of Geography, Hebei Acadamy of Sciences. Volume 10, Number 3, pp 261-269.
[29] ‘Taihang Mountain Greening Project’ Baike Baidu:<http://baike.baidu.com/link?url=PgC6Q-EITsGm3LfXRHj9YxCBisB-hJQd35byRY2jcaVZYl0bbbxerlm1eX1defTb6fK4rDUHEIf_WnSfI8Io8_>
[30] Li Wenhua, Degradation and restoration of forest ecosystems in China, Forest Ecology and Management, Volume 201, Issue 1, 1 November 2004, pp 33-41. http://www.sciencedirect.com/science/article/pii/S0378112704004360

the largest cement industry in the world, producing 2.18 billion tons in the year 2012.[31] Cement is the combination of crushed limestone and other materials like clay, heated at 1400°C. Mining limestone and producing cement takes an extraordinary amount of land and energy, and the environmental impact ranges from land degradation and desertification to the release of toxic and cancer-inducing chemicals into the air. There are approximately 1,840 limestone mines in China today[32] and approximately 12% of them are located in the Northern region where our site is located.

The cement industry has now become one of the major pollution sources in China, and may discharge more than 10 million tons of particulate into the air every year, some of it very toxic to humans. Hebei Land Resources Bureau has implemented the action plan of Mine Environment Restoration for preventing air pollution and has permanently closed 56 mines and shut down 251 mines in 2014.[33] In this year, in response to national planning regulations, Hebei Land Resources Bureau must implement a specialized regulation imposed on all the mines in Hebei province. The regulation is to strictly limit opencast mining permits and ambitiously finish ecological restoration of mines within three years. In particular, due to the potential safety danger and environmental concerns of limestone mining, the government would completely close all the limestone mining and force the limestone industry quit out of the industry chain in Hebei province.[34]

The cement industry accounts for about 5% of global carbon dioxide emissions. There are opportunities to mitigate emissions and particulate matter with efficiency measures and changing the calcination process, which creates emissions when limestone is heated and breaks down into calcium oxide and CO_2.[35] According to the China Mining Organization, "controlling pollution and improving environment are arduous tasks to be completed in the sustainable development of the Chinese cement industry…restructuring should be implemented to eliminate a group of small enterprises that employ backward technologies, waste resources and pollute environment[s]."[36]

Current state of Cement Industry in Baihe

Our site in Baihe is in Hebei in North China, which accounts for 12% of China's total limestone production, at around 6.2 billion tons per year.[37]It is along the southwestern edge of the Taihang mountain range, in the limestone region. Almost all of the industry in Baihe is related to limestone mining, cement, or glass manufacturing.[38]

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31 Staff, "China: First in cement." Global Cement. July 23, 2013. http://www.globalcement.com/magazine/articles/796-china-first-in-cement

32 Staff, "Development and Utilization of Cement Limestone Ore". China Mining: Facts. 2016. http://en.chinamining.com.cn/Facts/2006-10-17/1161069026d1628.html

33 "Heibei Province Repairs Dust Prolems by Closing 56 Mining Industry Sites in Mountain Area" <http://news.xinhuanet.com/local/2014-08/06/c_1111964849.htm>

34 Ministry of Land and Resources of the People's Republic of China: "Hebei Province Acts on Opencast Mining Mountains", <http://www.mlr.gov.cn/xwdt/kyxw/201601/t20160126_1395937.htm>

35 Rubenstein, M. "Emissions from the Cement Industry." State of the Planet, Columbia University. May 2014. http://blogs.ei.columbia.edu/2012/05/09/emissions-from-the-cement-industry/

36 "Supply and Demand" China Mining: Facts. China Mining. Web. 12 Feb. 2016. http://en.china

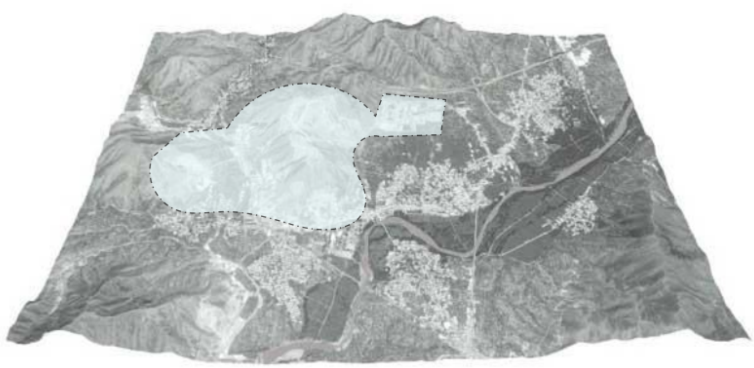
37 "Resources" China Mining: Facts. China Mining. Web. 12 Feb 2016. http://en.chinamining.com.cn/Facts/2006-10-17/1161069302d1629.html

38 Provided by SPD Ltd. "Tangxian Annuals." Tangxian Compilation Committee. 1991-2010.

Just like other mining-dominated small towns in China, Baihe relies on mining to thrive but also suffers from all the environmental impacts caused by mining. Baihe, ranking second provincially in discovered reserve of limestone ore which is 114.65million metric ton, has three mid-scale mining sites and one small-scale mining site based on national survey of 2000.[39] Relying on its abundant mineral resources, Baihe has established a Construction Material Industrial Park which is led by Ji Dong Cement Company and attracted investment from other companies. It has achieved 0.38billion of value-added in RMB and created 5460 job opportunities in 2015, and has been regarded as the pillar industry to boost economy in Baihe town. However, environmental pollution within in Baihe town is also generated from its industrial development. Air pollution is mostly resulted from coal burning, a lack of construction covering, waste gas discharging become one of the most serious environmental concerns in Baihe. Water contamination from industrial sources also threatens the livelihood of agricultural production. Ecological deterioration of mining area is the most astonishing impact of this mining-dominated development pattern.

Since 2014, Tangxian has issued the industry regulation specifically on nonmetallic mining industry, and the local government closed all the limestone mines and other industries in Baihe due to health hazards from air pollution.[40] Our client, SPD International Design, was tasked to create a Master Plan for the town that could grow the economy sustainably after the mines were closed.

Design Considerations for Baihe's Limestone Mines



Area for restoration strategy implementation

Site Conditions:
Soil:
Paddy soil along Tang River, the rest of area is cinnamon soil. Cinnamon soil includes Leached cinnamon soil, Calcareous cinnamon soil, Meadow cinnamon soil.

Climate:
Temperate Continental Monsoon Climate

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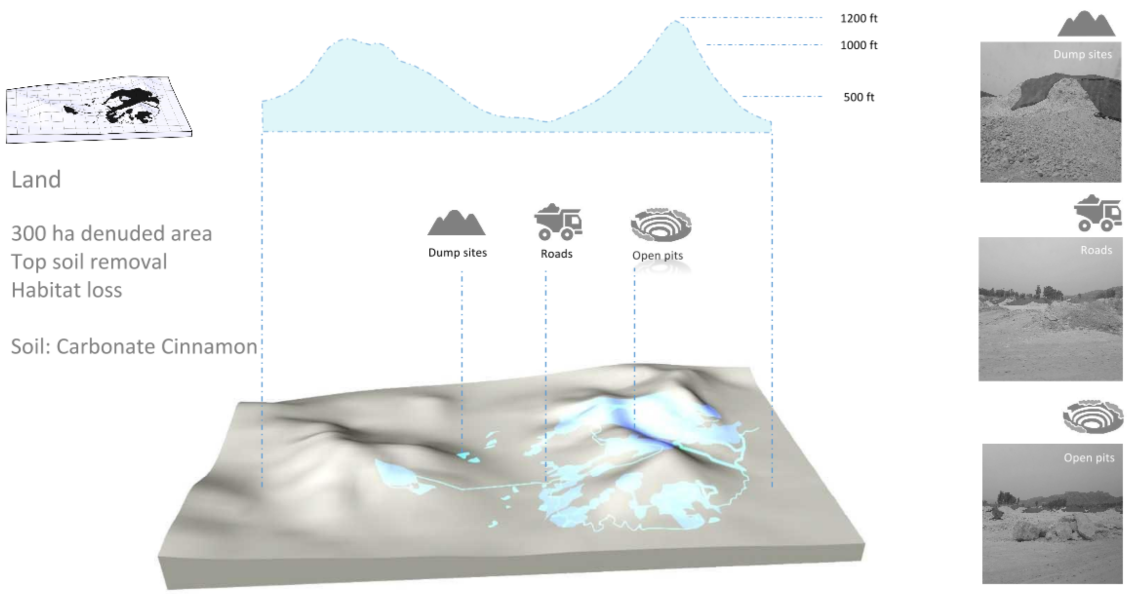
[39] Provided by SPD Ltd. "Tangxian Annuals." Tangxian Compilation Committee. 1991-2010.
[40] "Tang County's Three Acts for A Future of Ecological County", <http://mt.sohu.com/20150525/n413737509.shtml>

Winter: Cold and dry. Avg temp: -1 degree C. Lowest temp: -19 degree C. Precipitation: 19.8mm;
Spring: Windy. Precipitation: 34.4mm
Summer: Rainy, wet and hot. Precipitation:321.3mm. Highest temp: 34.2 degree C.
Fall: Precipitation: 91mm.
Rainfall: Annual average precipitation is 499.6mm. Heavy rainstorm is intensive during July to August.
Vegetation below 700 meters: Aspen, willow, birch, beech, elm, Chinese catalpa, tree of heaven, chaste tree, zizyphus jujube tree.

Goals of the sites

Ecological Restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed but beyond that as well, restoration is a reference point for the future, and establishing dynamic, ever-changing entities and processes.[41]

Land Site Analysis and Opportunities



Within the 200- 300 hectares of denuded area, degraded land can be characterized into dump sites, roads, and open pits, and re-forested according to slope, aspect, and soil composition and restored accordingly.

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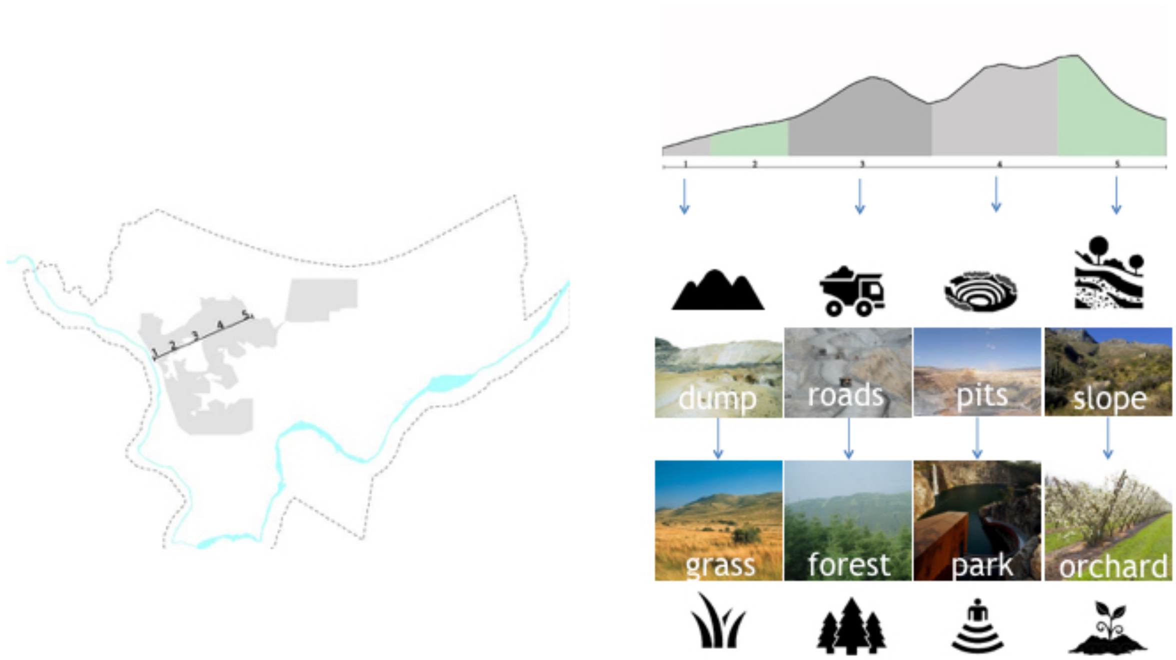
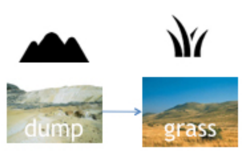
[41] Howell, E., Harrington A., and Glass, S.B. "Introduction to Ecological Restoration." Island Press, 2011.



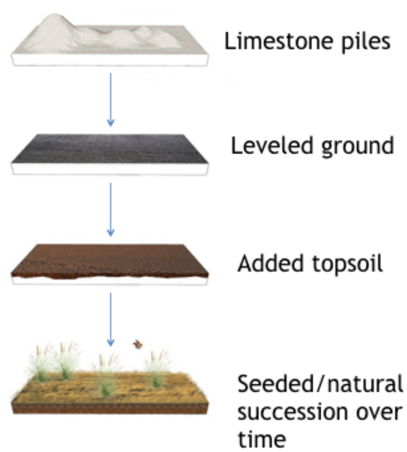
Above: Example restoration strategy for restoring degraded characterized land into recovered landscapes.



Environmental issue:
- nutrient-poor soils
- surface erosion
- habitat loss

Strategy:
- level piles, add top soil with organic matter, seed
- OR level piles, and manage natural succession.

Environmental benefits:
- Limestone-rich soils provide habitat for rare and endangered flora and fauna.
- Drainage and erosion restored



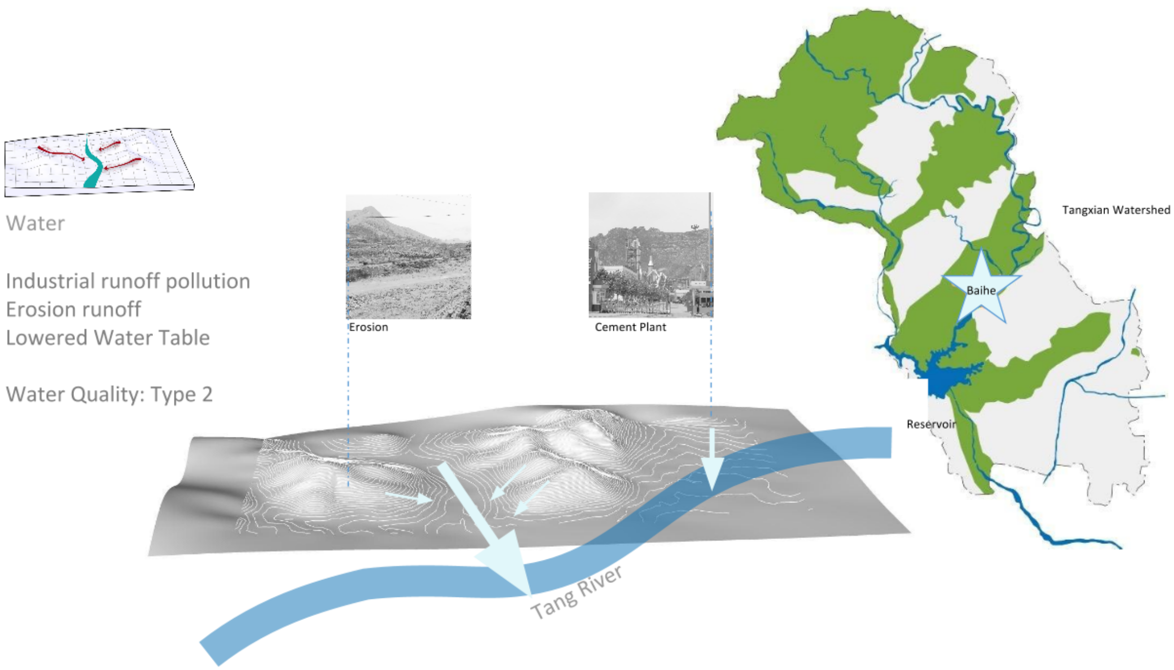
Above: Example restoration strategy for restoring dump sites into grassland.




Above: Afforestation with monoculture *of* Populus tremula*; Denuded slopes from the open pit mines*

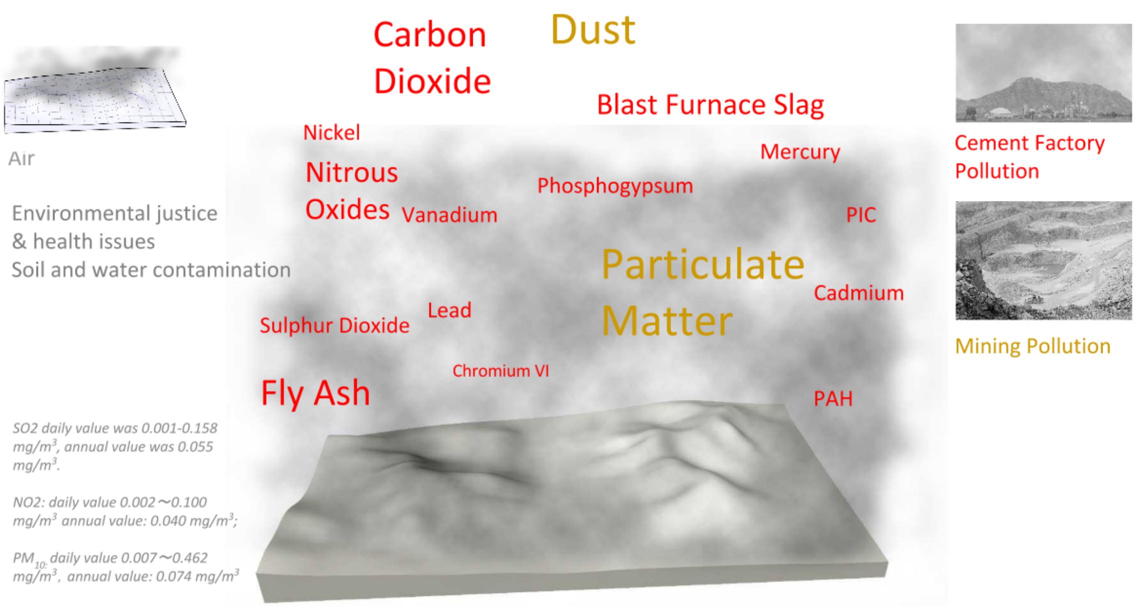
48% of native species are endangered in the southwest part of the Taihang Mountains. Previous afforestation efforts have used water-intensive monocultures of *Populus tremula*, the Eurasian poplar. The 300 ha of closed and degraded limestone mines provide an opportunity for reforestation with diverse native species that reestablish habitat and soil and cleanse the land, air, and water of pollutants.

Water Site Analysis and Opportunities



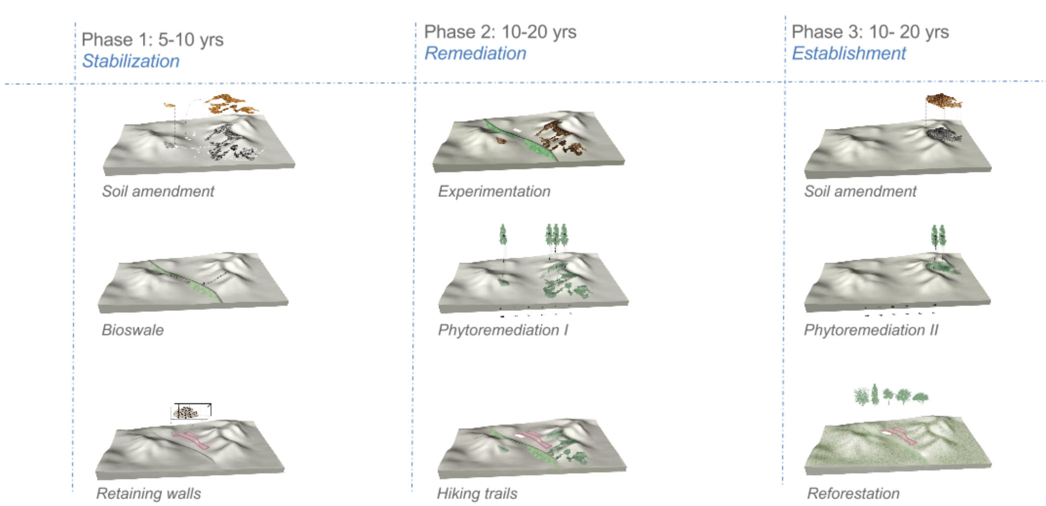
Water: The majority of the pollutants from the site are coming from the cement industry wastewater runoff. While the cement factory remains open, there needs to be wastewater treatment facilities. To cleanse pollutants from denuded slopes of closed mines, stormwater technologies should be installed in appropriate locations to increase infiltration and filter water before it enters the Tangxian watershed system.

Air Site Analysis and Opportunities



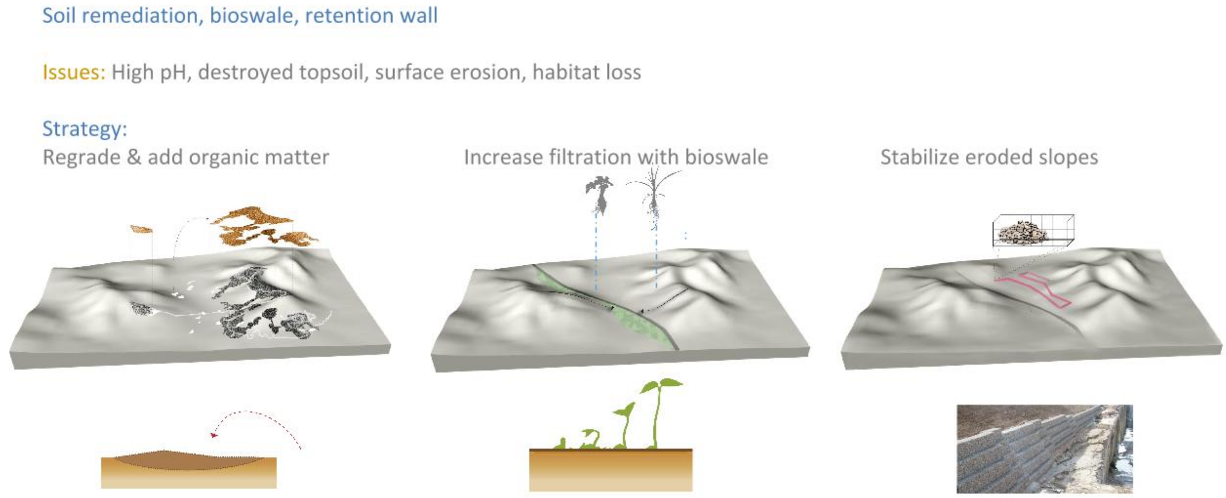
Air: Cement kilns produce large amounts of greenhouse gases, heavy metals, and particulate matter into the air. SO2, NO2 and PM levels in Baihe are higher than the EPA minimum standards and are potentially very dangerous to human health. These pollutants may be present in the soil and may require techniques such as amendment, removal, cleansing, or phytoremediation techniques for sequestration, extraction, or volatilization.

Site Strategy



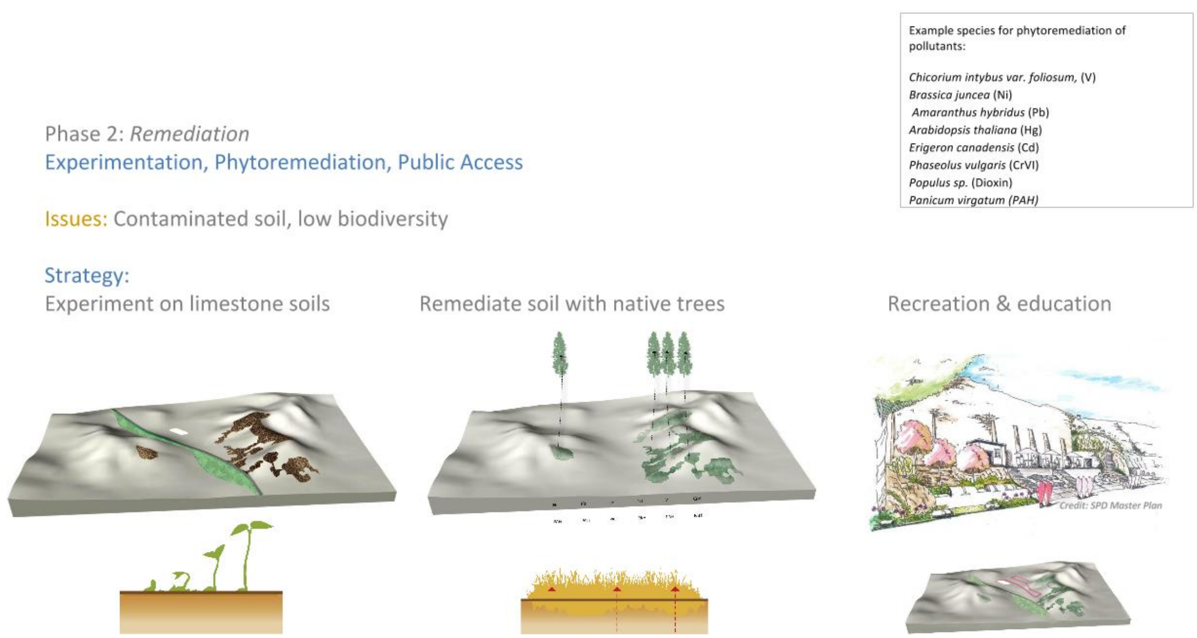
To provide an example of limestone reclamation, this is a design strategy in three phases. Stabilization, remediation, and establishment.

Phase I: Stabilization



For stabilization, the soil is amended with organic matter, the runoff is filtered with bioswales, and the slopes are stabilized with retaining walls.

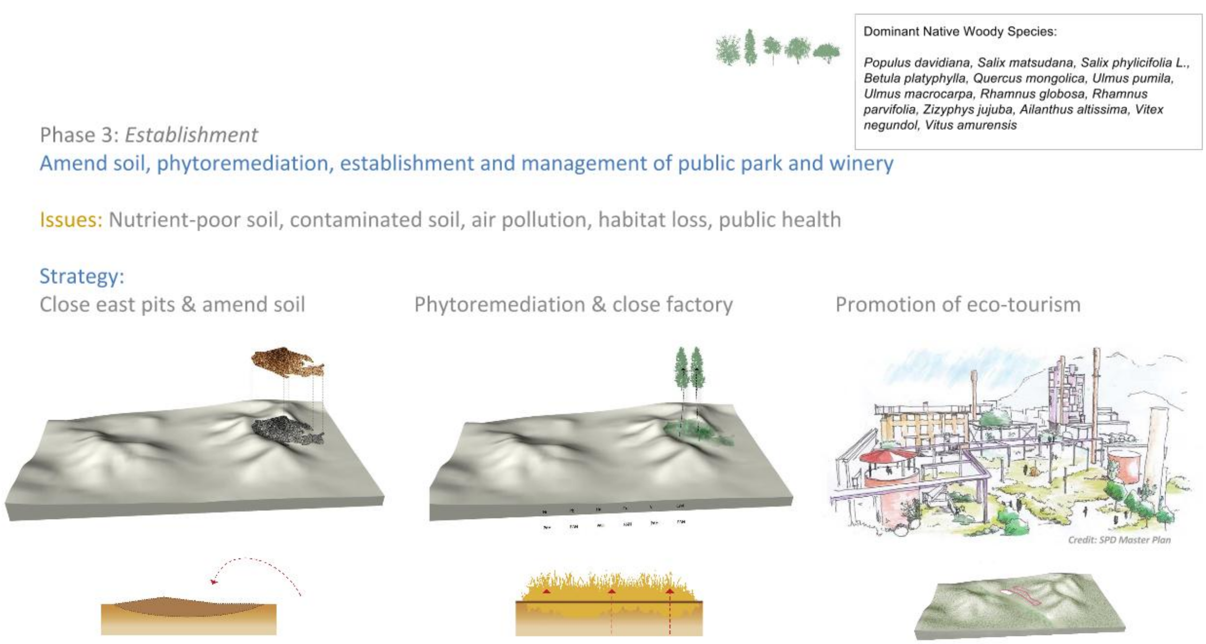
Phase II: Remediation



For remediation, the succession of and seeding of plants needs to be managed over time to ensure successful establishment of species. Phytoremediation with native trees, grasses, and forbs reduce present pollutants. And this is done using the public as volunteers for environmental stewardship and recreational purposes.

Pollutant	Phytoremediation species	Phyto-mechanism
Vanadium (V)	Chicorium intybus var. foliosum, Erigeron canadensis, Eupatorium capillifolium	Phytoextraction
Nickel (Ni)	Brassica juncea, Chicorium intybus var. foliosum, Erigeron canadensis, Eupatorium capillifolium, Helianthus annuus, Medicago sativa, Thlaspi caerulescens, Thlaspi caerulescens, Sebertia acuminata	Phytoextraction/phytosequestration
Lead (Pb)	Amaranthus hybridus, Amaranthus paniculata, Brassica campestris, Brassica carinata, Brassica juncea, Brassica napus, Brassica nigra, Brassica oleracea, Carex microptera, Helianthus annuus, Lemna minor, Medicago sativa, Nicotiana tabacum, Solanum elaegnofolium, Sorghum bicolor, Thlaspi caerulescens, Typha and Phragmites spp., Zea mays, Alnus tenuifolia, Betula occidentalis, Salix spp.	Phytoextraction/phytosequestration
Mercury (Hg)	Arabidopsis thaliana, Nicotiana tabacum,	Phytoextraction/phytovolatilization
Cadmium (Cd)	Brassica juncea, Chicorium intybus var. foliosum, Erigeron Canadensis, Eupatorium capillifolium, Helianthus annuus, medicago sativa, Nicotiana tabacum, Solanum elaegnofolium, Thlaspi caerulescens, Thlaspi caerulescens	Phytoextraction/ phytosequestration (alfalfa)
Chromium VI	Phaseolus vulgaris cv. Contender, Beta vulgaris, Brassica juncea, Helianthus annuus, Lactuca sativa cv. Cos, Thlaspi caerulescens, Typha and Scirpus spp.	Phytoextraction/phytovolatilization/ rhizofiltration
Dioxin	Cottonwoods	
PAH	Medicago sativa, Panicum virgatum, Schizachyrium scoparium, mixed grass community	

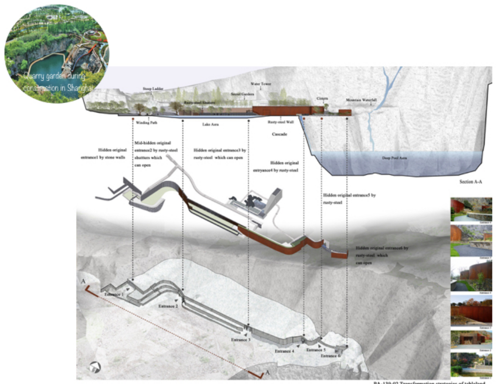
Phase III: Establishment

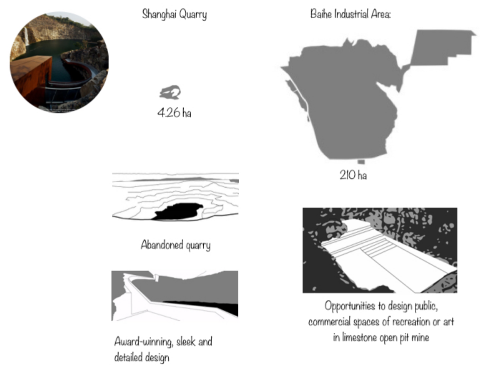


The final phase is to establish and maintain this area as a vibrant, healthy, and attractive park. The cement factory will eventually be closed once a viable economic transition can be made, and relic industrial parks provide recreation and eco-tourism.

Case studies for Industrial Landscape Architecture

Shanghai Botanical Quarry Garden, China

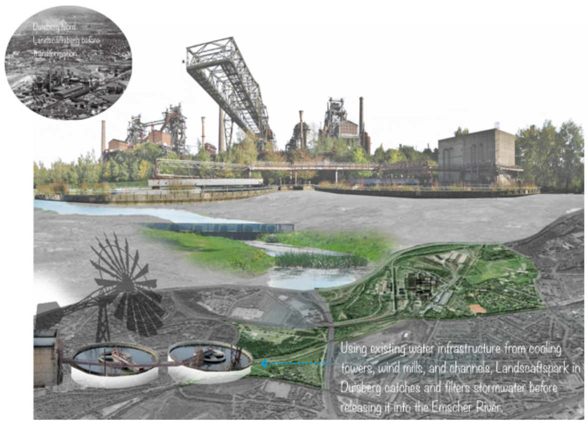


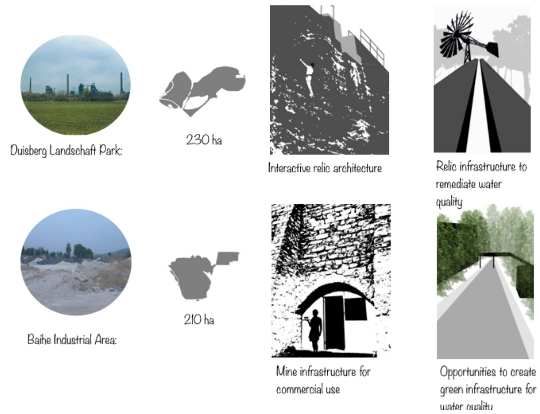


The Quarry Garden in Shanghai Botanical Garden is a successful quarry reclamation case study which changed a severely-damaged quarry into one attractive tourist resort. With stricter policies on mining industry and also more concerns on environment, the question of how to restore closed mines and abandoned pits back with ecological values becomes a challenge. With the Shanghai Botanical Gardens Quarry, the severely degraded ecological environment, which has very little vegetation cover, rock weathering and water and soil loss problems, is the critical challenge faced by designers. In their design, the master plan divides the quarry garden into three parts: The Lake Area, The Platform Area, and The Deep Pool, and so different strategies are applied to different area conditions. The lake area which used to be lifeless and rock surface has been reconstructed the landform and formed to a new “Mirror Lake” and “Flower-seeing Platform”. The platform area is designed to establish proper connection between quarry garden and people by using free stone wall and steel plate. The deep pool area as the core zone of this project has been created a sightseeing route to connect east-west quarry and to provide more angles and spaces to enjoy the dramatic sight. This quarry garden successfully displays a reshaped landform and new biocoenosis, and also incorporates traditional Chinese landscape painting into this project to create natural and cultural experience of oriental style. The dramatic highlights of this project is its capabilities of ecological restoration and culture reconstruction strategies.[42]

[42] “Quarry Garden in Shanghai Botanical Garden.” 2012 ASLA Professional Awards. https://www.asla.org/2012awards/139.html

Landschaftspark Duisburg Nord, Germany





Landschaftspark Duisburg Nord is another fitting case study which preserved as much of the existing sites as possible to heal the abandoned industries and to create a fascinating park landscape unlike any other in the world. Encouraged by rigorous policies requirement and the larger Emscher Regional Park Plan(IBA 1999), Duisburg Nord is designed to redevelop this former steel mill site to restore ecological values and stimulate the economy. With the Landschaftspark, the critical question is how to manage contaminants under a tight budget while retaining the steel mill's structure as the framework for the park. Designers separated rainwater from the highly polluted Emscher River water which was piped underground through the park, and kept clean rainwater flow in a narrow linear channel above ground. Brightly painted catwalks were designed to direct visitors to avoid parts of the site where residual contamination is greatest. As with contaminated debris from building demolition, less contaminated ones was grounded into concrete paving, and others were sealed and buried in former ore bunkers. The key tactic used throughout this project is the separation of visitors from contaminated areas and materials, and this makes this project a masterful landscape design that perfectly combines ecosystem functions and societal values.[43]

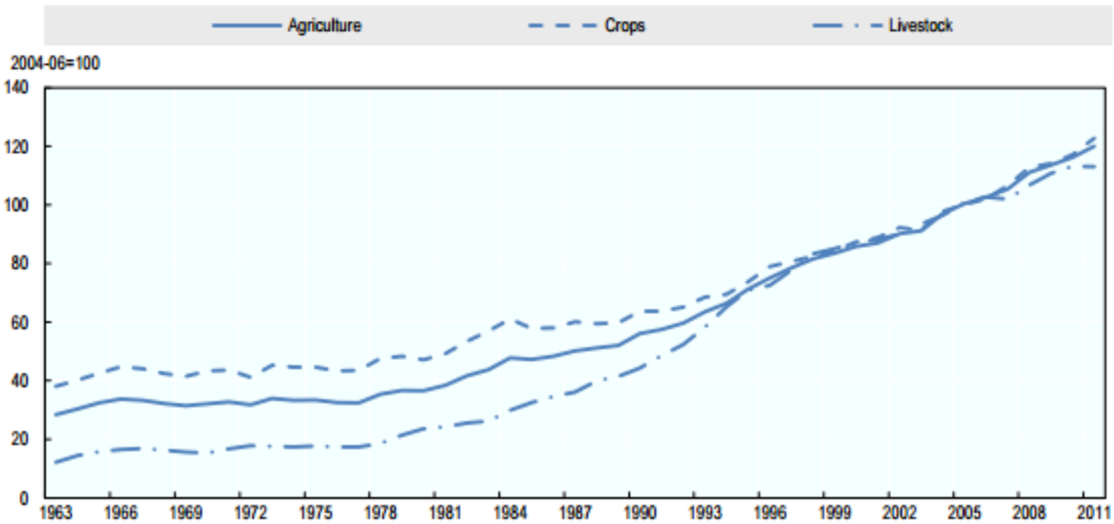
[43] "Landschaftspark Duisburg Nord." Landezine, Latz + Partner. http://www.landezine.com/index.php/2011/08/post-industrial-landscape-architecture/

Agriculture in China and implications for design

China's "historic economic and social transformation" since the 1970s has, and will continue to have, immense implications for its agricultural industries and for the markets that depend on what is grown within the country's borders.[44] The country possesses approximately seven percent of the world's arable land, spread across seventeen discrete provinces. In contrast, China's population comprises roughly twenty-five percent of the world's population. When viewing it on a map, China's vast 3.5 million square mile outline seems limitless, but that image belies the mountain ranges, desert and untenable soils that reduce the potential for arable land. Although still strong, agriculture has been declining as an industry as Chinese workers move to the cities: 2011 was the first year that China's urban population exceeded that of its rural population.[45] Employment in the agricultural structure has greatly declined as China urbanizes; persons employed in agriculture, forestry and animal husbandry fell from 4,850,000 in 2003 to 2,950,000 in 2013.[46] China's agricultural economy restructured itself after the Cultural Revolution, moving away from traditional grain crops and toward cash crops and livestock.[47] Moreover, its 2001 accession to the World Trade Organization shifted the country's emphasis toward crops for which there was an international demand, such as rice and corn. The two figures below, from FAO Statistical Programme of Work and China's National Bureau of Statistics, respectively, illustrate overall growth of agricultural production in China and then provide a breakdown of which crops/foods are emphasized between the years 1978 and 2011.

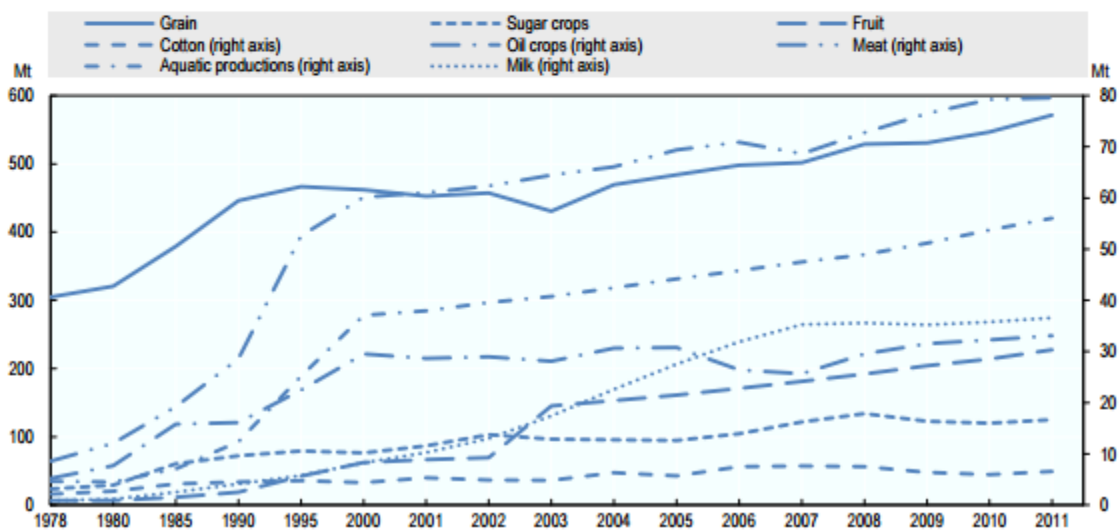
[44] Op cit., OECD & FAO, p. 51.
[45] China Statistical Yearbook, 2012.
[46] Huang, A.L. "Leaving the City: Artist Villages in Beijing." M/C Journal 14.4, 2011, p. 6. http://journal.media-culture.org.au/index.php/mcjournal/article/viewArticle/366
[47] Ibid, p. 8.

Figure 2.1. Agricultural production in China



Source: FAOSTAT.

Figure 2.2. Production of major agricultural products in China



Source: National Bureau of Statistics, China.

Today, agricultural production accounts for approximately 11% of gross domestic product, and in 2009 the sector employed nearly 50% of the population.[48] Given many challenges to agricultural production in China, such as limited quality cropland and many areas with very little water, the Chinese government has been active in providing financial support to the farm sector, ramping up funding significantly since 2004.[49] Doing so has also helped to mitigate the income disparity the country is experiencing overall, helping to "promote social harmony" by making the

[48] "China's Agricultural Trade: Competitive Conditions and Effects on U.S. Exports." United States International Trade Commission. USITC Publication 4219, p. 4-1. March 2011. https://www.usitc.gov/publications/332/pub4219.pdf
[49] Ibid.

country self-sufficient in domestic grain production, raise farmers' incomes, and augment rural development.[50]

China has worked carefully to protect small farmers, meaning that the average size of a farm in China amounted to just .55 hectares in 2000.[51] Most agricultural production is still carried out by small farmers, and they also play an important role in dairy and meat production.[52] Food security concerns about food produced in China have come to the forefront.[53] Despite challenges and limitations, major improvements in productivity have been made, particularly since the 1970s. Between 1978 and 2008, cotton cropland increased by 18% while production increased by 246%. Cropland for oil-bearing crops increased by 106%, while production increased by 466%. While these improvements were due in part to the adoption of better seed varieties and more advanced irrigation techniques, the Green Revolution introduced chemical inputs, such as pesticides and fertilizers. The benefits of these new changes were many, and it was many years before China began to reexamine its decision to apply such chemical inputs without limitations.[54] Environmentalists and landscape architects working today need to consider the historical context that informed the decision to use so many of the chemicals that are harming the ecosystems in which they work, as they seek solutions that are satisfactory for the agricultural industry, as well as the communities that rely on their outputs and the land on which they operate.

Agriculture in Baihe: an introduction

Baihe suffers from many of the same challenges as other rapidly developing and smaller aspirational towns in China. Its importance in the watershed for Hebei, its agricultural focus, and its status as a post-mining town seeking a new focus for its industry and its citizens' livelihood make it a useful example through which to consider water-sensitive design approaches other cities in China.

As with the rest of China's new policy focus, Hebei is seeking to increase protection of its agricultural ecosystems. We explore how a new, dynamic and growing design firm, working to create master plans for rapidly growing cities like Baihe, can support these goals of protecting ecosystems from agriculture, as well as re-creating ecosystems that respect and support an agricultural economy. We do this through several case studies and the examination of border edges - those places where agriculture comes right into the city center, which will become a more common occurrence as the city develops to keep pace with agricultural production.

Given that more than 60% of China's water is required for its agricultural industries, water scarcity and contamination has been, and remains, a critical concern within Hebei province.[55] While infrastructure for irrigation and water conservation have improved significantly over the last few decades--the effective area with irrigation grew by 37% between 1978 and 2011--enforcement of water-sensitive practices is inconsistent at best, especially in more rural, less

[50] Ibid.
[51] Op cit., Huang, p. 16.
[52] Ibid.
[53] Ibid, p. 18.
[54] Ibid.
[55] Op cit., OECD & FAO, p. 65.

affluent areas.[56] The nature of agricultural practices, and their management, are thus extremely important for preserving the ecological integrity the entire region, particularly in Baihe, given its location along the Tang River and upstream of the reservoir that irrigates the Tang watershed.

A critical responsibility weighing upon agricultural practices in Baihe is the presence of the Xidayang Reservoir approximately seven kilometers downstream. Hebei is a heavy provider of China's steel and iron, building materials, petrochemicals, and cement. Hebei as a province is home to seven of the ten most polluted cities in the entire country.[57] This is due, in part, to the province's role as a home for polluting industry and the presence of the Tanghai mountains to the west which exacerbate the heavy emissions. Baihe in particular is the home of a prominent cement mining operation, and in addition to Ji Dong Cement Company's mine, a second mine was closed last year due to the environmental hazards its waste presented to the community. The immediate and abrupt closure of the cement facility at Baihe represents a commitment to mitigating the area's pollution, and must be followed up with a strong strategy for the town's future management.

Agriculture is a primary focus for the province of Hebei wheat is a major crop, as are rice and mushrooms. Given Hebei's lack of water, the impact of agriculture on the environment is severe: as of 2014, the water table was dropping by two meters each year. While data is not available on exact use of water in China, the city of Hengshui's Water Bureau reported during the same year that there are 75,000 wells in the city that tap into the water table, and 3-4% of them are abandoned each year due to lack of water produced.[58]

A closer look at Baihe: site analysis

Opportunities

Baihe enjoys several strengths that give it great potential for becoming a strong economy supported by robust agricultural industry. While regions near Baihe are rapidly urbanizing, the area itself remains fairly rural, with a large focus on agriculture and mining as sources of local income. Farms in the area are small, which indicates they would likely be more dynamic and adaptable in response to sustainability-oriented interventions, such as the use of new technologies or farming methods. The local government, SPD's client, hopes that the area will experience a population boom alongside a steady increase in educational levels of community members and subsequent increases in standards of living. All of these factors would enable Baihe to more seamlessly integrate more innovative types of agricultural practices into local norms, in order to support the local community and meet their demand for healthier options.

Challenges

[56] Ibid, p. 54.
[57] Stanway, D. "China's war on smog will be won or lost in polluted Hebei." Reuters. March 30, 2014. http://www.reuters.com/article/us-china-pollution-hebei-idUSBREA2T0KX20140330
[58] Hong, Ning. "Water overuse threatens agriculture, industry in Hebei." CCTV.com, May 15, 2014. http://english.cntv.cn/2014/05/15/VIDE1400097356901501.shtml

While Tangxian's local government has big plans for its future, several factors present suggest that a population boom and a subsequent plan for rapid development may not be sustainable given the resources present. The challenges facing the region include, but are not limited to, a rapidly urbanizing population that is increasingly removed from its food system; younger citizens less interested in pursuing agriculture; and an increasing migration of working-age citizens away from the area and toward larger cities, leaving the elderly and children behind. In addition, pollution is a major problem: air quality in Hebei province is some of the worst in the country.[59] While water quality data was not available to us at the time of our visit, mining and agriculture in the Tangxian area--not to mention the severe problem with garbage and litter in waterways, on streets and roads, and near cropland areas--all point to a high probability that water contamination is rampant, if not the norm, due to upstream pollution, an arid climate that slows throughput of contaminants, and issues related to high levels of soil degradation. Given the current paucity of water resources and the average low income of the area, it is important to establish a realistic timeline for remediating the heavily degraded landscape, and have a clear understanding of what resources will be required in order to optimize chances for success.

Ecological infrastructure
When considering the design of ecological infrastructure in the context of Baihe and the agricultural areas surrounding it, we view future potential as a function of current opportunities and challenges. Overall, we have prioritized considering the following variables:

- Controlling development around (albeit limited) existing natural areas
- Protection of any existing quality habitat
- Attempting creation of new habitat; feasibility analyses of wetland habitat re-creation or exploration of other options and opportunities
- New development created with water-sensitive techniques that incorporate most relevant technologies and management practices
- Focus on water harvesting techniques

Design goals

These design interventions expand upon SPD's master plan for Baihe in order to provide a more nuanced and interdisciplinary approach to ecological design. Agriculture in Baihe will not remain unchanged as it develops: the strategies below lay out some of the most important strategies.

Key strategies for agriculture in Baihe

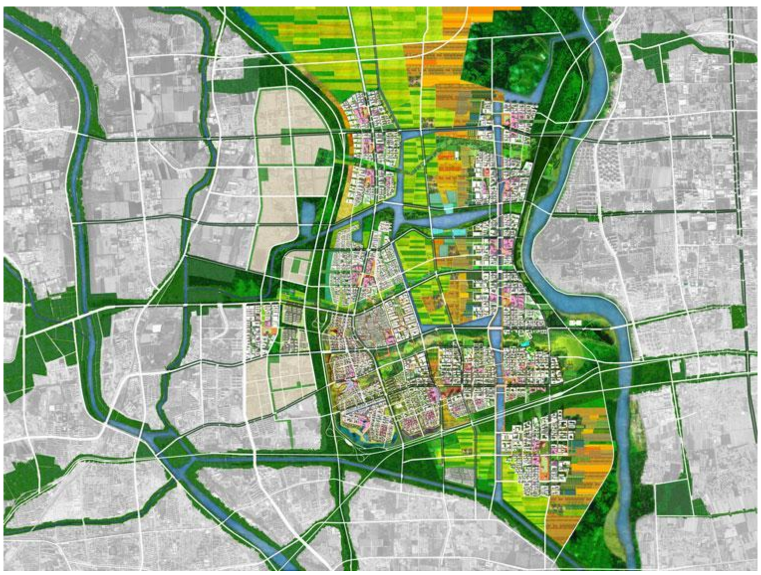
- Maintenance of existing farmland: in the interest of supporting current local economy and way of life as well as to create opportunities for sustainability in the future, existing farmland should be maintained where possible.
- Ecosystem protection: watershed protection for a healthy downstream to protect the reservoir and the entire watershed.
- Community buy-in: programmatic and spatial considerations to increase community awareness of sustainable gardening techniques.

[59] Wang, L. et al. "A Review of Air Pollution and Control in Hebei Province, China." Open Journal of Air Pollution, 2013. http://file.scirp.org/pdf/OJAP_2013082314391478.pdf

- Exploration of water harvesting: use of cisterns, reservoirs, tanks and other techniques to combat drought conditions.
- Policy focus: using policy to control grazing, deforestation and other issues.
- Infrastructural support of the watershed: techniques should always seek to protect the existing watershed's water quality, habitat, native species, and existing corridors to other habitat.

Case Studies for Agriculture

Songzhuang Arts and Culture City



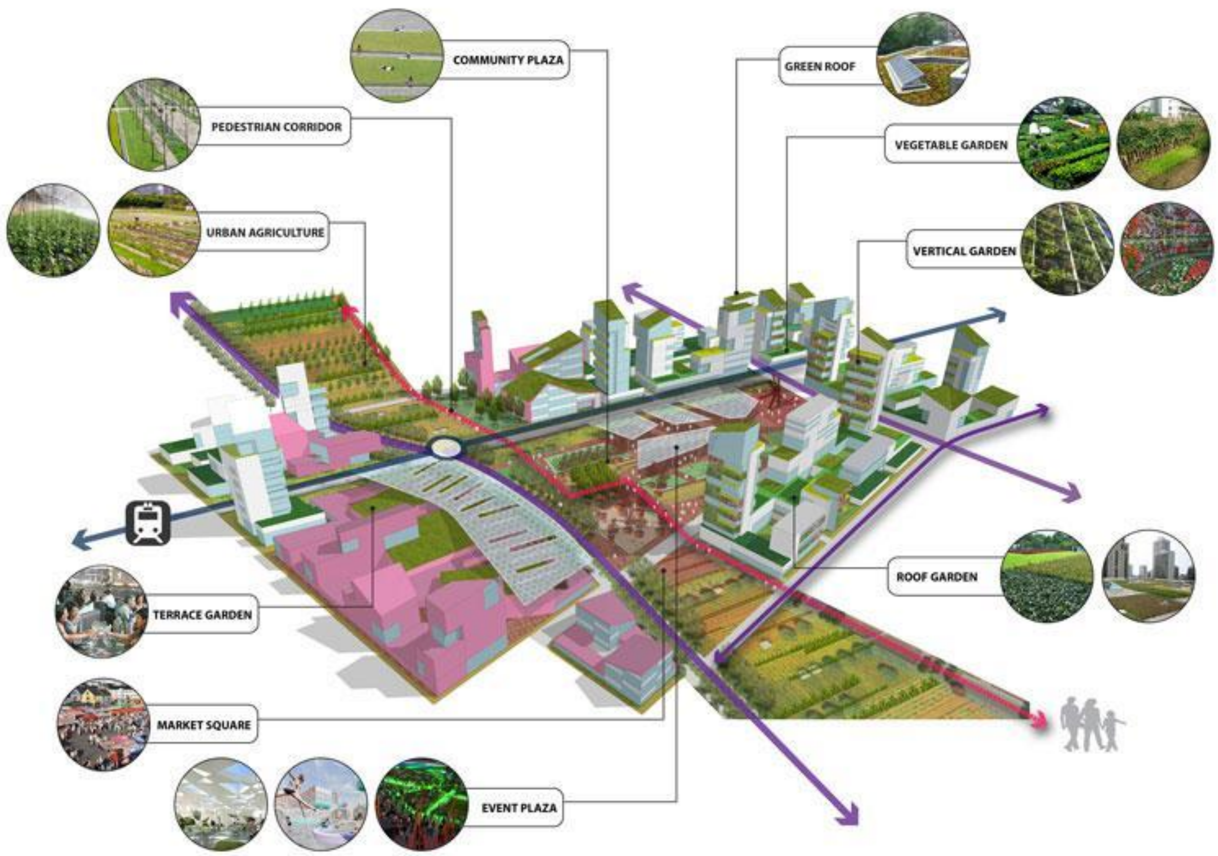
The Songzhuang Arts and Culture city is a fitting case study for examining Chinese cities struggling with how to incorporate and convert agricultural land into a rapidly urbanizing context. With a growing population and ever more strenuous demands on resources, the question of how cities relate to their agricultural surroundings is critical. With the Songzhuang Arts and Culture City, Sasaki faced the challenge of integrating agriculture with the city. Its master plan lays out self-sustaining areas that focus on different areas of the region's specialties. For instance,

Image Credit: Sasaki

Songhuajiang used to be located in a highly agricultural landscape at the eastern edge of Beijing, around 30 kilometers from Tiananmen Square. As Beijing sprawled and artists began seeking freedom of space and from the government, the artistic center found its home at Songzhuang and in the nearby 798 Art District. The visual arts flourish there, and as there are currently over four thousand artists in the area - this area represents a major conversion from an agricultural and manufacturing heritage to a modern space for a very specific part of society. Artists were pursuing tranquility and peace in a country setting - as Songzhuang has become more urbanized, the design firm Sasaki was hired to come in and prepare a master plan; their focus was on retaining ecological integrity, encouraging creativity, and providing a high standard of living for its residents. The defining characteristic of the master plan is its inversion of the more typical idea of agriculture being at the periphery of cities - its plan seeks to integrate the agricultural landscape into the pattern of the city itself.

Similarities to Baihe
This city is similar to Baihe in its location, although it is currently a much more urbanized site. Baihe, if development continues along its path, can expect to find itself in the same position as Songzhuang in a few years. Although Baihe is not known for its arts and culture, the new master plan attempts to create new clean industries and a new identity for Baihe. Baihe is much like Songzhuang of around thirty years ago, with lots of agricultural land and a degraded environment. It has the opportunity to improve upon Songzhuang's techniques of incorporating their agricultural system into a burgeoning city landscape.

Strategic placement of farming and buffer systems allows for productive systems



Songzhuang's plan allows for a layered approach to bringing agriculture into city life

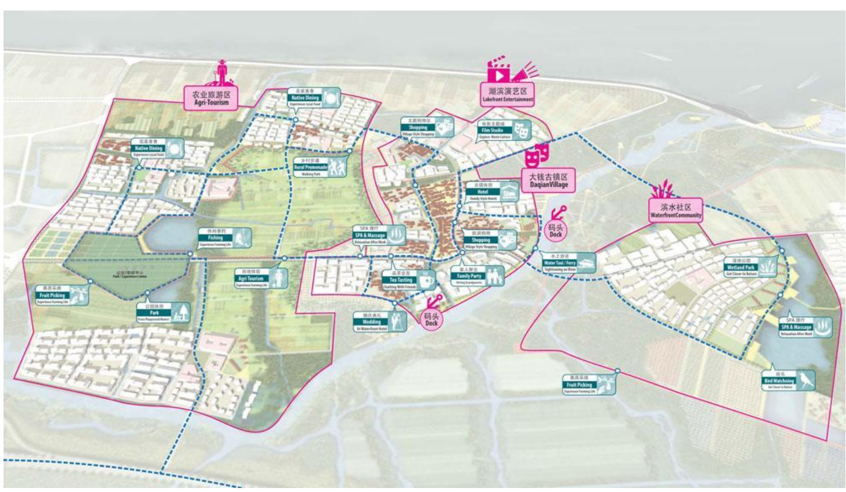
South Taihu Lake:
Sasaki's South Taihu Lake master plan responds to the fact that farmland in China is being increasingly sacrificed in favor of urban sprawl. Between 1997 and 2008, 47,500 square miles of China's land--an area that, in aggregate, is slightly larger than the state of Pennsylvania--has

been replaced by urban development between 1997 and 2008.[60]. At South Taihu Lake in the city of Huzhou in the Zhejiang province, Sasaki sought to challenge the idea that farmland must disappear for cities to expand. Additionally, the expansion of cities into former agrarian communities has meant that the economic and social structures of villages are destroyed with broad strokes of development. Sasaki also sought to address with this project the increasing separation from their food sources of generations of Chinese citizens. The site faces ecological challenges as well; Taihu Lake is home to ecological dead zones caused by agricultural runoff.

A strong educational component ties the project together, from insights into the contemporary agricultural production system to biomedical research to adaptive re-use of traditional villages in order to strengthen their connection with the land. The plan also puts a strong focus on the growing specialized agriculture industry such as organic production, pick-your-own agritourism businesses, and farm-to-table restaurants. The physical layout of the city preserves 75% open space and agriculture, and is meant to serve as a model for villages that find themselves at the edge of China's growing major metropolitan areas. The plan preserves eight self-sustaining 'nodes' that are no larger than a ten-minute walk from one end to the other, which promotes a close relationship between outlying farming homesteads and the village centers. Ecological benefit and re-generation is focused around a created wetland that weaves throughout the project to improve water quality, create habitat and reduce flood risk (Sasaki website and other, see below).

Similarities to Baihe

The South Taihu Lake project is similar to Baihe in the type of landscape it addresses - outlying areas of large, quickly developing megacities. Additionally, the need to protect Taihu Lake is similar to Baihe's position near the Xidayang Reservoir. Many of the challenges felt in Huzhou are seen all over China (and the world) such as distance from food sources, loss of agricultural land, and polluted runoff; this allows South Taihu Lake to be an interesting source of inspiration for many types of projects.



Sasaki's plan emphasizes self-sustaining clusters surrounded by agricultural land.

[60] "List of US States by Size." https://state.1keydata.com/states-by-size.php, "South Taihu Lake." Sasaki. http://www.sasaki.com/project/352/south-taihu-lake/

Agricultural land dominates the area while showing strong relationships to urbanized spaces.

Sasaki's plan demonstrates how agriculture and people can share a space in harmony.

Agricultural Design

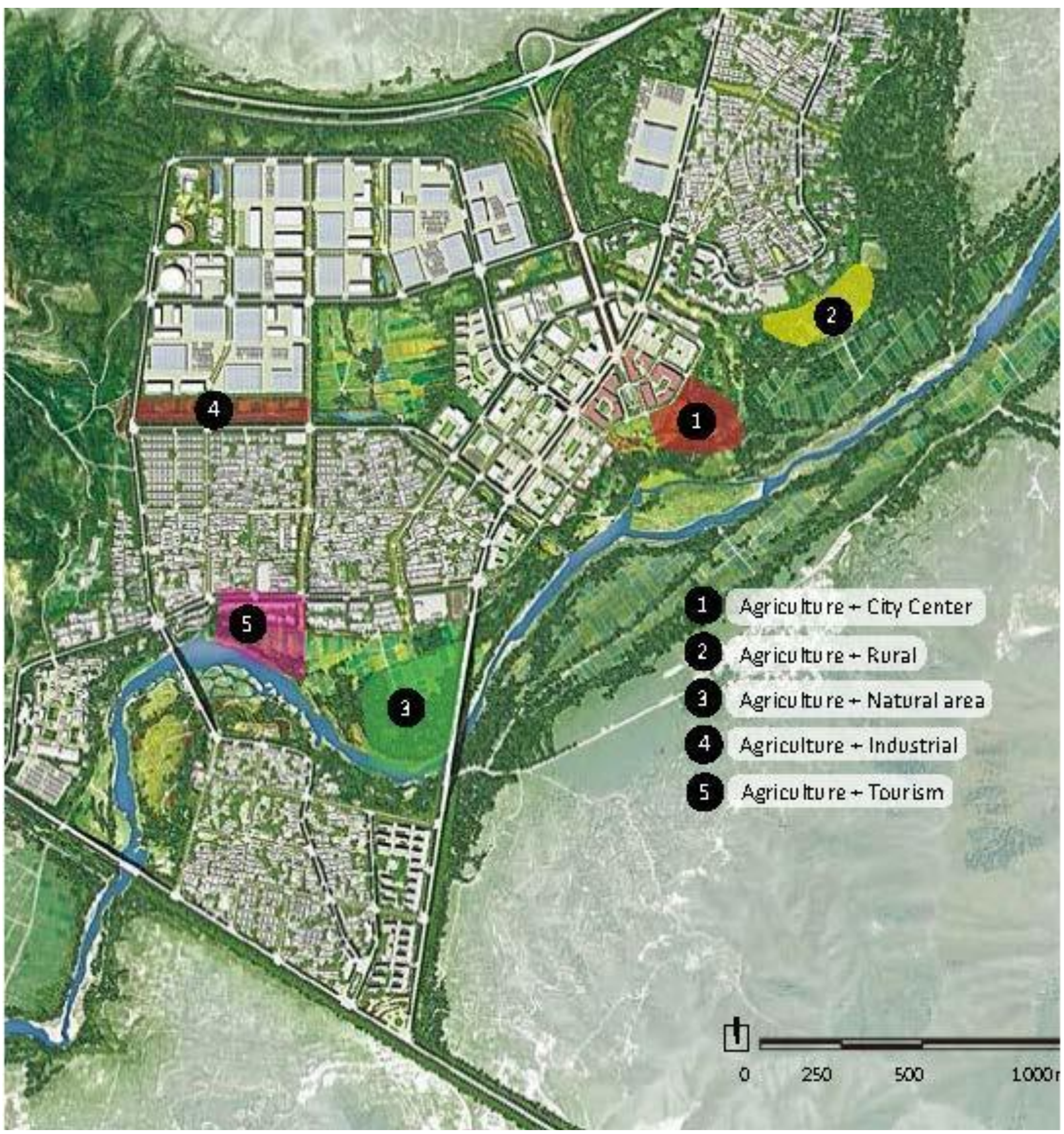
When approaching Baihe with landscape design in mind, any plan for incorporating ecological design into agricultural land planning must fit into existing farmland. While farmland will necessarily be lost in part to the city's expansion, it is critical to plan for farmers to ensure their protection and preservation. SPD's Master Plan has incorporated a large quantity of farmland, and we seek to expand upon that in our recommendations.

Due to the relative lack of power of urban planners and landscape architects to truly 'design' farmland, we have instead focused on recommendations for programming and infrastructure located at the 'edges'. We have defined these edges based on the relationship between the city and agricultural areas. The many interactions that occur between people and the agricultural landscape, as well as the city's infrastructure and landscape, form the basis for these recommendations.

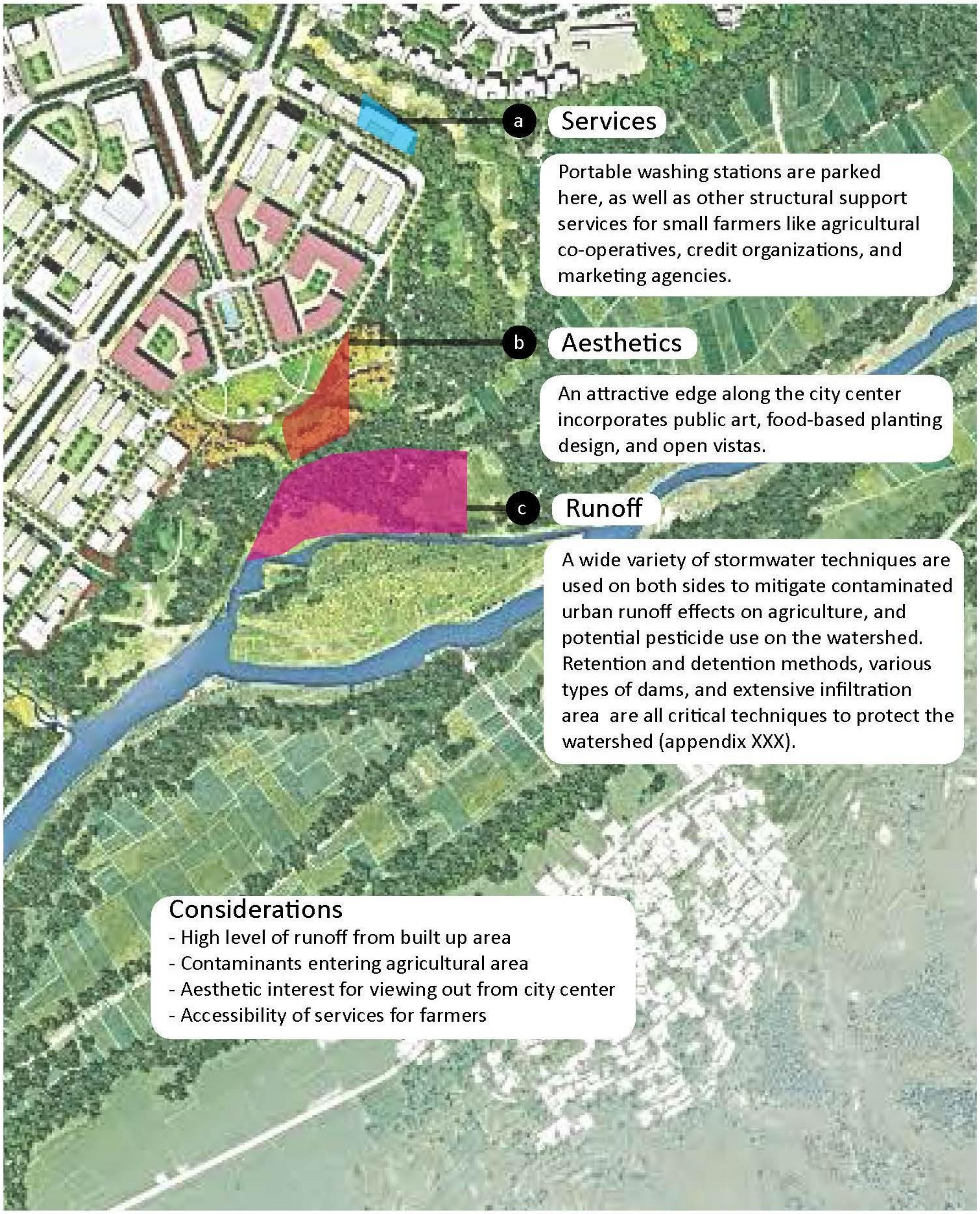
We have chosen to examine the relationship of agricultural land to the city center, where commercial and mixed density is at its highest; neighborhood/rural centers, among medium- to low-density residential areas and adjacent preserves, parks or natural areas; and industrial settings, where manufacturing and light to heavy industrial activities take place

While a certain amount of overlap exists between these sectors, we separate them based on the character of the places and their most defining functions. To this end, we have selected three zones in SPD's master plan for which we make recommendations. These zones were chosen with consideration of their overall fit into SPD's master plan; their proximity to existing agricultural areas; and the opportunities that exist for their interaction with community centers.

3 Agricultural Edge Types within Baihe's Master Plan



Agriculture + Urban



Considerations
When examining the relationship between agricultural land and the city center, the most immediate identified consideration is aesthetic. These edges should hold enough appeal to make the perceived 'intrusion' of the agricultural land into the city's center pleasing and welcome. A second consideration must be the availability of the services and infrastructure needed by both small and larger-scale farmers. The following design recommendations are made upon the basis of these considerations.

Aesthetics

Where agricultural landscapes are highly visible and close to civic and commercial centers, aesthetic and experiential considerations become much more important. The aesthetics associated with safety are also critical components in highly urbanized areas, particularly when an unaccustomed land use such as agriculture is encountered unexpectedly by passers-by. As found by Fisher and Nasar, people tend to deem 'unsafe' areas that afford large amounts of cover for a potential attacker and lack of escape routes for themselves as potential victims[61]. Concepts of prospect and refuge should be considered in these situations; the design should be accommodating of human preference to have relatively unobstructed visibility over open spaces while providing comforting security to one's back. Above, Olmstead's Endale Arch in New York's Prospect Park provides a safe vantage point that satisfies our ancestral desire to see but not be seen.

Case study focus: The Songzhuang Arts and Culture City plan is highly effective at framing attractive vistas. Where it lacks detail is primarily in the administration of city services and building mass growth that will eventually become detrimental to maintaining wide open views throughout the city.

Services
Another factor or agricultural facilities equally critical to their prime location is their worker-friendliness. This means not only that the spaces accommodate rest and physical necessities, but also structural and institutional benefits such as credit institutions for farmers, co-operatives and agencies that provide marketing support for small and organic farmers. This can be accomplished by careful funding and government support of such businesses in prime areas of the city, so that agricultural activity is not just relegated to the outskirts as it is currently.

Runoff
Following defined BMPs (Best Management Practices) for contaminated stormwater runoff is critical to any plan. These BMPs are particularly critical for the areas between agricultural and

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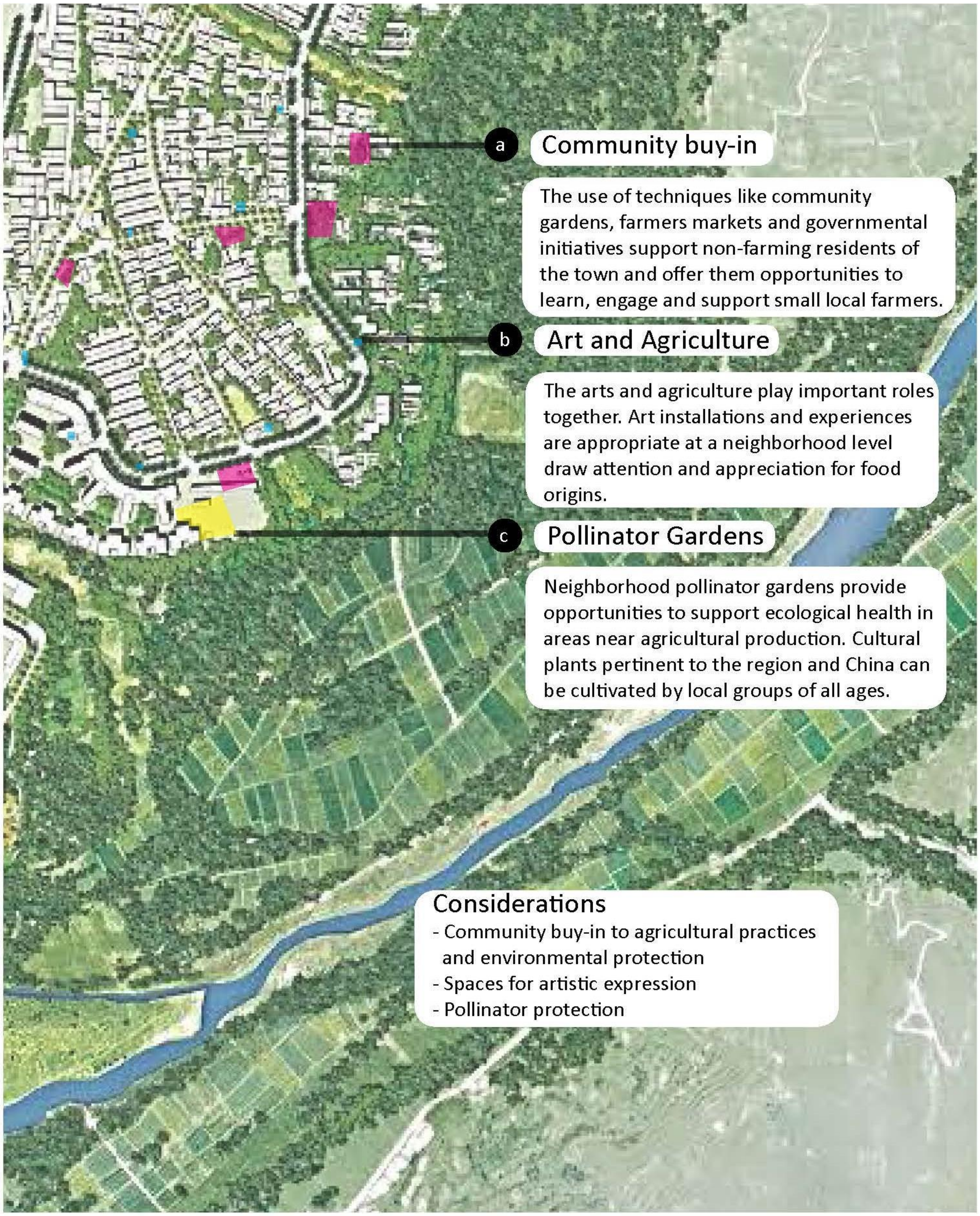
[61] Fisher, Bonnie S. and Nasar, Jack L. "Fear of Crime in Relation to Three Exterior Site Features: Prospect, Refuge and Escape" *Environment and Behavior 24.1.* Jan 1992, 35-65.
Image: http://designforwalking.com/the-ape-in-us-seeks-refuges-and-prospects/

urban uses. A primary consideration for this sector is the protection of humans from pesticide contamination, taking into account to the high population in dense urban cores. All technologies available must be utilized to protect both the human population from potential pesticide contamination, and to protect the agricultural land from hydrocarbons, heavy metals, nutrients and other contamination coming from the many impermeable surfaces of the urban core. One more attractive option for urban cores is the practice of water harvesting. In the practice of water harvesting, potentially contaminated agricultural or urban runoff is collected, treated and used for irrigation purposes. In this way, the urban core's runoff can be used (post-treatment) to support agricultural activities in a highly visible manner that is also educational for urban dwellers. This simple method can be implemented in many different and creative ways that are aesthetically appealing and culturally relevant. The simplest of these systems consists of an outer area that induces and collects runoff, then an area that is either within or outside of the agricultural space with crops like fruit trees or other 'treatment' vegetation (including naturally occurring wetlands in the vicinity) that help remove heavy metals and other contaminants without themselves becoming contaminated. After that, the water can pass into cultivated fields and be used for irrigation[62]

Another important aspect, covered at length in previous sections, is that of permeable pavers. The use of permeable paving technologies can greatly improve the rate of infiltration of contaminated stormwater runoff and protect fields. Bioswale techniques and rain gardens in more heavily populated areas also contribute to the health of crops and of people.

[62] "Water Harvesting and Agriculture" United Nations Food and Agriculture Organization. No date provided <http://www.fao.org/fileadmin/templates/cpesap/C-RESAP_Info_package/Links/Module_5/Water_harvesting.pdf>

Agriculture + Rural and Neighborhood



Considerations
The primary consideration in more outlying urban residential areas when considering ecological design for agricultural spaces is the the community's relationship to agriculture and their food source. In addition, the presence of natural areas and preserves located at the urban outskirts provides an appropriate tie-in between agricultural practice and ecological function. In the United States, it is often only in the suburbs that agricultural land abuts human dwellings. Little or no interaction occurs between residents and their surrounding fields beyond a sometimes fleeting appreciation of a sunset across open vistas. The untapped opportunity to connect urban dwellers to their landscapes is most achievable where agricultural land meets residential.

Community buy-in: food systems

One way to encourage community interest and investment in their food systems is the implementation of community garden projects. Public produce, community gardens, and institutional gardens all support many community benefits such as: improved health, quality of life, increased social capital and skill-building[63]. Community gardens can help to address many different types of social challenges, particularly when integrated with programming and with institutional support. Gardens that are located within close proximity of productive landscapes help enhance a culture of food, initiating a 'repaired' food cycle which promotes local, healthy food. Community gardens also support food security, local pride and a restaurant culture.

Art and Agriculture
Agricultural landscapes also provide a myriad opportunities for artistic expression. For sites where space allows for this type of cultural engagement, we recommend that SPD seek community input on what appeals to local tastes and which local artists may already be active in the region, in order to best align design plans with local tastes and initiatives that may already be underway. While each site will have specific aesthetic needs, potential, and local artists, we recommend exploring the work of Michael Heizer with insect effigy mounds,[64] Loma Jordan's Water Works Garden, and work by Robert Morris, such as "Ring with Light" and "Johnson Gravel Pit."[65] Work by Richard Serra, as well as the collections at Storm King, Dia: Beacon, and Glenstone, could also be useful references. These examples of art incorporated into agricultural spaces, from both past and present, help to illuminate the realm of possibilities available to SPD for aligning local art with its landscape designs.

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[63] Twiss, J., Dickinson, J., Duma, S., Kleinman, T., Paulsen, H. and Rilveria, L. "Community Gardens: Lessons Learned From California Healthy Cities and Communities." American Journal of Public Health. September, 2003. Vol. 93, Issue 9, pp. 1435-1438. Image retrieved from: https://communitygarden.org/wp-content/uploads/2014/01/Jon-Petersons-peterson-garden-project.jpg
[64] "Michael Heizer: Effigy Tumuli." Wordpress.com. https://enviromentalart.wordpress.com/2013/04/23/michael-heizer-effigy-tumuli/
[65] Umbanhowar, E. "Public Art: Linking Form, Function and Meaning." Green Museum. http://depts.washington.edu/open2100/pdf/2_OpenSpaceTypes/Open_Space_Types/public_art.pdf

Community buy-in: environment

Another critical tie-in for the places where agriculture meets residential is in the environment. Urban dwellers are often disconnected from natural areas, depending on parks and preserves to strengthen their connection to (their perception of) nature. One way to make these connections is with pollinator gardens, which are designed to be proximate to spaces where communities gather, able to feed pollinators such as bees, ants, and butterflies, and in doing so educate those nearby about the role of pollinators and their need for nearby sources of pollen. In implementing pollinator gardens, it is important to inform the public of what is happening, as some pollinator plants can come to be perceived as unkempt or 'weedy'[66].

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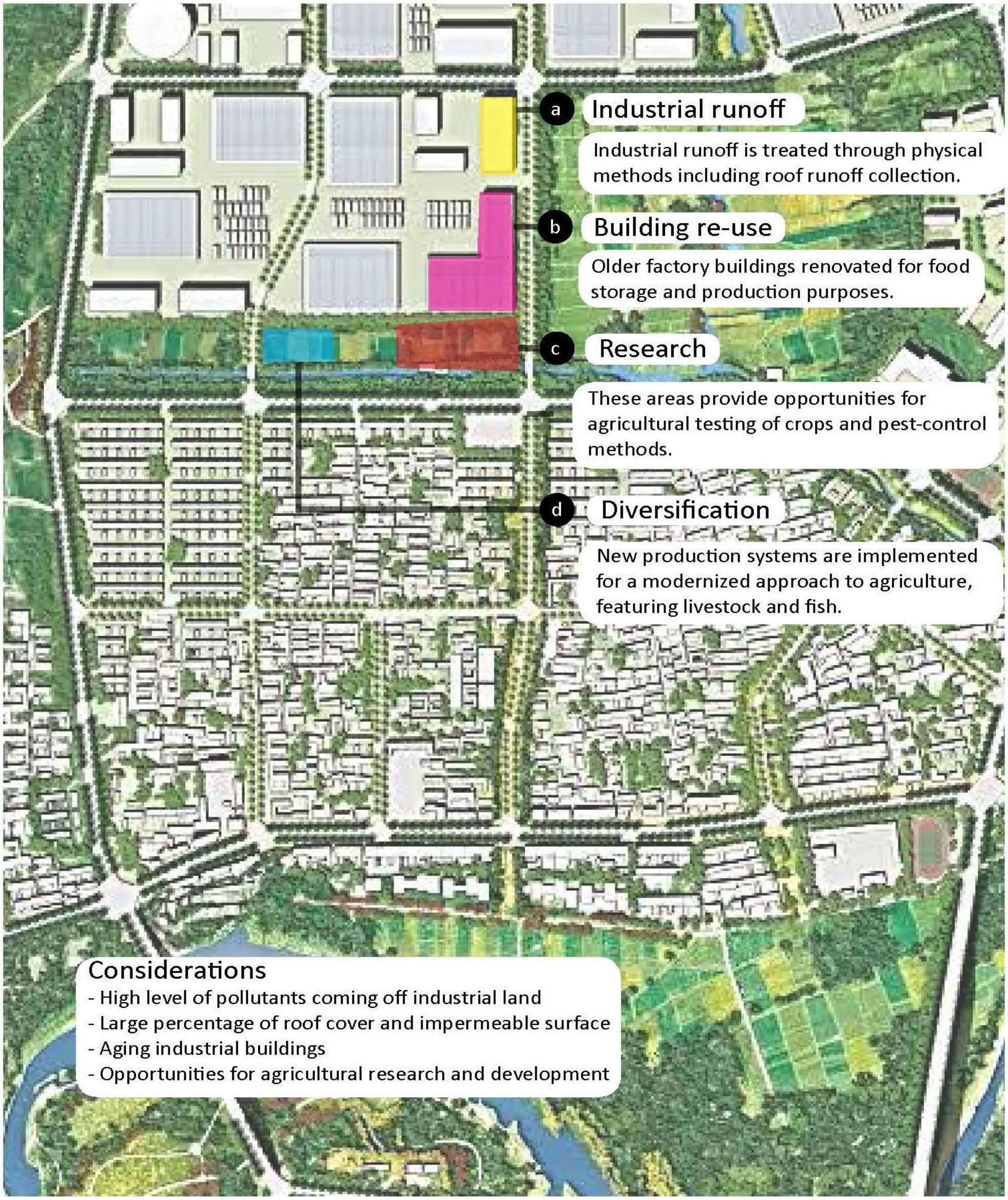
[66] Shepherd, M., Vaughan, M. and Hoffman Black, S. "Pollinator Friendly Parks." *Xerces Society for Invertebrate Conservation*, 2008, p. 15. http://www.xerces.org/wp-content/uploads/2009/05/pollinator_friendly_parks_21ed_xerces_society.pdf

Agricultural + Industrial



Considerations

When examining the areas that agricultural land abuts industrial or manufacturing space, the most important consideration is of the healthy relationship between the two systems.

Additionally, these spaces provide a more clear visual connection between production and manufacturing in the agricultural sector.

Industrial runoff

Industrial runoff has its own serious concerns. Beyond implementing BMPs of industrial runoff management, there are opportunities to integrate the agricultural and industrial complexes to the benefit of both. In Baihe, old industrial buildings are ripe for remodeling as well as water harvesting technologies. Harvested water could be used for irrigation purposes.

Building reuse

Industrial buildings are prime for reuse as storage for food products and food incubator businesses. The Plant in Chicago, Illinois is an old factory building that has been re-used as a food incubator and indoor farm[67]. These spaces can set up 'circular economies' that are self-supporting food production systems. With the multitude of abandoned or unused mining structures in Baihe, there exist many opportunities to incubate food-based businesses in burgeoning new industrial areas.

Case study focus: The Songzhuang Arts and Culture city takes the perspective of culture; Baihe can use similar techniques as outlined in the case study to support a food culture.

Research

The places where agricultural production comes alongside manufacturing and production facilities provides an opportunity for agricultural research and experimentation. By making these types of facilities more visible in the urban fabric, more robust research can be supported.

Diversification

Industrial runoff in areas where agriculture is present threatens croplands, environmental stability, and human health from both proximity to industrial areas and from consumption of food grown in the vicinity of toxic chemicals and other contaminants. These dynamics provide an opportunity to utilize diversification techniques within agricultural settings, such as intercropping and integrated pest management, in order to insure against crop failure and promote resiliency of crops and their ability to contribute to habitat, rather than counteract it.[68] By incorporating these techniques into their planning, design firms like SPD are able to promote the thriving of an ecosystem that can help to offset the environmental damage conducted by chemicals and other contaminants. Where manufacturing districts exist lie more opportunities to diversify production. Here, we recommend that SPD seek to incorporate native plant species along corridors and edges and elicit the help of agronomists or ecologists to ensure that plans to grow vegetation align with the overall habitat needs of the flora and fauna that exist nearby.

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[67] "Closed Loop, Open Source." Plant Chicago. http://plantchicago.org/

[68] Machado, S. "Does intercropping have a role in modern agriculture?" *Journal of Soil and Water Conservation.* March/April 2009, p. 56a.

Findings, Caveats and Limitations

Findings: Urban

China's rate of urbanization skyrocket from 20% urbanization in the 1980's to 54% in 2014[69]. SPD finds itself in a strategic position to have a great impact on the short and long-term environmental sustainability of cities. China has shown public support for creating sustainable urban environments, notably the 2014 creation of National New-Type Urbanization Plan to support the United Nation's Sustainable Development Goal 11 which seeks to "Make cities and human settlements safe, resilient and sustainable"[70]. With government goals focused on sustainable development, SPD holds a strategic position to impact the sustainability and resiliency of China's development with ecological and human-centered designs. This guidebook with technologies and case studies should be used to increase knowledge and awareness of water-sensitive design but also to start a conversation around the importance and complexities of water-sensitive design.

Working with SPD we found that though well-intentioned, the team lacked ecological knowledge as well as knowledge of and experience in water sensitive design techniques and technologies. Based on the complexities of water sensitive design in urban environments, it is suggested that SPD have access to experts to advise their designs in soil ecology, local flora and fauna and water-sensitive techniques and building materials in order to assess proper selection, number and placement of different water sensitive technologies in urban environments.

Findings: Industrial

Ecological restoration recovers damaged landscapes and transforms them into new dynamic ecosystems that support diverse species and habitats. Afforestation policy in China has not prioritized water efficient, native, or diverse species in the past and thus has further contributed to ecosystem destruction. Chinese urban design firms like SPD should familiarize themselves with successful ecological restoration theory, techniques, and strategies in order to design parks that maintain ecological health. The SPD Master Plan included the creation of a natural park system for the post-industrial sections of Baihe, but did not delve into specific recommendations on site design or landscape planning.

Learning from successful post-industrial park designs in Germany and China, we believe that the creation of a naturalistic park that maintains its historical significance through design for human use can attract visitors and educate the public. Due to the complexity of ecological

[69]"Building the dream." *The Economist*. April 19, 2014. http://www.economist.com/news/special-report/21600797-2030-chinese-cities-will-be-home-about-1-billion-people-getting-urban-china-work
[70]"China Sustainable Cities Report: Measuring Ecological Input and Human Development: 2015." UN Development Programme. http://www.cn.undp.org/content/dam/china/docs/Publications/UNDP-CH-Report-Sustainable%20Cities%202015%20English.pdf

restoration, we believe the successful transformation of the degraded site will take decades of intensive study, experimentation, and management. We recommend that designers work closely with soil ecologists for the creation of a site-specific design and management strategy for the remediation of the closed limestone mines into a human-centered and ecologically productive park.

Findings: Agricultural

SPD and other ecologically-focused urban design and landscape architecture firms are currently being presented with a unique opportunity to be at the forefront of determining how urban-dwellers will relate to agricultural production and manufacturing in the physical spaces they occupy. Examining SPD's master plan and taking into account other examples of attempts to integrate farmland into the urban fabric had led us to conclude that the edges are the most essential component of designing spaces that are able to be both supportive of agricultural lifestyles and production, as well as supportive of urban dwellers. The perceived 'intrusion' of agricultural space into a city must be reversed and made into a glowing positive for all residents; when properly administered it can bring better knowledge of one's food source, better health, and improved relationship to the environment. This requires a series of spatial and programmatic decisions to support the integration of farm and city. Our recommendations seek to frame a starting point for designers and city planners for identifying potential areas of conflict between agricultural and urban land uses, in order to effect the creation of spaces that incorporate the many benefits of bringing a traditional agrarian way of life into the city.

Caveats and Limitations

The caveats and limitations for this project fell into three major areas: first; geography and language barriers made it difficult to establish consistent, streamlined, and meaningful dialogue. Finding times for Skype meetings with a twelve-hour time difference was challenging, as was the language barrier at times. Second, SPD's time line for this project was extremely short given design firm standards. In the world of urban design, quick turnover is essential, and the Baihe client requested their design proposal to be completed by November. They were therefore less able to accommodate the schedules of students with many other commitments and moved on with the project well before we had finished our contribution. Our work since November has continued with almost no input from, or communication with, our client. Third, SPD is a new and small design firm, working in a competitive market and a challenging field. While ecological design appears to be a priority in theory, they have yet to suggest there will be any meaningful investment in ecological design capabilities within their company. We believe that without the committed, long-term work alongside an ecologist or other scientific experts, their ability to affect water-sensitive, ecological design will be limited. Despite these caveats, we believe our findings are still highly relevant and valid for SPD's future work, if a bit more generally, as they take on new projects and attempt to influence the face of innovative design in China.

Conclusions and Recommendations

Our experiences working alongside SPD and conducting research on ecological design work in China elucidated the fact that ecological approaches to design are often attempted during the design stage but fail to receive ongoing support and monitoring in order to measure and determine iterative success. Given that many sites in China have experienced intensive ecological degradation, and given that water contamination is more the norm than the exception, we urge SPD to consider investing in partnering with an ecologist--or team of ecologists--during the design phase. In addition, however, we advocate having SPD work with clients to ensure that SPD's sites will continue to be monitored in order to measure improvements in water, soil, and air quality, as well as phytoremediation outcomes, effectiveness of corridors, and the status and condition of different applied technologies.

Our second recommendation is to underscore the importance of remembering that ecological restoration is not a short-term enterprise. Heavily degraded landscapes in arid, drought-impacted landscapes will not be revitalized quickly, and several attempts at 'greening' Baihe may be required before one is implemented to success. Given these realities, it is important for firms like SPD, that are usually involved at an initial phase of implementation, rather than continuously integrated into the process, to have a clear aim for its role in affecting ecological and water-sensitive change within the sites where its designs are implemented.

When it comes to ecological and water-sensitive design, there is no 'drop-in' solution that can be applied ubiquitously. Each site will need to be assessed in detail, with attention paid to the potential agricultural and industrial contaminants present, the land use by the community, nearby activities, and future goals for the area, in order for designs to be applied in a resilient manner that will remain relevant for the short- and long-term. SPD has the opportunity to be a first mover in this space and play a major role in establishing best practices for ecologically and water-sensitive design throughout China. Well-planned initial implementation and careful monitoring of ecological progress within each site will legitimize SPD's work in this field and provide an ecologically-sensitive roadmap for design firms to follow, in order to improve environmental outcomes for their clients, and the People's Republic of China.