

# remediating on- and off-site stormwater on a post-industrial site

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**With deepest gratitude to my graduate committee -**

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# 1. Introduction

## 1.1 Objective

This design thesis seeks to explore the potential to remediate on- and off-site stormwater on a post-industrial rail yard site in downtown Albuquerque, New Mexico. The objective is to determine if it is feasible to daylight stormwater from storm drains within Albuquerque's South Valley East Watershed, a 19.3 square mile urban drainage area, within the rail yard site for biological remediation in a constructed wetland prior to discharge into the Rio Grande. Working within an existing urban and highly engineered landscape, this project rethinks the treatment of stormwater by demonstrating the opportunity to integrate stormwater remediation technology, ecological flood control, post-industrial adaptive re-use, Bosque and wetland habitat formation and the creation of a large civic space.

The Albuquerque Rail Yard has been chosen as the site for this study due to its downstream geographic placement in the South Valley East Watershed as well as its proximity to the Rio Grande and the river's degraded Bosque and wetland habitats. Additionally, the derelict and contaminated twenty-seven acre site in downtown Albuquerque has recently been purchased by the city and is the focus of redevelopment discussions.



Figure 1. Historic photo of polluting stormwater. Image from Drx.typepad.com

## 2. Contaminated (Storm)water

“In an age when man has forgotten his origins and is blind even to his most essential needs for survival, water along with other resources has become the victim of his indifference.”

-Rachael Carson, *Silent Spring*

The contamination of water is not unique to modern time, but has existed as a distinguishing characteristic of nearly every human society (Ponting, 1991). Prior to the Industrial Revolution of the 18th and 19th Centuries and the Green Revolution of the 20th Century, water

was consistently contaminated by human and animal waste, a source of pollution that has prevailed to present time. Exacerbated by the age of industry, modern agriculture and by increasing human populations and urbanization, water pollution has shifted throughout history from being highly localized in the urban bound stream, the mine site or the landfill, to global, existing to varying degrees in all bodies of water.

In increasingly urbanized landscapes, stormwater, which is runoff generated when precipitation flows over land or impervious surfaces and does not percolate into the ground, exists as a major source of water body impairment. As stormwater flows through a city, over its paved streets, parking lots, chemically treated landscaped areas and rooftops, the water accumulates debris, chemicals, sediment or other pollutants (U.S. Environmental Protection Agency, 2008). In many cities, including Albuquerque, stormwater is discharged to a local water body without treatment, adversely affecting water quality.

## 2.1 Albuquerque's Stormwater Drainage System

As Albuquerque has urbanized over time, the city's stormwater infrastructure has become increasingly complex. In 1963, the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) was created to alleviate property damage and injury or loss of life due to flooding. The organization realizes this goal by building and maintaining flood control structures throughout the city. The system for managing stormwater currently includes 16,000 catch basins, 480 miles of underground storm drain piping, 51 major flood control dams, 6 miles of dikes and diversion structures, 175 miles of constructed channels, and 55 stormwater quality facilities (ASCG Incorporated, 2005). While the risk of flooding has been reduced with infrastructure built and maintained by AMAFCA, the hydrology and water quality of Albuquerque's urban watersheds, which all drain into the Rio Grande, have been severely impacted.



Figure 2. Albuquerque stormwater infrastructure during rain event. Image from amafca.org.

## 2.2 Stormwater Contamination

Common pollutants in stormwater include bacteria from animal waste, metals, nutrients, pesticides, oil and grease, oxygen-depleting organic matter, trash, sediment, and toxic chemicals (Nancy Stoner, 2006). Priority stormwater contaminants according to the Environmental Protection Agency (EPA) are dissolved solids, suspended solids, total Kjeldahl nitrogen, total nitrogen, dissolved phosphorous, total phosphorous, biochemical oxygen demand, chemical oxygen demand, total extractable cadmium, total extractable copper, total extractable copper, total extractable lead, and total extractable zinc (Veenhuis, 2002).

An analysis of Albuquerque stormwater has shown that local gross pollutants and floatables, which are coarse sediments, trash, and the leachate from trash, include large natural material (51%), small natural material (17%), plastics (16%), cigarette butts (6.4%), lumber (3.5%), fabric and paper (1.6%), metals (1.3%), and other materials

(3.2%) (ASCG Incorporated, 2005). The leachate from analyzed trash in Albuquerque's stormwater contains levels of total copper, lead, zinc, arsenic, cadmium, chromium, nickel, and silver in detectable concentrations. In addition, petroleum hydrocarbons and solvents found in leachate include hydrocarbon constituents such as ethylbenzene, toluene, total xylenes, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, chrysene, fluoranthene, and pyrene. These chemicals are derived from plastics and other common products, as well as fuel spills within the watershed. Methyl ethyl ketone (or 2-Butanone) in association with acetone was detected in elevated quantities (ASCG Incorporated, 2005). This chemical is used in glue, paint remover, and varnishes amongst other applications. In elevated quantities this chemical acts as an irritant in animals and can cause birth defects (U. S. Environmental Protection Agency, 2007). Analyses of leachate have proven that significant water quality improvements can be made by mechanically screening trash. This method only removes a portion of the contaminants in stormwater and so, should be used in conjunction with other means of stormwater remediation (ASCG Incorporated, 2005).

In many areas of the city, contaminant remediation is challenging due to the high velocity by which stormwater travels through the drainage system (ASCG Incorporated, 2005). Those devices incorporated to harvest floatable trash and gross pollutants, such as bar screens at pump stations, typically become clogged easily, resulting in not only a system failure, but an ongoing maintenance issue (ASCG Incorporated, 2005). In the Rio Grande valley, where the Rail Yard is situated, slopes are typically less than 0.5% meaning that stormwater is moving through the system at a reduced velocity. This provides an opportunity to slow the movement of stormwater further to enable sufficient detention time to effectively remediate pollutants and remove trash.

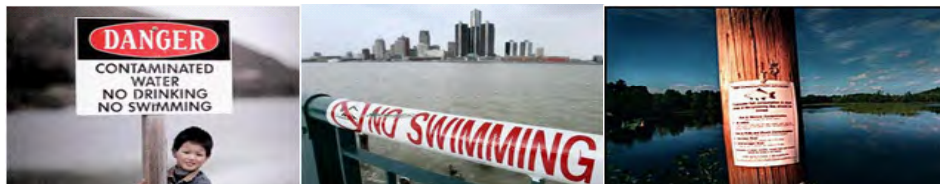


Figure 3. Contaminated water signs. Images from [Pesticidedanger\\_newmediaexplorer.org](https://www.pesticidedanger.org), [media.canada.com](https://www.media.canada.com), [pressherald.mainetoday.com](https://www.pressherald.com).

## 2.3 Stormwater Remediation

Municipalities and other entities that must reduce stormwater contamination determine location-specific guidelines for stormwater pollution control termed Best Management Practices. Best Management Practices (BMPs) include approaches that prevent pollutants from contaminating stormwater (i.e. education programs, erosion control, increased vegetated areas, street sweeping, materials storage and handling practices) and treatment facilities that remove contaminants from stormwater (i.e. bioswales, constructed wetlands and other detention systems, and mechanical devices such as oil/water separators) (Portland Bureau of Environmental Services, 2009). Due to the nature of this thesis, BMPs that remediate existing stormwater contamination will be emphasized over preventative measures. Remediating stormwater has been explored at a range of scales from individual sites to entire watersheds. Methods employed across spatial scales include increasing surface permeability and slowing stormwater to allow for bio- or phyto-remediation.

### 2.3.1 Site Scale and Land Use

The method for stormwater remediation on an individual site is dependant upon on the size of the site and the nature of the land use. For the single family home, for example, stormwater can be treated by reducing the amount of impervious surfaces, i.e. parking areas, roof area and bare earth common to newly developed residential sites. Greenroofs can be applied to absorb and filter rainwater which reduces the amount of runoff. Downspouts can be directed into planted areas, creating rain gardens and reducing the need for supplemental irrigation. Driveways and walkways can be made of permeable surfacing. These methods allow for stormwater filtration and infiltration, reducing the amount of contaminated stormwater entering into storm drains.

At the scale of industrial properties, constructed wetlands and bioswales can be added to a system of green roofs, permeable paving

and increased planted areas, such as at the Rouge Ford Factory in Dearborn, Michigan. This combined ecological remediation system allowed this operating Ford plant to avoid the costly construction of a water treatment plant for remediating stormwater prior to discharge into the River Rouge and to renounce the site's former brownfield status (Rouge Communications Team, 2003).

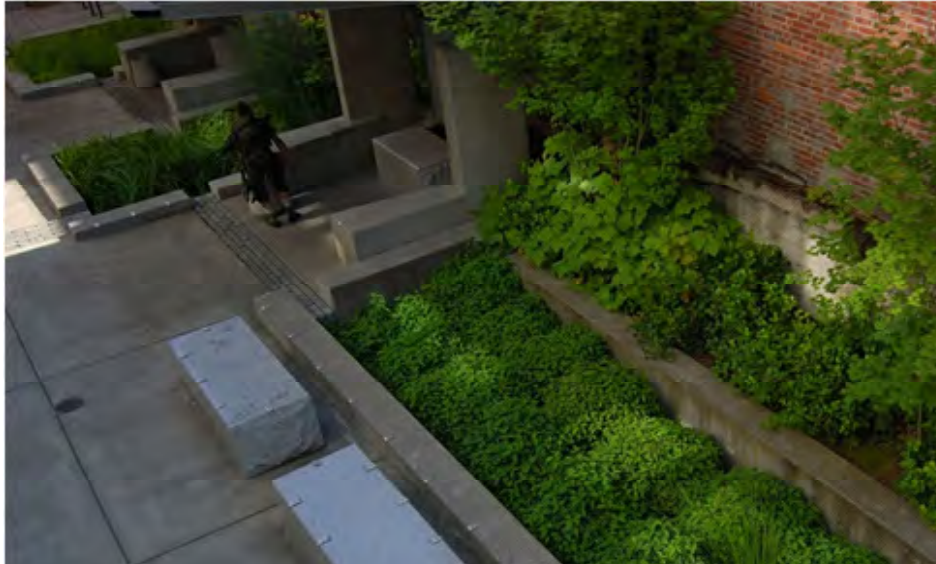


Figure 4. Portland State University Stormwater Garden. Image from [sustainablestormwater.com](http://sustainablestormwater.com).



Figure 5. Portland stormwater remediating streetscape. Images from [portlandonline.com](http://portlandonline.com), [landscapedesign-build.com](http://landscapedesign-build.com).

### 2.3.2 Street Scale

The City of Portland has been aggressive in remediating stormwater at the street scale prior to conveyance in the city's storm drains. Infiltration swales now line many streets in highly developed areas. Curb cuts are employed to direct stormwater into the infiltration swales where water is allowed to sit, infiltrate, and be remediated by phytoremediation. These infiltration swales also enhance the aesthetics of Portland's streets, providing rain-fed gardens of native trees, shrubs, and aquatic plants (Portland Bureau of Environmental Services, 2009).

### 2.3.3 Watershed Scale

Constructed wetlands have been employed to remediate stormwater conveyed from larger catchment areas greater than five acres (Alcove Watershed Protection Project, 2009). Under the Clean Water Act, wetlands are defined as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas" (U. S. Environmental Protection Agency, 2009). Constructed stormwater wetlands are shallow wetlands that temporarily detain and treat stormwater (Alcove Watershed Protection Project). Within these wetlands suspended sediment and organic matter are filtered, settled, and retained; metals are bound by clay particles in the soil; and nutrients, such as nitrogen and phosphorous, are taken up by plants. In constructed wetlands, phytoremediation, or the treatment of pollutants using plant tissue, and bioremediation, the removal of pollutants using microorganisms, are employed with adequate aeration and the appropriate flow rate and retention time to produce a condition optimal for contaminant remediation. Other benefits of constructed wetlands include the reduction of downstream peak flows, which, in turn, protects channels from scour, erosion and sedimentation by reduced peak flow; enhanced aesthetic value; and improved wildlife habitat

(Alcovy Watershed Protection Project, 2009).

Constructed wetlands are most effective during the growing season when plants are active and available for phytoremediation and the soil is sufficiently warm for microbial activity. Dry weather base flow should be maintained so as to ensure the survivability of the system when stormwater is absent (Alcovy Watershed Protection Project, 2009). This can be accomplished by terracing the wetland or by supplementing with harvested and stored water.

## 2.4 Site Selection

The Albuquerque Rail yard was selected for the purpose of remediating stormwater from Albuquerque's South Valley East Watershed due to its advantageous position within the city's existing stormwater drain infrastructure, its downstream location within the watershed and its close proximity to the Rio Grande. Adjoining the Rail Yard on the uphill side is the South Broadway Detention Basin, a stormwater detention pond maintained by the City of Albuquerque. Storm water lines from the South Valley East watershed drain to this pond. Water from this pond can be day-lighted in a constructed wetland on the Rail Yard for remediation. The Bell/Commercial #37 pump station currently transports water from this watershed to the Rio Grande (Lavato, 2009). The wetland could be designed to use the existing pump station to transport remediated stormwater to the Rio Grande.

## 3. Contaminated Site(s): America's Post-Industrial Landscape

The industrial landscape of America is in a state of decay. Globalization has led to a decline in American production, as companies move overseas seeking lower cost production, lower wages, limited environmental regulations, access to raw materials, and to new markets.

This has led to mass abandonment of industrial properties in the closing decades of the 20th Century. Factories sit abandoned, waterfronts are isolated from urban centers, railroads lie without the passing of trains, and mines have been exhausted. These landscapes, left in ruins, are symbols of our shifting domestic economy from one dominated by production to one predominantly of information and service. The post-industrial sites left in the wake were largely exploited prior to the existence of environmental regulations in America, meaning that the Clean Water Act did not apply. A legacy of environmental pollution is the result of industrialization and deindustrialization in America, with 450,000 brownfields (contaminated properties) currently scattered across the country.

The Albuquerque Rail Yard is one of these brownfields with contamination existing in the soil and groundwater. Environmental remediation of existing contaminants will be necessary to adaptively reuse the site for purposes of stormwater remediation, habitat formation and the creation of a civic space. Benefits to redeveloping the Albuquerque Rail Yard brownfield include curbing consumption of previously undeveloped land for stormwater infrastructure and park space, reconnecting neighborhoods disjoined by the Rail Yard, reactivating under-used urban areas, and potentially catalyzing redevelopment in this section of downtown Albuquerque.



Figure 6. Albuquerque Rail Yards brownfield site. Images from the author.

### 3.1 Standard Approaches to Site Remediation

Environmental engineers commonly handle issues of site remediation. Methods are selected specific to the type of contaminant, contaminants concentrations and location as well as the budget and time line of the project. Excavation and disposal is the most common method for site remediation when a quick-fix solution is desired (Jimmy Wong, 1997). This is increasingly the case as the feasibility for redevelopment of brownfields has widened with State Voluntary Programs. Other common solutions to site remediation include containment of contaminated soil with a cap, soil vapor extraction systems, bioremediation systems, pump and treat systems, and phytoremediation (Jimmy Wong, 1997). In the case of excavation and disposal, the most common method employed, contaminants are not remediated but are simply relocated. As a result, a great opportunity exists to integrate remediation system design with landscape design, using both phyto- and bioremediation in a variety of forms to produce a cleaner site by using ecological means.

### 3.2 The Role of Landscape Architecture in Site Remediation

Landscape architects have played an active role in transforming derelict sites into social spaces, handling issues of contamination remediation, historic preservation, and perception of place in various ways. Early precedents of brownfield redevelopment include Gas Works Park in Seattle, Washington, a coal gasification plant redesigned by Richard Haag to be a new iteration of the public park landscape typology. In Haag's design, industrial infrastructure remains as sculpture and as artifact, while the contamination declines by way of bioremediation technology. A layer of sewage sludge and saw dust was applied to contaminated soil, allowing for microbial activity to breakdown shallow contaminants in the soil.

At Duisburg Nord in the Ruhr Valley in Germany, landscape architect Peter Latz designed a park landscape that both remediates contami-

nated stormwater and soil on the former coal and steel production plant while creating a playful and inventive park from the industrial ruins. Industrial structures have been repurposed for recreational activities. Ore bunkers are now ascended by rock climbers; scuba diving takes place in gas tanks and water cooling pools and intimate gardens have been designed into sintering bunkers (Peter Reed, 2005). A system for slowing and treating on-site stormwater has been incorporated into the park design prior to being discharged into the Old Emscher River. Spouts and gutters convey water to two basins located in the footprints of two demolished cooling towers near the gasholder. The first basin fills with stormwater and when full, spills into the second basin. When the second basin becomes full, water flows to a series of ponds via an open trench canal. A wind powered water wheel carries water from the clarified canal along an elevated promenade to the bunker gardens, providing irrigation. Excess water flows through a



Figure 7. Stormwater remediation at Duisburg Nord. Image from Gary Vincent.

collection basin and is discharged back into the Old Emscher River via an elevated water spout. This process aerates water, enhancing the water quality for biological activity. This design retains water for the landscape design, maintains flows to the river during dry periods, and remediates contaminants in the site's stormwater (Landschaftspark Duisburg Nord, 2009).

### **3.2.1 In Situ, Ecological, and Evident Remediation Strategies**

The Gas Works Park design and the Duisburg Nord design provide precedents of landscape architects assuming responsibilities for remediating contaminated sites previously done by environmental engineers. In both design strategies, the landscape architects created multifunctional spaces integrating remediation with park design. These approaches have the potential to effectively remediate contamination while making places that are didactic of past land use and which also serve as an element of green infrastructure, providing habitat and open space.

## **4. Habitat**

The Albuquerque Rail Yard site lies within the historic Rio Grande Bosque and floodplain. A constructed wetland, the method employed for stormwater remediation, is an ecological approach in that it is inherently multifunctional. A constructed wetland in close proximity to the Rio Grande and its degraded Bosque and wetland habitats can be designed to serve migratory and resident wildlife. To design for the creation of habitat, one must first understand the functionality of the habitat that has been degraded in order to design toward that function – one must, in other words, know what once was there, why and what happened to it.

### **4.1 The Rio Grande Bosque Prior to Damming and Channelization**

Prior to major human intervention in the Rio Grande Valley which began in the 14th Century, the Rio Grande flowed year round as a sinuous, meandering stream (Ellis, 2009). Braided channels of the river shifted across the floodplain in response to changing currents and flooding. The vegetative communities of the Rio Grande Bosque responded to the meandering movement of the river and existed as a mosaic of Rio Grande cottonwood forest, shrub lands, marshes and wet meadows. Sediment deposited in spring floods would create nutrient rich sandbars necessary for the germination of cottonwood seeds. Other seedlings, such as willow, sumac, and the native olive, would likewise establish on the sandbars in conditions of limited competition for available light, water and nutrients. With time, these sandbars would become Bosque habitat. Throughout the Bosque, wetlands formed from river meanders cut off from the main channel flow and from the high water table. These wetlands took the form of wet meadows, marshes, sloughs, ponds, and oxbow lakes, and each type hosted a complex web of plant and animal life of migrating and resident species, greatly affecting the species diversity of the Bosque. Low intensity flooding in the Bosque acted to flush the ecosystem and aid in nutrient cycling, enhancing water quality in the wetlands and removing accumulated litter on the forest (Ellis, 2009). The Rio Grande Bosque, with its annual floods and free movement across the floodplain, allowed for an ecologically rich river ecosystem prior to major human alterations.

### **4.2 The Constricted Channel**

Rapid settlement along the river starting in the early 1800s and accompanying human industries such as cattle grazing within the watershed resulted in increase sedimentation in the Rio Grande (Ellis, 2009). The accumulation of deposited sediment caused aggradation, a process in which the river rises relative to the surrounding floodplain, which in turn exacerbates flooding intensity. In response to



Figure 8. Cochiti Dam along the Rio Grande. Image from [spa.usace.army.mil](http://spa.usace.army.mil).

this flooding, the Middle Rio Grande Conservancy District (MRGCD) was formed in 1925 with the mission to provide levees and irrigation ditches to protect people and property from flooding and to drain the valley wetlands to make the area more amenable to farming.

#### 4.2.1 Engineered Solutions to Flood Control

Under the authority of MRGCD, six major dams in the Rio Grande watershed were constructed, as well as 345 miles of drainage canals, 181 miles of river levees, 250 miles of main irrigation ditches, and rehabilitation of 400 miles of old irrigation ditches (Ellis, 2009). To further protect the valley against flooding, four more dams were constructed, with the last being Cochiti Dam in 1975. The result was a constricted river system, channelized by the levees and controlled by dam release.



Figure 9. Sandhill Crane. Image from [chihuahuandesert.org](http://chihuahuandesert.org)

#### 4.2.2 Wetland Decline

Draining valley soils to increase acreage of arable land and suppressing spring floods meant the decline of wetlands within the Bosque ecosystem. Between 1935 and 1989 the Middle Rio Grande Valley lost over half of its floodplain wetlands due to extensive draining for farming and flood control (Ellis, 2009). Today, the wetlands of the Rio Grande Bosque stand at less than 20% of their former area prior to 1935 (Friends of the Rio Grande Nature Center, 2009).

#### 4.3 Bosque Restoration Precedents and Studies

The Rio Grande Nature Center State Park is located within the Bosque of the Rio Grande in Albuquerque. There are four constructed wetlands at this park for the purpose of restoring former wetlands in the Bosque for wildlife habitat. Water is pumped into these wetlands

from the aquifer due to the lack of natural flooding in the Rio Grande floodplain.

Bird species that utilize the created wetland habitat in winter are ring-necked ducks, American wigeons, Northern harriers, ruby-crowned kinglets, hermit thrushes, chipping sparrows, dark-eyed juncos, western meadowlarks, sandhill cranes and bald eagles. In the summer, warblers, western meadowlarks, black-chinned hummingbirds, black phoebes and western kingbirds use the wetland habitat during their migration. Immigrant mammals, amphibians, reptiles, and arthropods, also utilize the wetlands for habitat. The Candelaria Wetland, opened in 2001, is a nine acre wetland within the park. This wetland was planted with 98 species of native aquatic and riparian vegetation, restoring habitat once common in Albuquerque along the Rio Grande (Friends of the Rio Grande Nature Center, 2009).

Bosque del Apache is a wildlife refuge located within the historic floodplain of the Rio Grande near Socorro, New Mexico. The refuge is 57,191 acres and is comprised of 12,900 acres of moist bottomlands, 3,800 acres of which are in the active floodplain of the Rio Grande and 9,100 acres of which are areas where water is diverted to create wetlands, farmlands and riparian forests (U. S. Fish and Wildlife Service, 2009). Wetlands in the refuge are maintained for Neotropical migrant land birds which nest in the United States or Canada, and spend the winter primarily south of our border in Mexico, Central or South America, or in the Caribbean. Amongst the 377 species of birds that have been observed at the refuge are hawks, hummingbirds, warblers, and tanagers, flycatchers, thrushes, and vireos. Many of these birds are experiencing population declines due to loss of wet-



Figure 10. Wetland restoration in the Rio Grande Bosque. Image from rgnc.org.

lands and other habitats necessary for survival (U. S. Fish and Wildlife Service, 2009). Preservation, restoration and creation of habitats for nesting, wintering, and migratory stopover are vital for the survival of many bird species.

The wetlands in this refuge are highly maintained to ensure their functionality as wildlife habitat. Various wetland areas are rotated between wet and dry periods to supply a variety of habitats. Water levels are lowered in wetlands creating moist fields to promote the growth of native marsh plants. Dry areas are burned and re-flooded to allow for marsh plants to grow. When mature marsh conditions are reached, the cycle is repeated. Smartweed, millets, chufa, bulrush, and sedges are wetland plants that have been managed for wildlife forage (U. S. Fish and Wildlife Service, 2009).

## 5. Civic Space

Adapting the Albuquerque Rail Yard as a site for ecological stormwater remediation opens the site up to a host of other opportunities, including the creation of a large civic space to serve the Baretas, South Broadway and Downtown neighborhoods, as well as the rest of Albuquerque.

### 5.1 Green Space

Although there is a high percentage of green space in the vicinity of the Rail Yards (i.e. Tingley Beach, the Rio Grande Bosque, and Kit Carson Park), these parks are concentrated toward the western edge of the Baretas neighborhood and are disjoined from the South Broadway neighborhood by the Rail Yard. The area lacks safe pedestrian and bicycle connections between the neighborhoods and the area's green spaces. Community members have stressed the importance of enhancing pedestrian and bike connections to existing green spaces and throughout the community in order to enhance the quality of life

in the neighborhoods. There currently is no pedestrian bridge connecting the neighborhood to the Bosque, exemplifying the need to enhance connections to important green spaces (City of Albuquerque Planning Department, 2008).

The residents of the community have indicated that they desire additional public space in the neighborhood. They would like to see a plaza or other community gathering space developed, as well as areas for community gardening and urban farming. The communities surrounding the Rail Yard have relatively high youth population compared to Albuquerque, especially between ages 10 to 19 (City of Albuquerque Planning Department, 2008). This high youth population would benefit from an additional open space in the vicinity. The Rail Yard would be an ideal location for an open space that serves as a connection and destination between the Barelás and South Broadway neighborhoods.

## **5.2 Local Economy**

Both Barelás and the South Broadway neighborhoods are subject to depressed economic activity. There is significant interest in enhancing the economic vitality of South Fourth Street, to the west of the Rail Yards (City of Albuquerque Planning Department, 1994). This effort would not benefit the South Broadway neighborhood if physical connections are not made between the two neighborhoods. The community has stressed that the redevelopment of the Rail Yards should benefit the community economically, aesthetically, and functionally, as expressed in the Barelás Neighborhood Sector Plan (City of Albuquerque Planning Department, 2008). An open space for stormwater remediation would benefit the community aesthetically and functionally, meanwhile providing an anchor for economic revitalization. There are currently 100 vacant lots surrounding the Rail Yard site and 170 vacant lots in all of Barelás (City of Albuquerque Planning Department, 2008). These lots could be developed for housing, retail, and services reportedly needed by the community with the redevelopment of the Rail Yards as a stimulating force. The community has also

stated in a series of public meetings held for the development of the Barelás Neighborhood Sector Plan, the desire to have a place for an open air market for food, retail and arts. This could take place within a new open space in the Rail Yard.

## **6. Method**

### **6.1 General Approach**

The approach for the design of the Albuquerque Rail Yard site is to integrate brownfields remediation and redevelopment with ecological stormwater remediation infrastructure, toward an end of producing a large civic space and wildlife habitat.

### **6.2 Site Design Method**

The method employed for the design is to repurpose existing industrial forms on the Rail Yard site to produce a landscape with a new and much broader functionality, while noticeably referencing to the site's former industrial use.

## **7. Site Analysis**

### **7.1 Site Boundary**

The Albuquerque Rail Yard and Backshop site is 27.3 acres and lies between the Barelás and South Broadway neighborhoods in downtown Albuquerque, New Mexico. Second Street in Barelás provides the boundary to the west and Commercial Street in South Broadway forms the eastern boundary of the site. The site is bound to the north and south by land currently owned and operated by the BNSF Railway



Figure 11. Site Boundary. Image from Google Earth.

(Urban Land Institute, 2008).

## 7.2 Site History

In 1880, Albuquerque was designated as the division point between two major railroads, the Atchison, Topeka, and Santa Fe Railroad and the Atlantic and Pacific Railroad (Wilson, 1986). The offices, repair shops and the depot for these railroads were located in Albuquerque with this designation, providing industry and transforming the city from being a farming village to a major commercial and industrial center in the west and the largest city in New Mexico (Wilson, 1986). By 1919, the Rail Yards employed a quarter of the city's workforce at 970 people, particularly in the locomotive shops. Subsidiary industries such as a foundry, lumber and wool scoring mills, and dry goods, grocery and hardware warehouses, as well as the railroad depot and hotel, accounted for the majority of employment for the remaining workforce (Wilson, 1986). As the birthplace of industry in Albuquerque and as a major source of employment within the city, the Rail Yard was viewed with community pride as a source of progress and prosperity (Wilson, 1986).

In 1935, the Santa Fe Railroad converted from coal-powered steam engines to diesel engines in order to run longer distances and to reduce maintenance requirements (Wilson, 1986). The central diesel engine repair shops were located in San Bernardino and Cleburne, diminishing the use of Albuquerque's facilities which were designed to service steam engines. The Albuquerque site was used from 1953 to 1991 as a facility for repairing equipment used for the maintenance of the rail lines, requiring less than 200 employees and under utilizing the full industrial potential of the site (Wilson, 1986). In 1991, all industrial operations ceased and the site was abandoned (Intera, 2007). The City of Albuquerque purchased the site from the Railroad Company in 2007 and commissioned a redevelopment study by Urban Land Institute, with the goal of reusing the site for a variety of uses (Urban Land Institute, 2008).

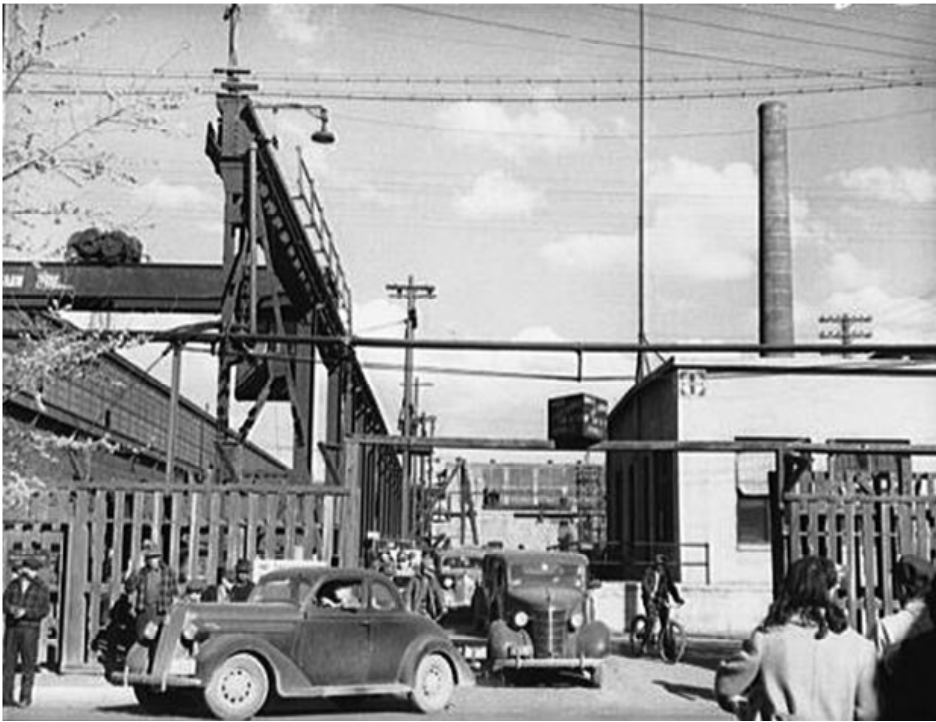


Figure 12. The Albuquerque Rail Yard during World War II. Image from [www.wheelsmuseum.org](http://www.wheelsmuseum.org).



Figure 13. The Rail Yard site in context. Image from Google Earth.

### 7.3 Geographic and Geological Context

The site is located within the Albuquerque Basin, bordered by the Sandia and Manzano Mountains to the east and the Colorado Plateau to the west (Intera, 2007). Geological formations underlying the site are Rio Grande Fluvial deposits (Quaternary), Ceja Formation of the Upper Santa Fe Group (Tertiary) and the lower and middle subgroups of the Santa Fe Group (Tertiary) from youngest to oldest (Intera, 2007). The site is in the southwest quadrant of the city of Albuquerque and lies within the historic floodplain of the Rio Grande.

### 7.4 Hydrology

#### 7.4.1 Precipitation

The area surrounding the Rail Yard received approximately 8.6 inches of rainfall per year with the majority falling with the summer monsoons in July, August and September. Peak intensities for rain storms range between 4.7 and 5.6 inches per hour during a 100-year rain-storm event (ASCG Incorporated, 2005).

#### 7.4.2 Catchment Area

The catchment area for the purpose of stormwater remediation in this project includes stormwater from both on- and off-site sources. Due to the proximity of the site to the South Broadway Detention Pond and the Bell/Commercial Pump Station, only off-site stormwater that flows through these existing features will be directed to the Rail Yard site for remediation. On-site stormwater to be remediated in the design come from the roof and the grounds of the 27.3 acre site.

### 7.4.2.1. Urban Watershed

The site is located within the South Valley East urban watershed of Albuquerque, New Mexico. Within this urban watershed is a sub-watershed in which stormwater drains to the South Broadway Detention Pond. The catchment area for this Pond is approximately 2.5 square miles (1600 acres) and stretches from the eastern boundary of the Rail Yard site to the vicinity of the University of New Mexico to the east (See Figure 14). Based on calculations from the USDA's Urban Hydrology for Small Watersheds TR-55, stormwater flowing into the South Broadway Detention Pond is at a capacity of 93.3 acre feet during a 100 year rainstorm event (USDA, 1986).

### 7.4.2.2. Roof Collection

The total roof area of the existing buildings on-site is 254,000 square feet (Intera, 2007). On an annual basis, the potential exists to harvest approximately 3 acre feet from the total area of building roofs with the majority collected in July, August and September.

### 7.4.3. Topography

The topography of the site is very flat, with slopes less than one percent. The elevation ranges from 4,952 feet above sea level in the northeast corner of the site to 4,948 feet above sea level in the south-

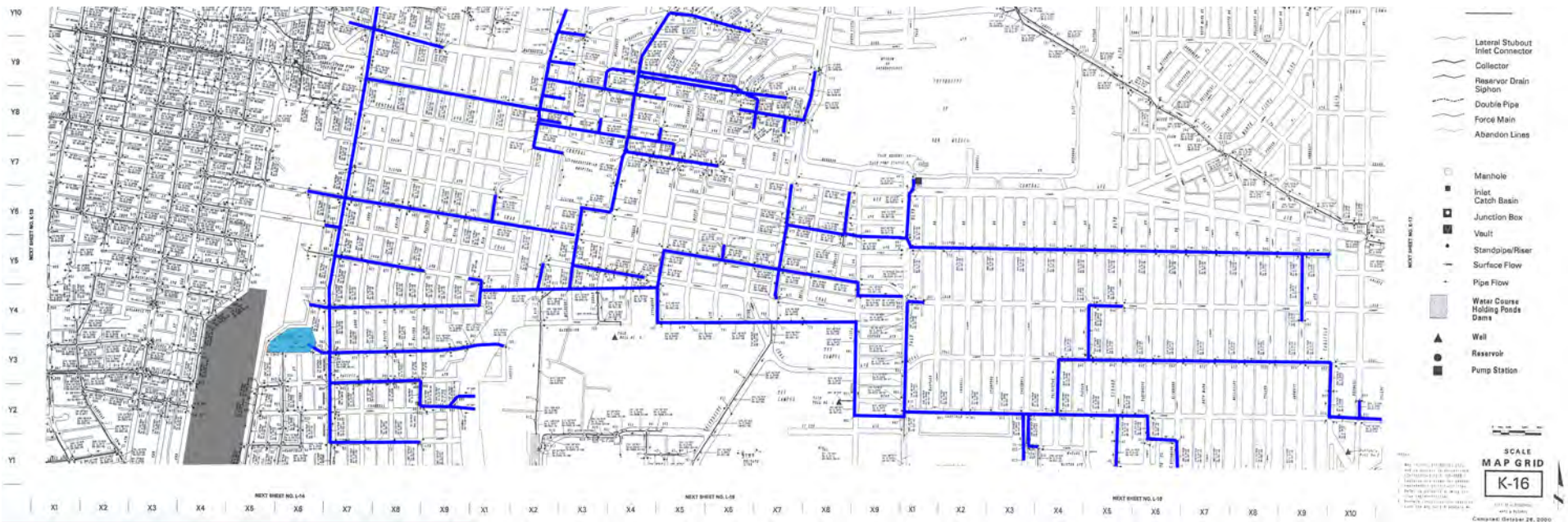


Figure 14. The sub-watershed catchment area showing storm drains (dark blue), the South Broadway Detention Pond (light blue), and the Rail Yard (light gray). Image produced by the author.

west corner. The site is gently sloping to the southwest and there are several man-made depressions that are approximately 4 feet deep.

#### 7.4.4. Water Table

As evidence of the imbalance of demand and supply for water in Albuquerque, the depth to groundwater on-site ranges from 29 to 38 feet below the surface (Intera, 2007). This is remarkably low for a site so close to the river. Groundwater flow is currently to the northeast, due to groundwater pumping for the city in the foothills of the Sandia Mountains. The historic direction of groundwater flow, prior to the 1930s, was to the southwest in accordance with the flow of the Rio Grande (Intera, 2007).

## 7.5 Soils

### 7.5.1 Naturally Occurring Soils

The soil type that occurs on the Rail Yard site is classified as Glendale Clay Loam. This soil type occurs in flood plains and stream terraces. The parent material is alluvial deposits derived from igneous and sedimentary rocks. A typical soil profile for this soil type is clay loam from 0 to 70 inches below the surface. Slope for this soil type is 0 - 1 percent. The drainage class of this soil type is well drained with the capacity to drain 0.2 – 0.6 inches per hour. This soil is non-saline to very slightly saline. The available water capacity for this soil is high at 11.4 inches. (USDA Natural Resources Conservation Service, 2006)

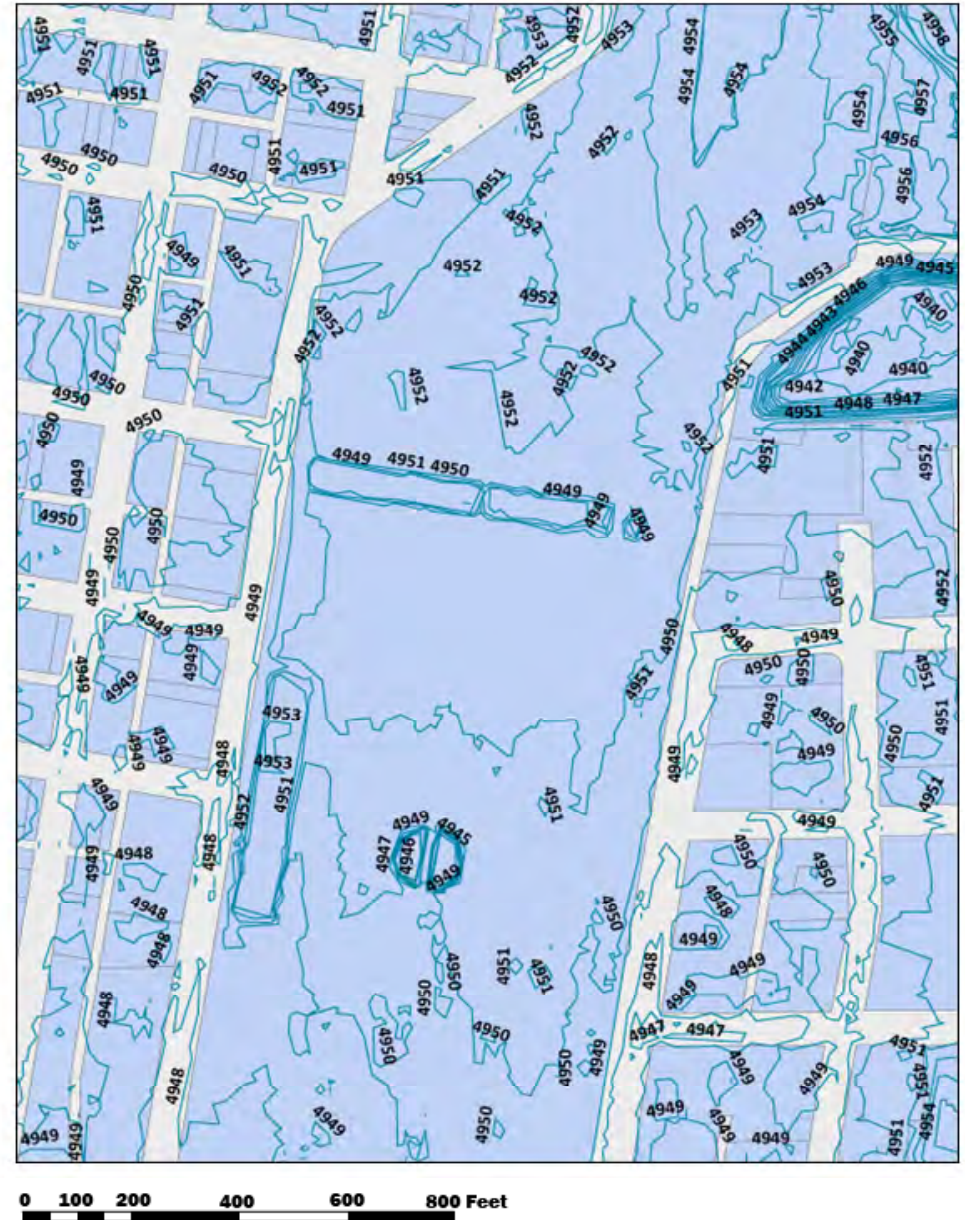
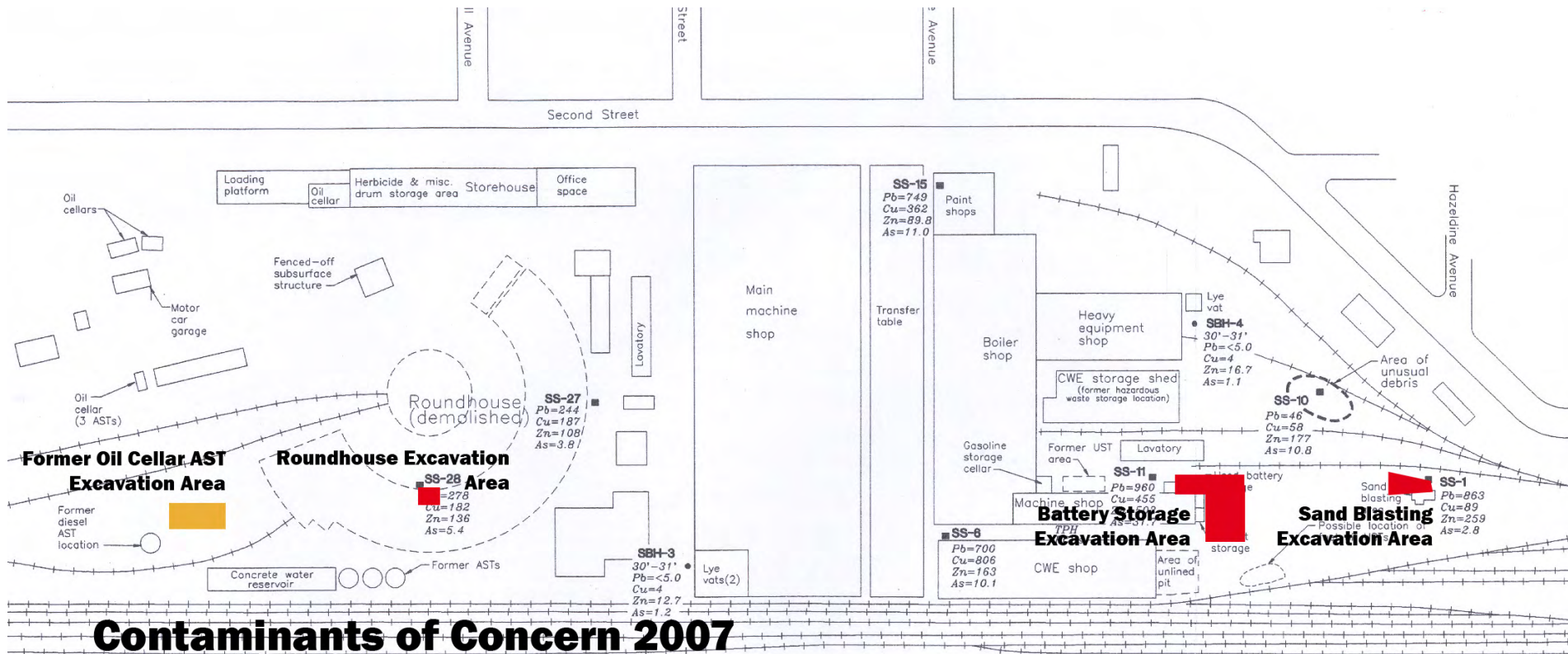
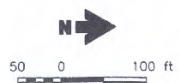


Figure 15. Topography of the Rail Yard site. Image from GIS.



# Contaminants of Concern 2007

- Lead - Most Lead Impacted Soils Have Been Excavated, None Have Been Removed From The Site Or Treated (0-5' bgs)**
- Diesel + Motor Oil Range Organics - 330 Cubic Yards Have Been Excavated, A Sump Has Been Installed, Soil is Stockpiled At The Site**



- Explanation**
- SBH-3  
30'-31' Subsurface soil metals concentration (mg/kg) with corresponding sampling depth (feet below surface)
  - SS-28 Surface soil sample showing metals concentrations (mg/kg)
  - Sump
  - Railroad tracks
- DANIEL B. STEPHENS & ASSOCIATES, INC.**  
4-15-97 JN 5036

**Notes: Metals** Priority pollutant metals; EPA methods 6010/7000  
 Metals detected above background levels:  
 Pb = lead  
 Cu = copper  
 Zn = zinc  
 As = arsenic

**TPH** Total petroleum hydrocarbons as gas/diesel; EPA method 8015 modified  
**PCBs** Polychlorinated biphenyls; EPA method 8080

SANTA FE RAILWAY CWE FACILITY  
**Phase II Investigation**  
**Metals Concentrations in Subsurface and Surface Soil Samples**

Figure

Figure 16. Contaminants of concern in 2007. Image from Intera.

## 7.5.2 Contaminated Soil

Soils on site are contaminated with metals and with hydrocarbons. Lead occurs in the soil around the Battery Storage, Roundhouse, and Sand Blasting Excavation Areas. Diesel Range Organics and Motor Oil Range Organics occur in the soil surrounding the Oil Cellar and the AST Excavation Area. Areas of contaminated soil above soil screening levels for New Mexico have been excavated and remain untreated and stockpiled on-site (Intera, 2007).

## 7.6 Historic Structures and Industrial Remnants

### Roundhouse and Turntable

The Roundhouse was built in 1915 with reinforced concrete, a modern industrial material for the time. Daily maintenance and repairs of steam locomotives occurred in the roundhouse and the turntable was the infrastructure for transferring the locomotives to one of the 35 stalls of the roundhouse. Although the roundhouse was demolished in the 1960s, the turntable is still present on the site (Wilson, 1986).

### Machine and Boiler Shops

Built between 1921 and 1923, the Machine and Boiler Shops were designed to house periodic overhauls of locomotives (Wilson, 1986). These buildings are 240 by 604 foot, one story, steel framed structures clad with massive glass curtain walls. These buildings have not been demolished and account for the majority of usable indoor space on the site.



Figure 17. The Turntable. Image from the author.



Figure 18. The Machine and Boiler Shops with the Transfer Table in between. Image from the author.



## 8. Albuquerque Rail Yard Preliminary Site Design

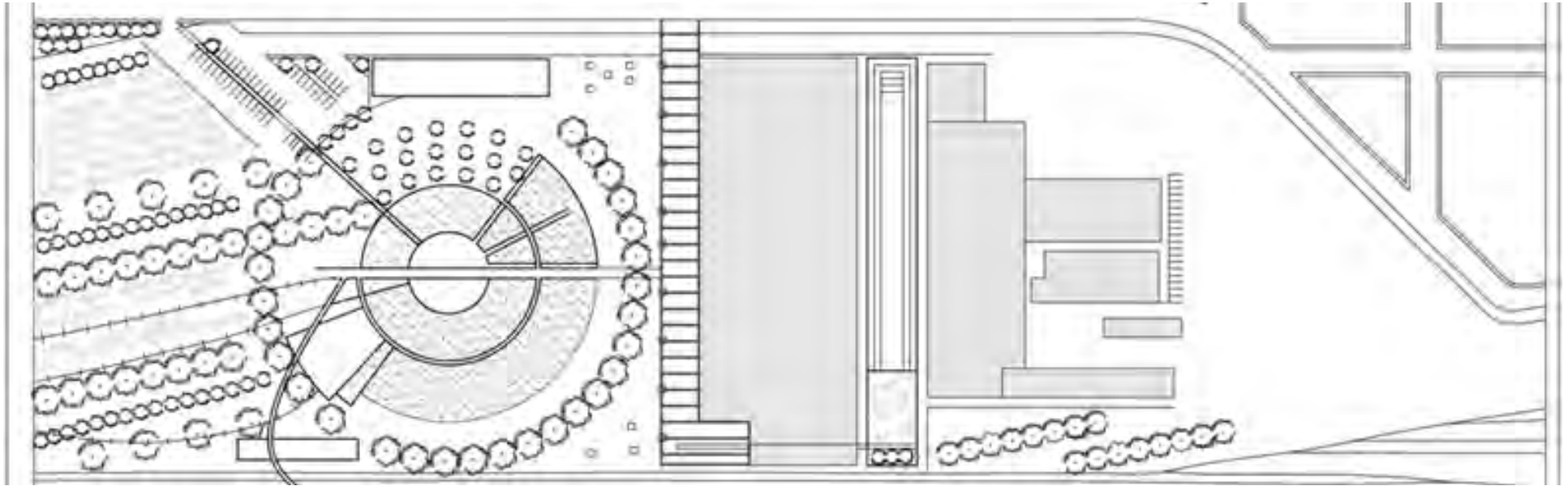


Figure 20. Preliminary site design. Image from the author.

### 8.1 Design Concept

The design goal for the Albuquerque Rail Yard site is to integrate Brownfield remediation and redevelopment with ecological stormwater remediation infrastructure, toward an end of producing a large civic space and wildlife habitat. The concept for the design is to reference the site's former industrial use, overlaying remnant industrial forms with new function and meaning. In the Rail Yards first iteration, the site was a place where trains travelling at high velocities on long, linear paths, i.e. the railroad, would come to be repaired and reworked before departing again on the railroad. The next design iteration, one for the treatment of stormwater rather than the treatment of trains, looks to this historic use for design inspiration. Stormwater too, travels along long, linear paths at high velocity (in this instance via



Figure 21. Design parti representing the linearity of rail lines and storm drains and the circular place of repose for trains (historically) and stormwater remediation (designed). Image from the author.

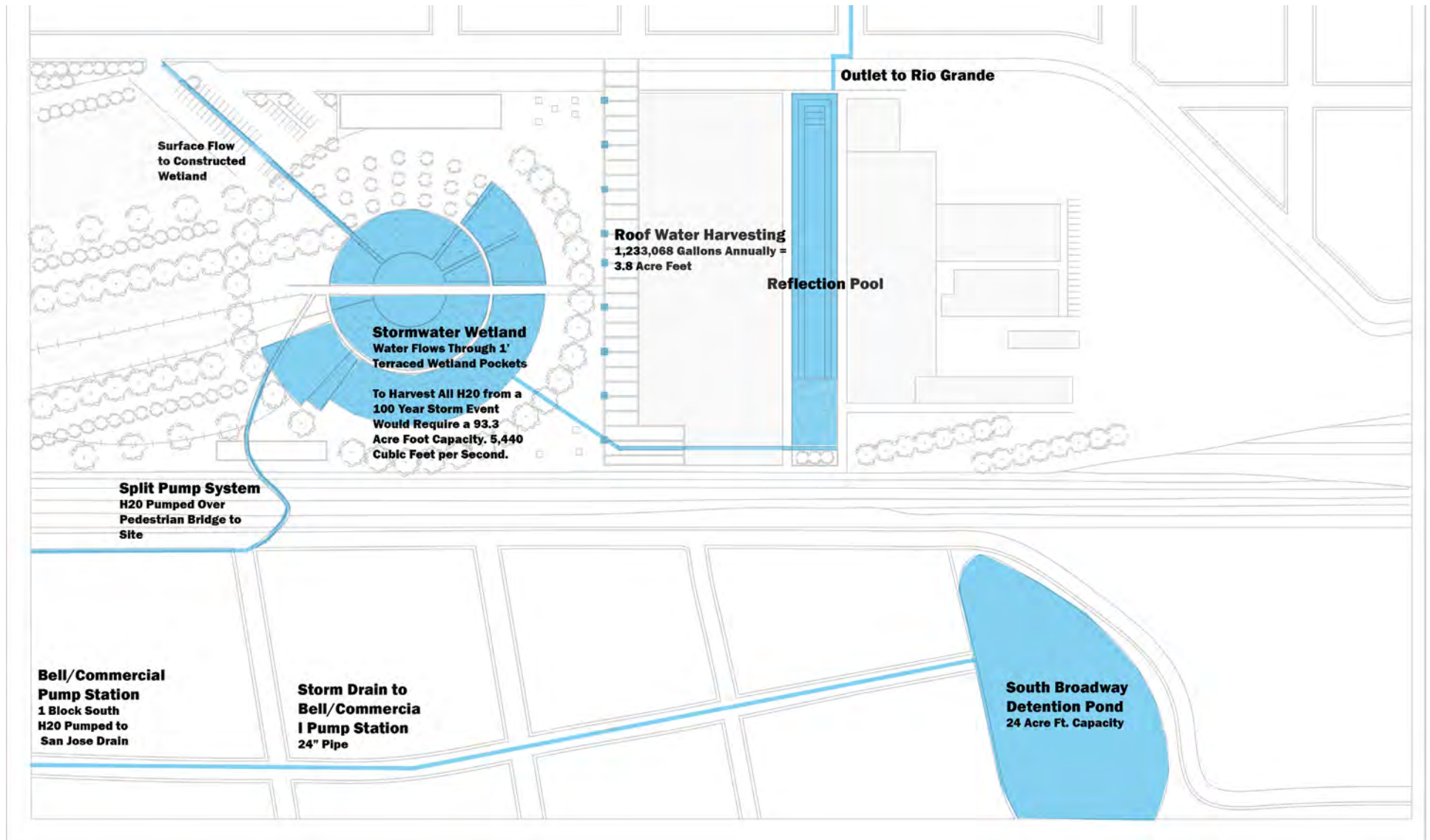


Figure 22. The path of stormwater in the preliminary design. Image from the author.

drainage networks). In this design the site will become a place where stormwater is designed to slow and be repaired. The parti shown in Figure 21 demonstrates the site as palimpsest, layering historic forms and meanings with the next iteration of the Rail Yards.

## 8.2 Preliminary Design

The preliminary site design includes alternating fields, hedgerows and cottonwood stands to attract wildlife, the constructed wetland for stormwater remediation, a roofwater harvesting industrial-scale pergola, the reflection pool and space for local business in the industrial building shells.

## 8.3 Stormwater Remediation



Figure 23. Preliminary terracing concept for the constructed wetland. Image from the author.

Stormwater from the South Broadway Detention Pond will be directed to the Rail Yard site for biological remediation in a constructed wetland. The designed wetland has a capacity to treat 14 acre feet of stormwater in 1 foot deep terraces. These terraces are planted with watercress, common reed, sedges, cattail, bulrushes, and yellow flag iris. Each plant has been selected for its ability to remove pollutants from stormwater and for the ability to withstand both dry and wet periods. Pathways and a pedestrian bridge have been integrated into the wetland design to allow for people to interact with the wetlands.



Figure 24. Linear mounds of contaminated soil will be formed in the fields (southern) portion of the design and will be inoculated with oyster mushroom mycorrhiza and planted with Indian mustard to remove lead and hydrocarbons from the soil. Image from the author.



Figure 25. Once soil remediation has taken place, the mounds will be planted with bands of cottonwoods, field plants and hedgerow plants to attract wildlife. Image from the author.

## 8.4 Site Remediation

The strategy employed for soil remediation involves phytoremediation and mycoremediation, the removal of contaminants from soil using plants and fungal mycelium. Excavated soil that is currently stockpiled at the site will be formed into a series of mounds. These mounds will be planted with Indian mustard and will be inoculated with the mycelium of oyster mushrooms for a period of one to two growing seasons. After this time, the roots and the mycelium will have degraded the contaminants and the mound can then be planted with a variety of field and hedgerow species for wildlife habitat. The parallel lines of the mounds reference the lines of the train tracks in the southern portion of the former Rail Yard site.

## 8.5 Wildlife Habitat

Wildlife habitat will be designed into the southern end of the site, where alternating rows of cottonwoods, field plants such as corn, wheat, sunflowers, milo, millet and sorghum, and hedge plants such as desert willow, gambel oak, black locust, sumac, wolfberry, and currant, will be planted to attract Sandhill cranes and songbirds. The constructed wetland will also be designed to provide habitat for amphibians and other wildlife that have experienced habitat fragmentation and degradation with the draining of Bosque wetlands.

## 8.6 Civic Space

All areas will be designed to maximize human accessibility, enjoyment and comfort. For instance, the constructed wetland will be intersected and wrapped by pedestrian paths and will include direct access to the water to provide places for viewing wildlife, contemplation and refuge. It is of the utmost importance to return the site to the community and to the city to be a new typology of the public park, one that integrates sound ecological services within contemporary park design. People and their interaction with and enjoyment of the on-site ecological processes, is a fundamental goal in the design of this site.

# 9. Albuquerque Rail Yard Final Site Design

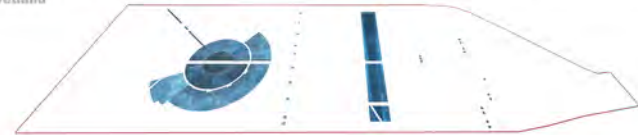
## 9.1 Design Program

The program for the final site design for the Albuquerque Rail Yard is intended to serve the community's economical, ecological, social, and infrastructural needs. The site is a large civic space, designed to be a park or large open space, a venue for local businesses and services, such as day care facilities and a community kitchen, an urban wildlife refuge, and a system for remediating stormwater. Areas such as the constructed wetland, the reflection pool and the community garden have been programmed for more structured use, whereas the fields and the meadow are intended for less programmed use.

## design layers

### water

stormwater is remediated in the constructed wetlands . clean water is then stored in the reflection pool to be used for irrigation . 24 cisterns store water harvested from the site to ensure year round flows in the wetland



### vegetation

permeable vegetated areas reduce the runoff generated on-site . vegetation is irrigated with remediated stormwater from the constructed wetland, stored in the reflection pool



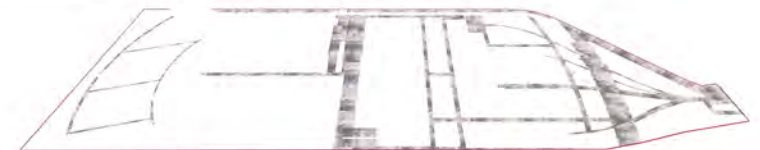
### recycled concrete

concrete from the existing industrial site will be salvaged, refigured and reused as a permeable crusher fine type material . the permeable nature of this material will reduce runoff while reducing landfill waste



### permeable pavers

permeable pavers allow for an urban aesthetic for the site design while allowing for maximum stormwater infiltration and retention



### water harvesting surfaces

roofs, the south parking lot and other impermeable surfaces are used as water harvesting aprons, capturing stormwater to supplement lower watershed inflows during dry months

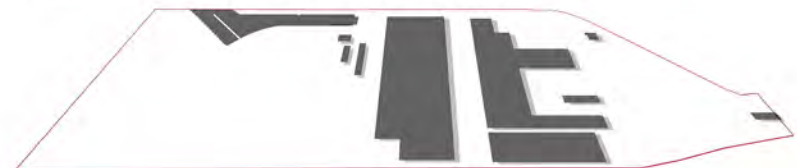


Figure 26. Layers of the site design. Image from the author.

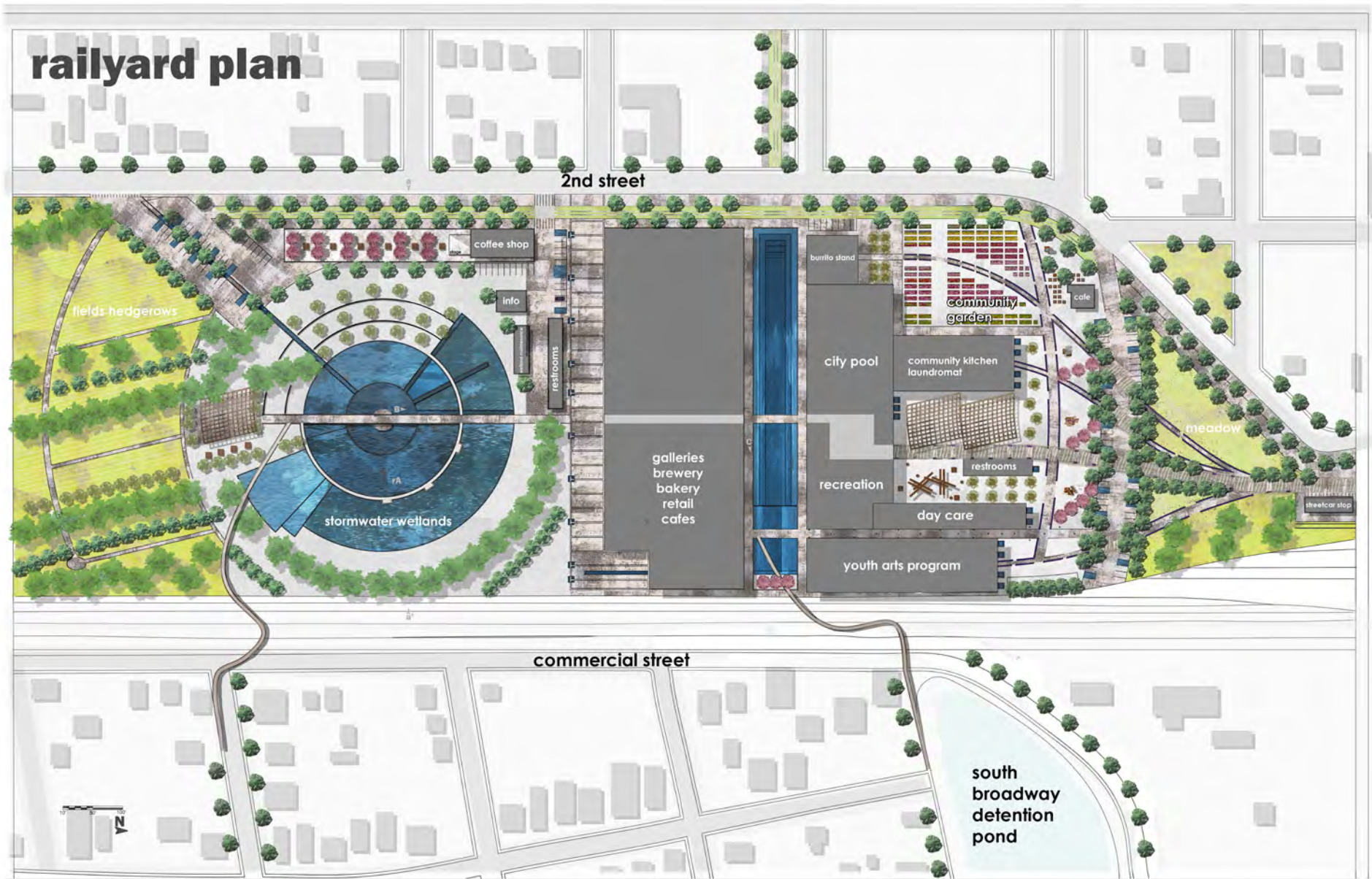


Figure 27. Plan. Image from the author.

## 9.2 Ecological Site Remediation

The site will undoubtedly need to undergo major demolition, cleaning and preparation before it is ready for the proposed design. Contaminated soils exist on site and will need to be remediated or removed before the site is suitable for human occupation and before the site should be designed to encourage the presence of wildlife. Although removal of contaminated soil is often employed as a remediation strategy due to the brevity of the process, it is often significantly more expensive than in-situ remediation strategies.

The remediation strategy proposed for the Rail Yard site is to mound contaminated soils to be approximately four feet tall in the southern end of the site. The contaminated soil should then be inoculated with the mycorrhiza of oyster mushrooms, which will degrade motor oil and diesel range organics in the soil and planted with Indian mustard, which will take up the lead in the soil. The mounds should then be monitored and maintained until contamination levels drop to New Mexico Soil Screening levels. This should take approximately one growing season.

In-situ remediation strategies, such as the one proposed, truly remediate contaminated soil rather than simply moving it. It is more labor intensive, but it is often significantly cheaper.

## 9.3 Ecological Stormwater Remediation

Stormwater is remediated in a series of wetland cells located in the circular constructed wetland in the location of the former roundhouse and turntable. The slope across each wetland cell is 1% so as to ensure proper drainage of the stormwater to the next cell while allowing for sufficient detention time to allow for the remediation process. See Appendix 1 for the proposed water budget for the site.

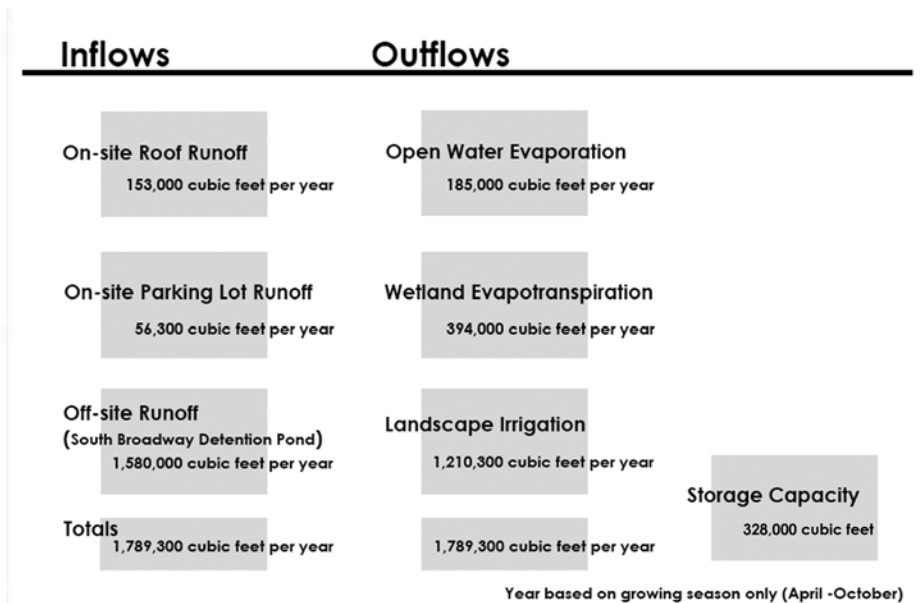


Figure 28. Water budget. Image from the author.

### 9.3.1. Catchment Area

The stormwater catchment area for off-site stormwater is 2.5 square miles of the South Valley East urban watershed. Stormwater that falls on the city's streets, buildings and other impermeable surfaces within this sub-watershed, is directed to the South Broadway Detention Pond via subsurface storm drains. The stormwater then flows to the Bell/Commercial Pump Station, across Commercial Street on the east side of the rail yard site. The water will then be rerouted to the constructed wetland where it will undergo remediation, storage and use for irrigation on site. Approximately 1,580,000 cubic feet (36 acre feet) from the watershed will be harvested and treated in the constructed wetland from April to October, depending on annual rainfall.

Other catchment areas for on-site stormwater include an impermeable parking and platform area and roof surfaces, accounting for approximately 56,300 cubic feet and 153,000 cubic feet from April to October respectively.

# water flow diagram

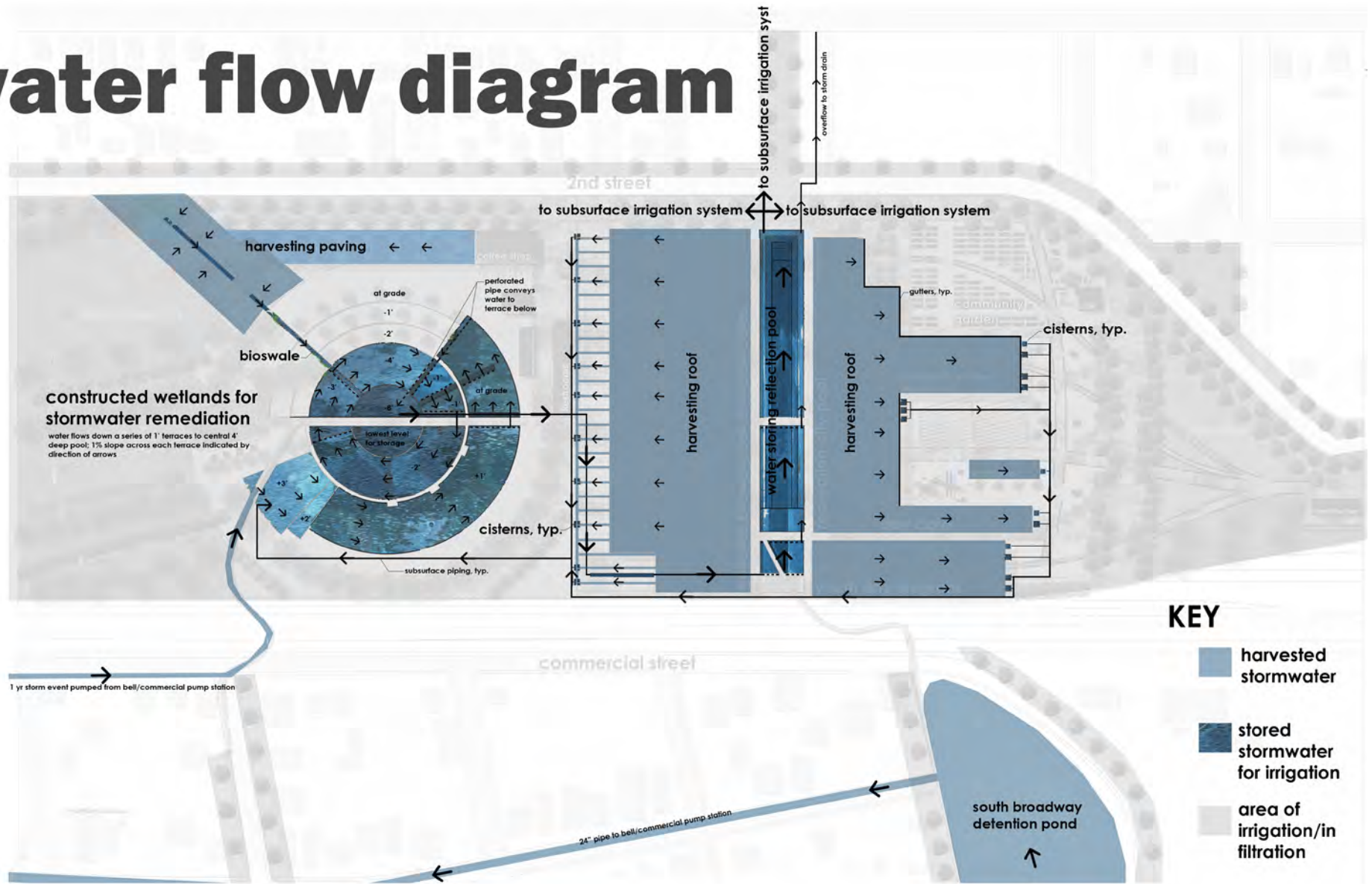


Figure 29. System of stormwater flow. Image from the author.

stormwater from albuquerque's south valley east watershed flows into the south roadway detention pond where it drops sediment before flowing to the bell/commercial pump station . from the pump station water will be rerouted to the constructed wetland on the railyard site for remediation, storage and use in the landscape for irrigation

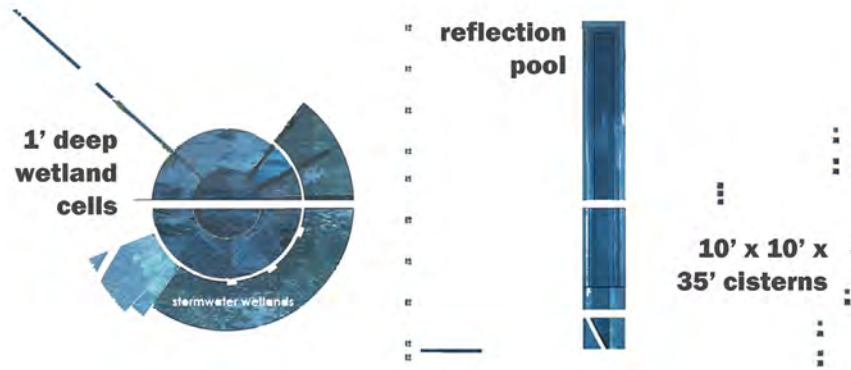


Figure 30. Water storage features. Image from the author.

### 9.3.2. Plant Palette

The plant palette for the constructed wetlands includes watercress, common reed, sedges, cattail, bulrush, yellow flag iris and purple flag iris. These plants will be planted in a medium within the one foot deep wetland cells for the purpose of stormwater remediation. Dissolved metals and soluble phosphorus in the stormwater will adsorb to soil particles. Nitrogen, organics and pathogens will be degraded by microbial processes including nitrification and denitrification. Nutrients including nitrogen and phosphorous will be taken up by plants and pathogens can degrade by exposure to sunlight and dryness.

### 9.3.3. Trash Removal

The removal of trash in this system occurs in the South Broadway Detention Pond, where a water quality feature for this purpose is currently operating.

### 9.3.4. Infiltration and Evapotranspiration

Open water evaporation is approximately 185,000 cubic feet from the wetland cells and the reflection pool where remediated stormwater

is stored. Wetland evapotranspiration accounts for approximately 394,000 cubic feet of the water budget from April to October. Infiltration or evapotranspiration from the landscape plantings irrigated with remediated and stored stormwater accounts for 1,210,300 cubic feet during the growing season of April to October.

### 9.3.5. Altered Discharge to the Rio Grande

Due to the large volume of water that will be rerouted to the Rail Yard site, used for irrigation or that will evaporate from the open water storage areas, the discharge to the Rio Grande from the South Valley East Watershed will be approximately 1,789,300 cubic feet (41 acre feet) less than current discharge volumes from April to October. This

## plant materials



Figure 31. Plant materials. Image from the author.

will reduce bank erosion, sedimentation and contamination of downstream flows.

### 9.3.6. Ecological Flood Control

The designed system has a capacity to store 328,000 cubic feet (7.5 acre feet) of stormwater and so therefore can serve as ecological flood control infrastructure.

### 9.3.7. Supplemental Water

Stormwater harvested off the roofs of the buildings on-site will be stored in 24 above-ground cisterns that will supply stormwater to the wetland system during dry months.



Figure 32. A bridge crosses all terraces of the constructed wetland, remaining level with the surrounding finish floor elevation. Stormwater flows through a series of 1' deep terraces full of wetland plants that have the ability to remove pollutants from the water. The deep center pool stores water after it has been remediated and before it flows into the reflection pool to ultimately be used for irrigation. Image from the author.



Figure 33. A path encircles the inner wetland cells allowing people to experience the remediation, life and growth occurring in the 1' deep wetland cells. Seat walls designed into the wetland terraces provide a point from which to observe and experience the urban riparian area. Image from the author.



Figure 34. The reflection pool is where stormwater is stored after it has flowed through the constructed wetland and prior to being used for irrigation. This storage infrastructure doubles as a reflection pool, providing a unique urban environment cooled by the shade of industrial buildings and the presence of water. Image from the author.

## 9.4 Habitat

The site has been designed to serve the biological community associated with the Rio Grande Bosque and wetlands. The hedgerow plants, including cottonwoods, lacebark elm, desert willow, eastern redbud, gambel oak, black locust, sumac, wolfberry and currant, will be planted throughout the site and concentrated in the fields area in order to attract songbirds. The field plants, including corn, wheat, sunflowers, milo, millet, and sorghum, have been chosen to attract sandhill crane, Canadian geese and other migratory and resident species.

The wetlands will serve a host of biological activity. Mallards, Canadian geese, cooper's hawk, great blue herons, sandhill cranes, killdeer, flycatchers, tanagers, and other bird species should benefit from the presence of open water in the urban environment. Amphibians such as the northern leopard frog and the western chorus frog should also inhabit the site and benefit from the added presence of water.

## 9.5 Civic Space

The site has been designed to connect neighborhoods that have been disjointed by the industrial facility, namely the Barelmas neighborhood, the South Broadway neighborhood and the downtown neighborhoods. This is accomplished in the design by located pedestrian bridges over the train tracks on the eastern side of the site connecting it with the South Broadway neighborhood, by providing a pedestrian promenade to downtown Albuquerque along the western edge of the site and running north and by opening the site to be civic space for all community members.

The site serves the community as a large park for outdoor recreation, as an economic engine for local business growth and for the availability to community services, such as laundry facilities and day care. The design allows for community members to grow their own food in the community garden and to add value to the food grown in the community kitchen. Value added products could then be sold at a farmers' market, accommodated by the design of the north parking lot. The

# use diagram



Figure 35. Use diagram. Image from the author.

design also provides spaces for live music and informal food vending, creating business and social opportunities for the people of Albuquerque.

## 10. Conclusion

This design thesis aims to show the potential to and purpose for remediating on- and off-site stormwater on a post-industrial rail yard site. By interrupting the current urban hydrologic flow to include infrastructure for stormwater remediation, a whole host of benefits can arise for the community, both human and non-human. This project not only impacts Albuquerque's residents and the biotic community of the Rio Grande bosque, but it also impacts downstream communities along the Rio Grande by reducing the amount of untreated contami-

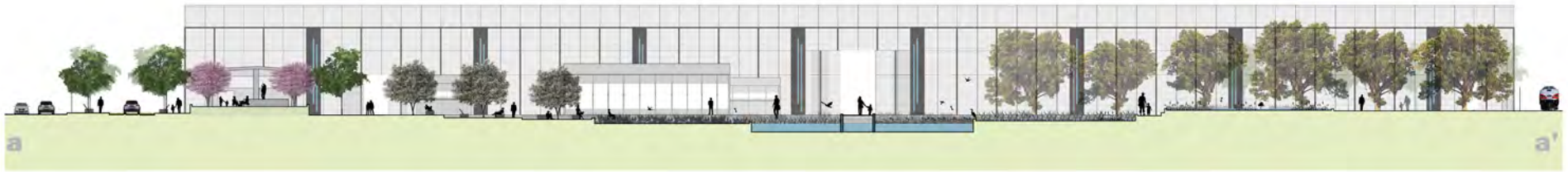


Figure 36. Cross-section of wetland looking north. Image from the author.

nation entering this important waterway.

This design project aims to be an example for the City of Albuquerque and other municipalities that desire meaningful and socially and environmentally responsible reuse of urban brownfields in conjunction with multifunctional means of stormwater remediation.

## Figure List

Figure 1. Historic photo of polluting stormwater. Image from [Drx.typepad.com](http://Drx.typepad.com)

Figure 2. Albuquerque stormwater infrastructure during rain event. Image from [amafca.org](http://amafca.org).

Figure 3. Contaminated water signs. Images from [Pesticidedanger\\_newmediaexplorer.org](http://Pesticidedanger_newmediaexplorer.org), [media.canada.com](http://media.canada.com), [pressherald.mainetoday.com](http://pressherald.mainetoday.com).

Figure 4. Portland State University Stormwater Garden. Image from [sustainablestormwater.com](http://sustainablestormwater.com).

Figure 5. Portland stormwater remediating streetscape. Images from [portlandonline.com](http://portlandonline.com), [landscapedesign-build.com](http://landscapedesign-build.com).

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Figure 8. Cochiti Dam along the Rio Grande. Image from [spa.usace.army.mil](http://spa.usace.army.mil).

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Figure 10. Wetland restoration in the Rio Grande Bosque. Image from [rgnc.org](http://rgnc.org).

Figure 11. Site Boundary. Image from Google Earth.

Figure 12. The Albuquerque Rail Yard during World War II. Image from [www.wheelsmuseum.org](http://www.wheelsmuseum.org).

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Figure 35. Use diagram. Image from the author.

Figure 36. Cross-section of wetland looking north. Image from the author.

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# Appendix 1

## Water Balance Calculations for Rail Yards

### Water Balance Calculations for Railyards

Description	Roof	Parking Lo	Reflecting	Wetland	Dryland
Area (ft <sup>2</sup> )	2.83E+05	1.04E+05	4.41E+04	1.23E+05	5.40E+05

Month	INFLOWS (ft <sup>3</sup> /month)					OUTFLOWS (ft <sup>3</sup> /month)										Accumulation (ft <sup>3</sup> /month)
	Monthly Precip (in/mon)	Monthly Precip (ft/month)	Roof Runoff	Parking Lot Runoff	AMAFCA	Open Water Evap (in/mo)	Open Water Evap Rate (ft/mo)	Open Water Evap Loss (ft <sup>3</sup> /mo)	Wetland ET (in/mo)	Wetland ET (ft/mo)	Wetland ET Loss (ft <sup>3</sup> /mo)	Dryland ET (in/mo)	Dryland ET (ft/mo)	Dryland ET Loss (ft <sup>3</sup> /mo)		
April	0.52	0.04	1.22E+04	4.50E+03		8.7	0.51	2.24E+04	4	0.33	4.00E+04	1	0.08	4.50E+04	-9.06E+04	
May	0.5	0.04	1.18E+04	4.32E+03		11.8	0.69	3.03E+04	6	0.52	6.37E+04	2	0.17	9.00E+04	-1.68E+05	
June	0.59	0.05	1.39E+04	5.10E+03		13.5	0.79	3.47E+04	7	0.58	7.16E+04	5	0.42	2.25E+05	-3.12E+05	
July	1.37	0.11	3.23E+04	1.18E+04		12.5	0.73	3.22E+04	8	0.69	8.47E+04	7	0.58	3.15E+05	-3.88E+05	
August	1.64	0.14	3.86E+04	1.42E+04		10.8	0.63	2.78E+04	8	0.63	7.77E+04	6	0.50	2.70E+05	-3.23E+05	
September	1	0.08	2.35E+04	8.65E+03		8.5	0.50	2.19E+04	5	0.39	4.76E+04	5	0.42	2.25E+05	-2.62E+05	
October	0.89	0.07	2.10E+04	7.70E+03		6.1	0.36	1.57E+04	1	0.07	8.28E+03	1	0.08	4.50E+04	-4.03E+04	
Totals (ft <sup>3</sup> )	6.51	0.5425	1.53E+05	5.63E+04	0	0	71.9	4.19	1.85E+05	38.49	3.21	3.94E+05	27	2.25	1.21E+06	-1.58E+06