Llano Estacado: Landscape Design Alternatives for Precipitation Management

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ABSTRACT

Lubbock County, Texas, in the southern portion of the High Plains ecoregion called the Llano Estacado, was historically characterized by short-grass prairie and bison herds. Today this area has a growing and urbanizing population, rapidly declining groundwater supply, and is semi-arid receiving only 18 inches of precipitation annually (Texas Parks and Wildlife 2017). The physiography is generally considered flat with an expansive horizon. A more detailed investigation reveals tens of thousands of shallow bowl-like depressions dimpling the surface with ephemeral playa lakes defined by Randall clay pans in their low points. Very few streams and rivers cross this vast plain, so surface water is scarce over large land areas during seasonal dry periods and droughts. The region has quality agricultural soils and sits atop the High Plains/Ogallala Aquifer, as well as the Permian shale oil and gas formation. The region is dependent upon the finite groundwater resources of the High Plains/Ogallala Aquifer for human consumption, and row crop agricultural production that is the base of the regional economy.

While the playa's ephemeral qualities do not offer continuous surface water resources for consumption, or agricultural use, the clay pans dry and crack becoming the primary source of groundwater recharge for the High Plains/Ogallala Aquifer. Temporal wet periods in the playas create biodiversity hot spots along their edges in the annulus zone, and serve as the ecosystem forage and habitat host to migratory waterfowl and invertebrate species. Playa lakes are critically important, however are not preserved, conserved, or managed to maintain their important hydrologic and ecologic functions or services in current agricultural or suburban development.

The City of Lubbock is the largest urban center in the region with an MSA (Metropolitan Statistical Area) population of 307,714 (2015) project to add 21,547 people by 2020, and grow to 379,545 by 2030 (Texas Demographic Center 2018). Given the rapid population growth, land use is changing from agriculture production to suburban single family detached developments with ranch style homes with large roof areas. While groundwater used for crop irrigation decreases in this development scenario, suburban water use and stormwater runoff increases dramatically. Texas Water Development Board (TWDB) statistics indicate by 2020 both the irrigation and urban demand for Lubbock County will exceed the existing supply. The High Plains Water District (HPWD) 2018 water level measurements indicated an average decline in aquifer levels of -0.16 feet and average saturated thickness at a very thin 56 feet.

This case study employs a combination of landscape architecture and geodesign methods to understand how agricultural crop implementation and typical single family developments can be redesigned to increase soil moisture via infiltration to decrease crop and landscape irrigation water use, protect playa flood plain areas, and maintain pre-development playa hydrology to maximize potential recharge, and regional biodiversity. Results indicate that pre-development playa runoff conditions can be met by proposed design alternatives implementing green infrastructure approaches.

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CHAPTER 1

INTRODUCTION

The City of Lubbock, located within Lubbock County Texas, is a growing urban center residing at the southern tip of the High Plains ecoregion referred to as the Llano Estacado. Lubbock has a population over 250,000 people and is expected to grow to nearly 400,000 by 2050 (Texas Demographic Center 2018). Lubbock is home to Texas Tech University (TTU), Lubbock Christian University, and it is also the regional medical and trauma center. The Llano Estacado is a semi-arid region known for cotton, cattle, and oil and gas production all dependent on the High Plains Aquifer, also called the Ogallala Aquifer, which is rapidly declining. The Llano Estacado is a globally unique physiographic region characterized by a west to east low sloping plain dotted with tens of thousands of ephemeral playa lakes that sit at the bottom of shallow bowl-like basins. The region has very few streams and river systems. Precipitation captured in playa lakes are the major source of aquifer recharge and hot spots of biodiversity, which is essential for millions of migratory waterfowl, local terrestrial and invertebrate species.

Regional development patterns rigidly follow the Public Land Survey System (PLSS) Township. This pattern is a range and section grid system with sections or quarter sections often covered by center pivot irrigation systems commonly referred to as crop circles (Figure 1.1). Often roads built along section lines will not deviate from the grid and are built right through playa basins severely altering the hydrology and ecosystem functions and services. Agricultural land uses nearest to Lubbock are rapidly converting to suburban developments to meet the housing demand of the growing population spurred by urban in migration, TTU and medical center growth, and the expanding oil and gas production in the Permian shale formation. Like the roads, suburban developments in the area also fail to protect existing playa systems, or to maintain the hydrologic functions and services critical to recharge the regional biodiversity and ecosystems depended on by migrating waterfowl.

Figure 1.1 View of Playa Lake on the Llano Estacado. Source: Steiert, 1995, p.70

Playa Lakes are critical to the region for ecosystem functions and services, serving as the primary source for recharge for the High Plains Aquifer and primary source of food and water for the migratory waterfowl and invertebrate species. Playas must be valued in future development. The scope of this project aims to educate and communicate the following:

- Unique regional physiography, hydrology and biodiversity characterized by playa basins and their temporal hydrology and ecosystem functions and services.
- Regional semi-arid climate, water availability and water demand/use patterns and types.
- Existing agriculture and suburban development patterns with detailed types of land use, land cover, material and management practices and their corresponding stormwater runoff calculations.
- The implications of existing typical developments on playa basins hydrology.
- To design and communicate alternatives for high water runoff and high irrigation water use for agricultural and suburban landscapes. Focusing on precipitation management to catch and infiltrate stormwater, increasing soil moisture to reduce irrigation water use while maintaining pre-development hydrologic and ecologic functions and floodplain elevations for playas.

Alternative designs to typical agriculture and suburban developments in the Llano Estacado region can achieve pre-development playa flood plain levels and vitally important hydrologic and ecologic functions and services by managing development runoff increases outside the playa 1000-year floodplain. Alternative designs focused on infiltration precipitation management strategies to increase soil moisture and reduce irrigation water use for both agriculture and urban landscapes. Maintaining natural playa hydrologic functions maximizes recharge of the High Plains/Ogallala Aquifer, while increasing soil moisture lowers aquifer water use for irrigation which are essential to a more sustainable future given population growth.

This case study employs a landscape architecture design process coupled with the geodesign method to understand the landscape's functions and capacities, and to compare the predevelopment landscape runoff effects on a playa basin to both typical and alternative row-crop agriculture and suburban development. Models of agriculture and suburban development scenarios were built representative of existing patterns, densities, and land cover uses to replicate typologies present in Lubbock. The models were then analyzed using geographic information systems (GIS) and building information modeling (BIM) software, using commonly practiced stormwater management calculations for City of Lubbock defined storm events: 1-year, 10-year, 100-year, 500-year, and 1000-year. Results indicate that changing land use-land cover will result in significant increases in stormwater runoff, leading to the inability for storage within the existing playa basin and flooding likely to extend beyond the 1000-year floodplain boundary. Extending beyond the 1000-year flood boundary could prove detrimental to the playa hydrologic and ecosystem functions and services. This landscape architecture research project is focused on understanding and communicating the Llano Estacado unique hydrology, water scarcity, and land development alternatives to preserve playas to maximize recharge and decrease aquifer irrigation water use by increasing soil moisture.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

This section aims first to describe the unique characteristics of regional physiography, hydrology, and biodiversity characterized by playa basins, including their temporal hydrology and ecosystem functions and services, semi-arid climate, water sources and availability. Secondly, existing typologies of agriculture and suburban developments and patterns will be explored with detailed types of land use, land cover, material and management practices and their corresponding stormwater runoff calculations. Finally, alternative design opportunities will be explored to understand and communicate the implications of existing typical developments on playa basin hydrology and potential design alternatives.

High Plains

The High Plains Ecoregion (Level III) covers parts of 8 states: South Dakota, Wyoming, Nebraska, Colorado, Kansas, New Mexico, Oklahoma, and Texas (EPA 2013)(Figure 2.1).

Figure 2.1 Map of Level 3 Ecoregions. Source: (EPA 2013)

The High Plains Ecoregion is generally characterized as a flat, or gently sloping plains, with elevations ranging from 2379-6676 feet (725 to 2,035 meters) above mean sea level. Historically, the area was covered in short-grass prairie, draining eastward to the Platte, Kansas, Arkansas, Canadian, and Red Rivers of the Mississippi River system, or into the Gulf of Mexico via the Brazos and Colorado Rivers (Figure 2.2). The High Plains geology consists of “Tertiary and Cretaceous sandstones, siltstones, claystones, and caliche layers. Mollisols, Alfisols, Entisols, and Aridisols occur, with mesic and thermic soil temperature regimes, and ustic and aridic soil moisture regimes” (CEC 2011). The soils are considered to be prime farmland if an irrigation source is available.

The southern High Plains is located south of the divide in the ecoregion created by the Canadian River valley north of Amarillo. The Canadian River flows out of the Sangre de Christo Range of the southern Rocky Mountains and into the Arkansas River and the

Mississippi River. The western edge of the southern High Plains is higher in elevation than the eastern edge, it erodes downward to the west and into the Pecos River valley. The Pecos River is a consistent water source that flows out of the Sangre de Christo Mountains near Santa Fe and along the western and southern edges of the High Plains. The area south of the Canadian River and east of the Pecos River is called the Llano Estacado (Figure 2.3)

The Llano Estacado plateau of the southern High Plains covers approximately 32,000 square miles (Leatherwood 2012) and is incised with several canyons along the eastern edge by the very few streams and rivers. The Prairie Dog Town Fork of the Red River cuts through the Palo Duro Canyon southwest of Amarillo and is the second largest canyon in the contiguous United States to the Grand Canyon. The North Fork of the Double Mountain Fork of the Brazos River incises the Yellow House Canyon near Lubbock. The Mustang and Sulphur Springs Draws converge at Big Spring forming Beals Creek which flows into the Colorado River that has headwater creeks and a starting point near Lamesa to the north of Big Spring. Today, the area locally referred to as the Llano Estacado, includes 33 Texas counties, and four New Mexico counties stretching from the Canadian River to the north, blending into the Edwards Plateau to the southeast, and from eastern New Mexico on the west, to the harsh, drastic edges of the Caprock on the east. It. The Llano Estacado slopes on average only 0.20%, or ten feet in elevation change per mile, from west to east.

The Commission for Environmental Cooperation (CEC 2011) study on ecoregions of North America states, “Historically, the region had mostly short and midgrass prairie vegetation with expansive areas tilled and converted to production agriculture. Numerous waterfowl on the Central Flyway of the continent depend on the playa lake habitats (CEC 2011)." The CEC Level III Ecoregion report documents the following key species in the High Plains Ecoregion:

Shortgrass prairie dominate species: Blue Grama, Buffalograss, Fringed Sage, Sideoats Grama, Western Wheatgrass, and Little Bluestem.

Sandsage prairies Species: Sand Sagebrush, Sand Bluestem, Prairie Sandreed, Little Bluestem, Indian Ricegrass, and Sand Dropseed

Shinnery Sands (area in the south): Harvard shin oak, fourwing saltbush, sand sagebrush, yucca, and mid- and short grasses.

Wildlife species (historic): Bison, black-tailed prairie dogs, black-footed ferrets, gray wolf, and cougar.

Wildlife species (today): Pronghorn, coyote, swift fox, jackrabbit, cottontail rabbit, ferruginous hawk, lesser prairie-chickens. (CEC 2011).

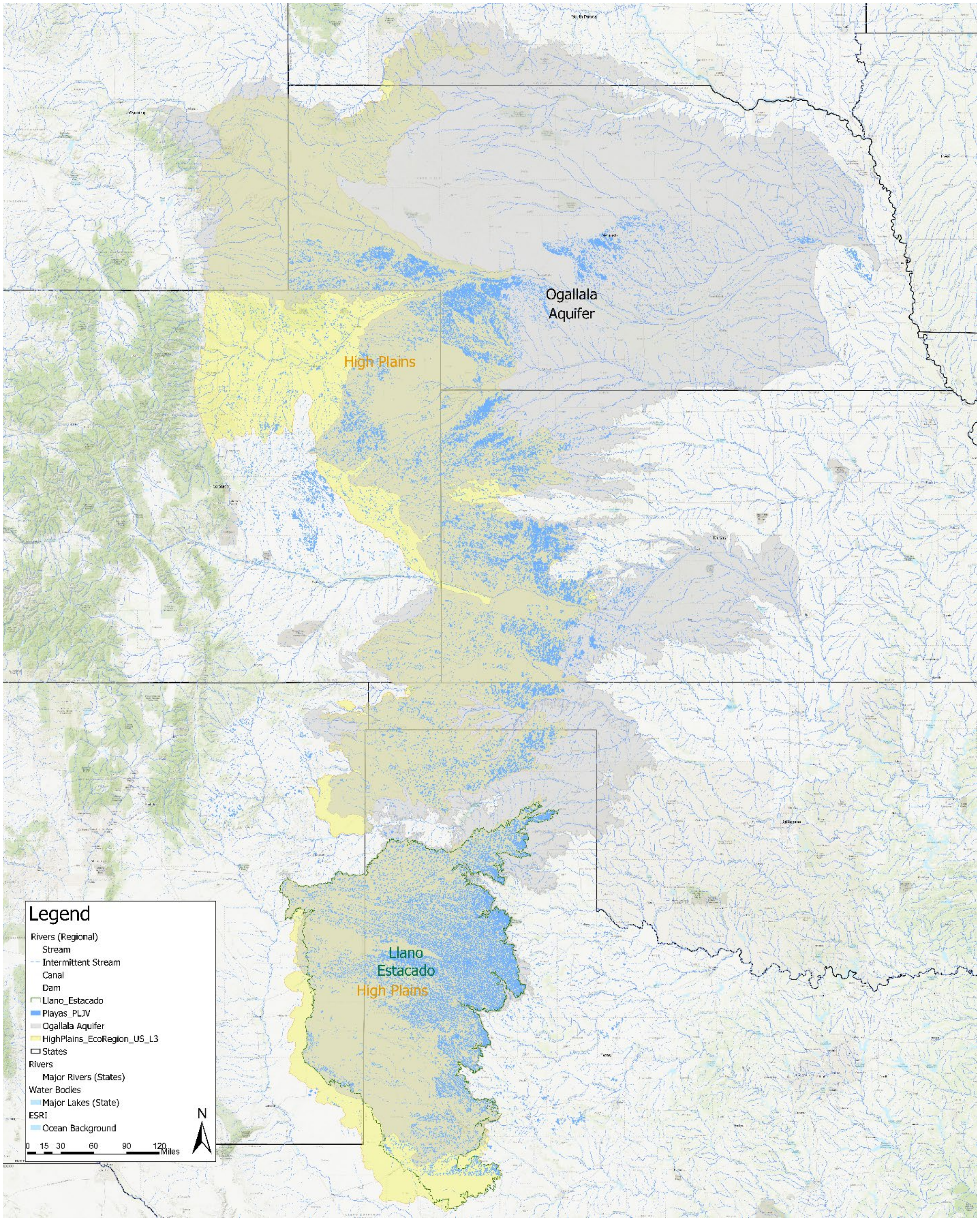


Figure 2.2 Map representing the High Plains Level III Ecoregion, Llano Estacado, and the Ogallala Aquifer, Playa Lakes emphasized. Source: Tyson Watson, ESRI, USDA-NRCS

As illustrated on the map (Figure 2.3), the hydrology of the High Plains is intermittent and ephemeral streams, especially atop the Llano Estacado, a distinct, elevated plateau, which has few to no streams. Surface water on the Llano Estacado is found in ephemeral pools called playas. These serve as recharge areas for the important Ogallala Aquifer. Water withdrawals from the aquifer usually exceed recharge (CEC 2011).

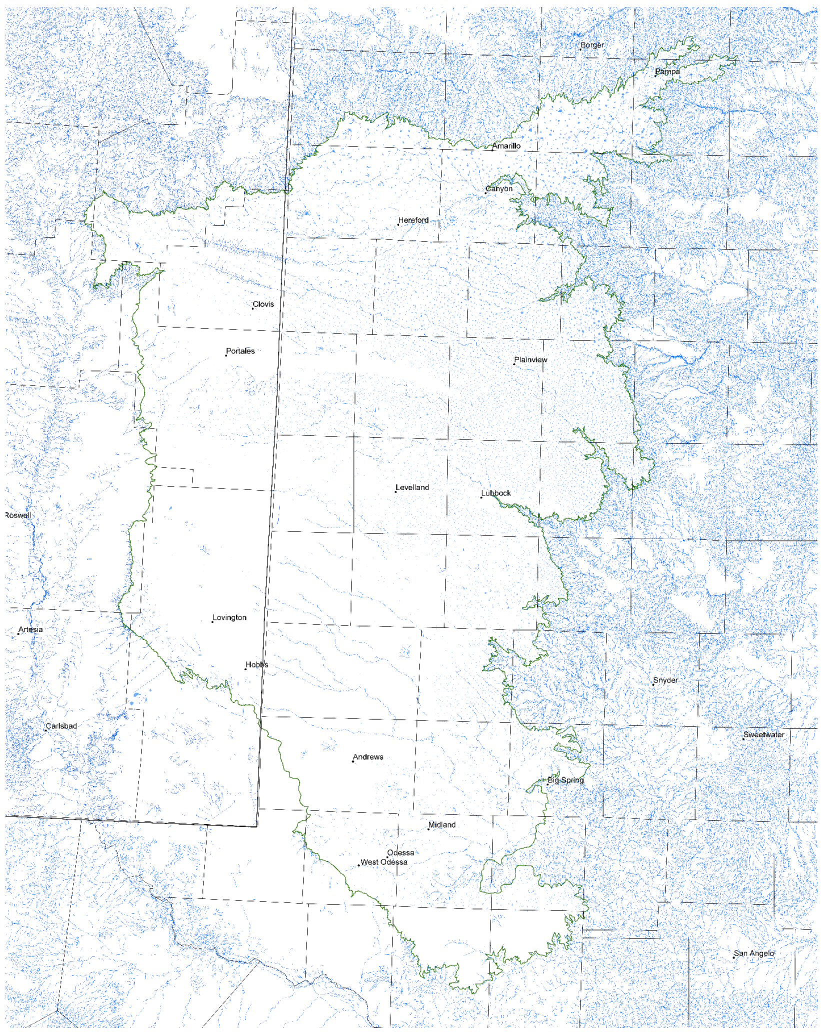


Figure 2.3 The Llano Estacado Waterways Playa lakes shown at actual size. Source: Tyson Watson, USDA, TNRIS

Playas

One of the most unique features of the Llano is its system of interconnected, ephemeral lakes, called "playas." Playas are defined as,

> …shallow, circular-shaped wetlands that are primarily filled by rainfall, although some playas found in cropland settings may also receive water from irrigation runoff. Playas average slightly more than 15 acres in size. Although larger playas may exceed 800 acres, most (around 87 percent) are smaller than 30 acres. Approximately 19,300 playas are found in the Texas High Plains, giving us the highest density of playas in North America. (Texas Parks & Wildlife n.d.).

The Llano's surface is dotted with tens of thousands of such playas, which are a mystery to many who see the playas merely as random depressions that may occasionally contain water but are usually dry. It is not immediately evident that they are, in fact, important water collection ponds during the few storm events that do occur over the Llano Estacado. In wet years playas are home to several annual plants, such as smartweeds and millets. The wet/dry nature of playas, along with their high plant production, means they also produce an abundance of invertebrates (Texas Parks & Wildlife n.d.). Playas continue to play a vital role throughout the Llano Estacado's ever-evolving history, in particular the migratory fowl that have traversed this region for millions of years. Many varieties of geese, ducks, birds, and butterflies find respite and food in the playa ecosystem in their long trek along the Central Flyway of the North American Continent.

Playa lakes are critically important to recharge the High Plains/Ogallala Aquifer. Dr. Ken Rainwater a Texas Tech Civil Engineering professor who researches groundwater and playas states, “Even though soils in the playa bottoms are clay, they dry out and desiccate with big cracks between rainfall events. So, when you have your first flush of water coming into the playa, when there is enough rainfall, it’s real easy for water to go down through those cracks and head down through the clay toward the aquifer below”. As the clay absorbs water, it expands, sealing the cracks, and filling the basin with water from rainfall and runoff, which provides water, food and shelter for birds and other wildlife (PLJV.org, 2019).

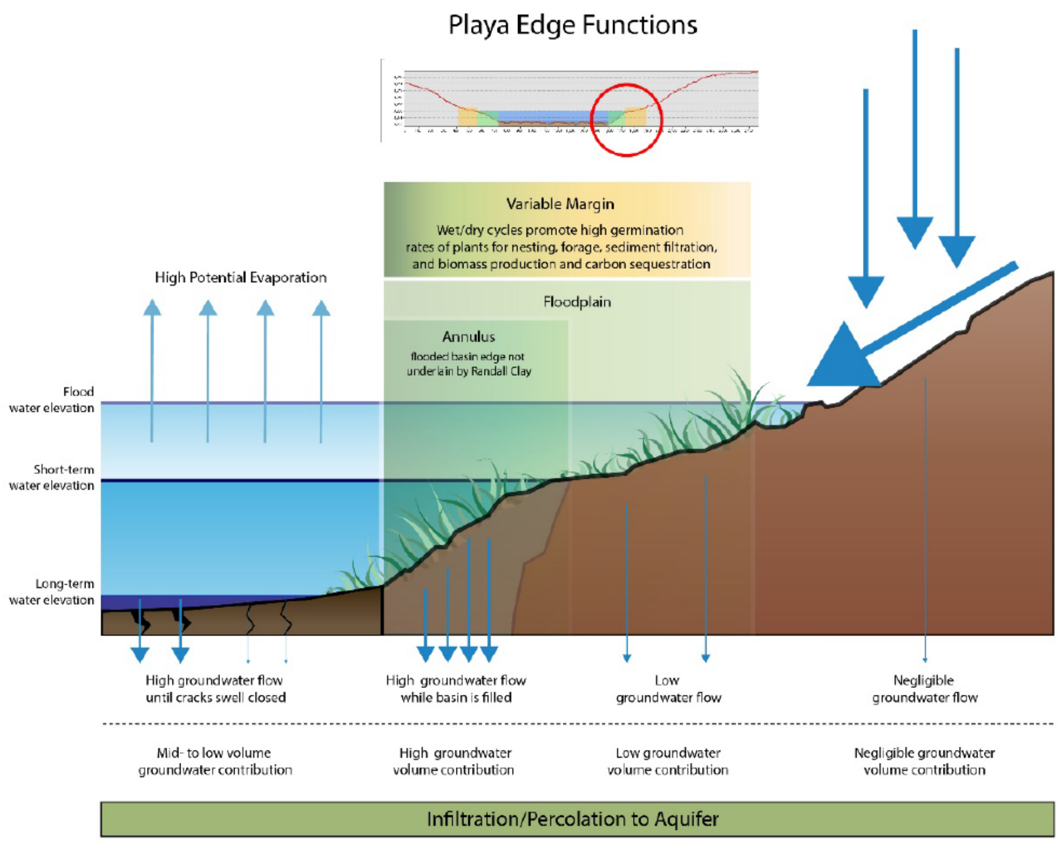


Figure 2.4 Physical and temporal functions of playa margins. Source: Horsford Thesis, 2017, p. 19

Dr. Rainwater's research also indicates many playas have lost capacity to recharge groundwater and to filter and clean water in the playa, due to erosion sediment clogging the clay cracks. He recommends establishing native grass buffers around playas to filter runoff water and trap sediment. As illustrated by Jared Horsford's in (Figure 2.4), the annulus zone is dependent upon wet and dry cycles for key smart weed and millet growth essential to migratory waterfowl (PLJV 2019).

In addition to the importance of playas in the natural environment, they have been instrumental in the story of mankind's presence in the region. In historic times, playas supplied watering holes to the Native Americans traveling along the Llano Estacado in search of bison herds. One playa of special significance is the historic Lubbock Lake Landmark, which contains a complete record of nearly 12,000 years of ancient human history and extinct animals (Figure 2.5). The site no longer contains an actual lake, but its many levels of cultural deposits can be seen through the presence of clear geological stratigraphy. Human habitation in North America is generally divided into five cultural periods, all of which are represented at Lubbock Lake Landmark: Paleo-Indian, Archaic, Ceramic, Protohistoric, and Historic (Museum of Texas Tech University 2018).

Figure 2.5 Lubbock Lake Landmark site shown during spring. Source: Texas Tech Today.

Despite its rugged beauty, the Llano Estacado can be a harsh place to live, as there is no such thing as a "regular" weather season. Weather on the Llano can change in a matter of minutes, bringing a long thunderstorm or harsh north wind in the winter months. Playas made the initial habitation, exploration, and development of the Llano Estacado possible. The early settlers were dependent on the playas for water, and later the playas were utilized as a source for irrigation. In contemporary society, playas are also used in developed areas as green spaces for urban dwellers to enjoy, and are typically used as retention/detention ponds for stormwater runoff. Most often urban playas green spaces are mown up to the edge of the typical water line, or Randall Clay pan eliminating habitat and forage essential to migratory waterfowl and invertebrates.

Humans on the High Plains

Since the beginning of human life in West Texas, the availability of water has played a crucial role in making survival possible. Early Native American history indicates communities inhabited and created trade routes along the three key rivers where water was consistently available and hunted bison who relied on the playa lakes atop the vast plain (Gwynne 2010).

The Llano Estacado was explored by Spanish explorer Francisco Vazquez de Coronado in 1541 (Leatherwood 2012). Early Spanish explorers referred to the area as an expansive grassland, difficult to navigate like the ocean given its vastness and plain and continuous horizon qualities. They termed the area the Llano Estacado, translated Staked Plains (Leatherwood, 2012), or more recently identified in historical research of original documents as Llano Estancado, translated "pooled plains" (Meredith, 2018).

Settlement and development patterns imbedded in land use today, started in the area in the 1870s and continued into the 1920s, with grazing and farming as the dominant land uses. Early settlers struggled, given highly variable climate and weather patterns and limited water resources. Emerging technologies and techniques in the early 1900s made the rich, dry region more productive and survivable through the use of windmills and machine-powered pumps drawing groundwater to the surface. This innovation allowed for a reliable potable water supply and supplemental irrigation for crops on the Llano Estacado.

Today the region's economy is based on irrigated and dryland farming, natural gas and petroleum extraction, cattle, higher education and medical services. Crop and grazing land uses continue to dominate the Llano Estacado landscape. Crops include: cotton, winter wheat and sorghum, corn, peanuts, and grapes. The region is also productive in oil and natural gas, which were discovered in 1917 and 1921 (Leatherwood 2012).

Climate

The region receives an average of 15 to 22 inches of precipitation a year, the majority of which falls between April and September (Texas Parks and Wildlife 2017). Annual rainfall has historically been quite variable; however, with years of drought, it is a normal part of the regional climate (Figure 2.6). Over time, the region was developed for agricultural production which carries with it a high demand for water. This sets up an inherent conflict between water supply and demand in times when rainfall is scarce. Within the current century the region has seen more than one extended drought, and this condition has directly corresponded to an increase in water consumption.

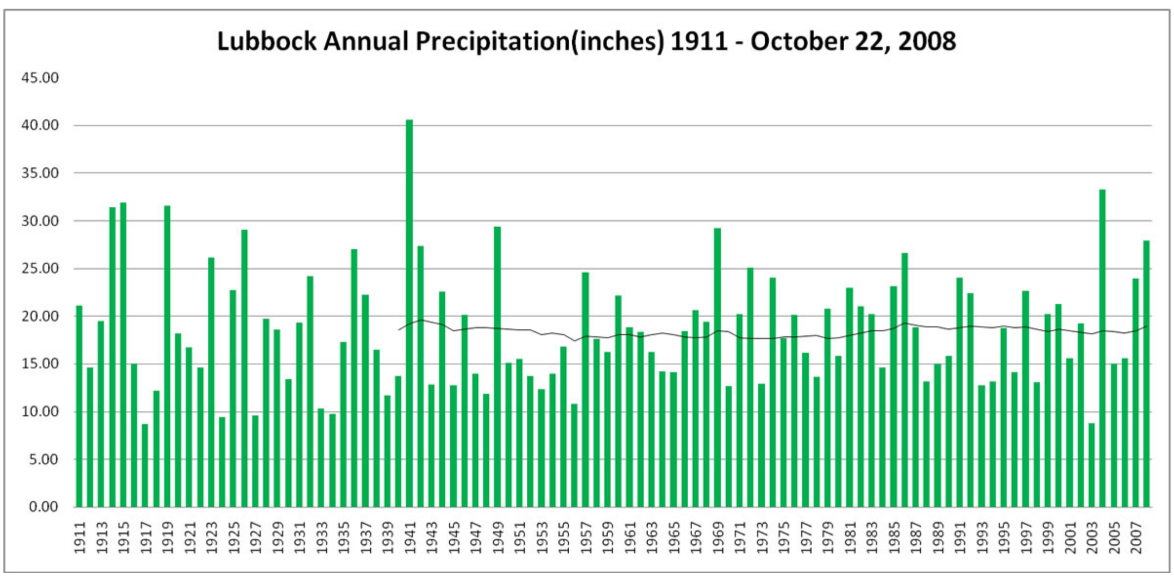


Figure 2.6 Plot of the annual Lubbock precipitation (green bars). Source: NOAA National Weather Service.

The highly variable nature of the West Texas climate is further subject to a myriad of impacts from the effects of climate change that are occurring on a global scale. Climate change effects include a warming atmosphere that leads to increased evaporation, which in turn increases humidity, average rainfall, and the frequency of heavy rainstorms in some places, but leads to drought in others (EPA 2016) .Over the last century, the western part of Texas has warmed twice as much as the eastern part (EPA 2016). Future projections suggest there will be an increase in the number of days exceeding 100 degrees Fahrenheit and longer durations between rain events, with the rain events having more substantial amounts of precipitation associated with them (EPA 2016). The changing climate will be a significant factor in the future of the region's economy as the growing population faces variable patterns in precipitation and decreasing groundwater supply and potentially decreasing surface water supply during extended drought periods.

High Plains/Ogallala Aquifer

Underlying eight states within the Great Plains, the High Plains Aquifer (Figure 2.7), also called the Ogallala Aquifer, covers 174,000 square miles, with the Texas portion being 35,450 square miles- (McGuire, et al. 2003). The depth to the aquifer varies, from region to region, and its saturation thickness also varies with an average ranging around 200 feet. Today, the High Plains Aquifer is the primary source for agricultural irrigation in the Great Plains region. Agriculture began around the turn of the 20th century in the form of small, dryland farmsteads. The region experienced one of the nation's worst natural/human-made disasters in the 1930s, known as "The Dust Bowl." Severe dust storms exacerbated by extended drought and the lack of land management practices blew away precious top soil and buried farms, leaving the region decimated by poverty and abandonment. At the time, agricultural producers did not have the technology to reach the aquifer to utilize groundwater for irrigation. Originally, the aquifer was utilized only as a last resort for supplemental irrigation due to high costs (Brooks, et al. 2000). Reliance on the aquifer by the agriculture industry has grown along with the scale of the region's farms. The aquifer now supports nearly one-fifth of the nation's agricultural production of cotton, corn, wheat and cattle (McGuire, et al. 2003). Extraction rates have reached extreme levels in some areas, however, and groundwater supplies are dangerously low (Figure 2.7). To date, there are regions of the High Plains Aquifer that could go dry in the next few decades, which would lead to an economic catastrophe throughout the High Plains region (Steiert 1995).

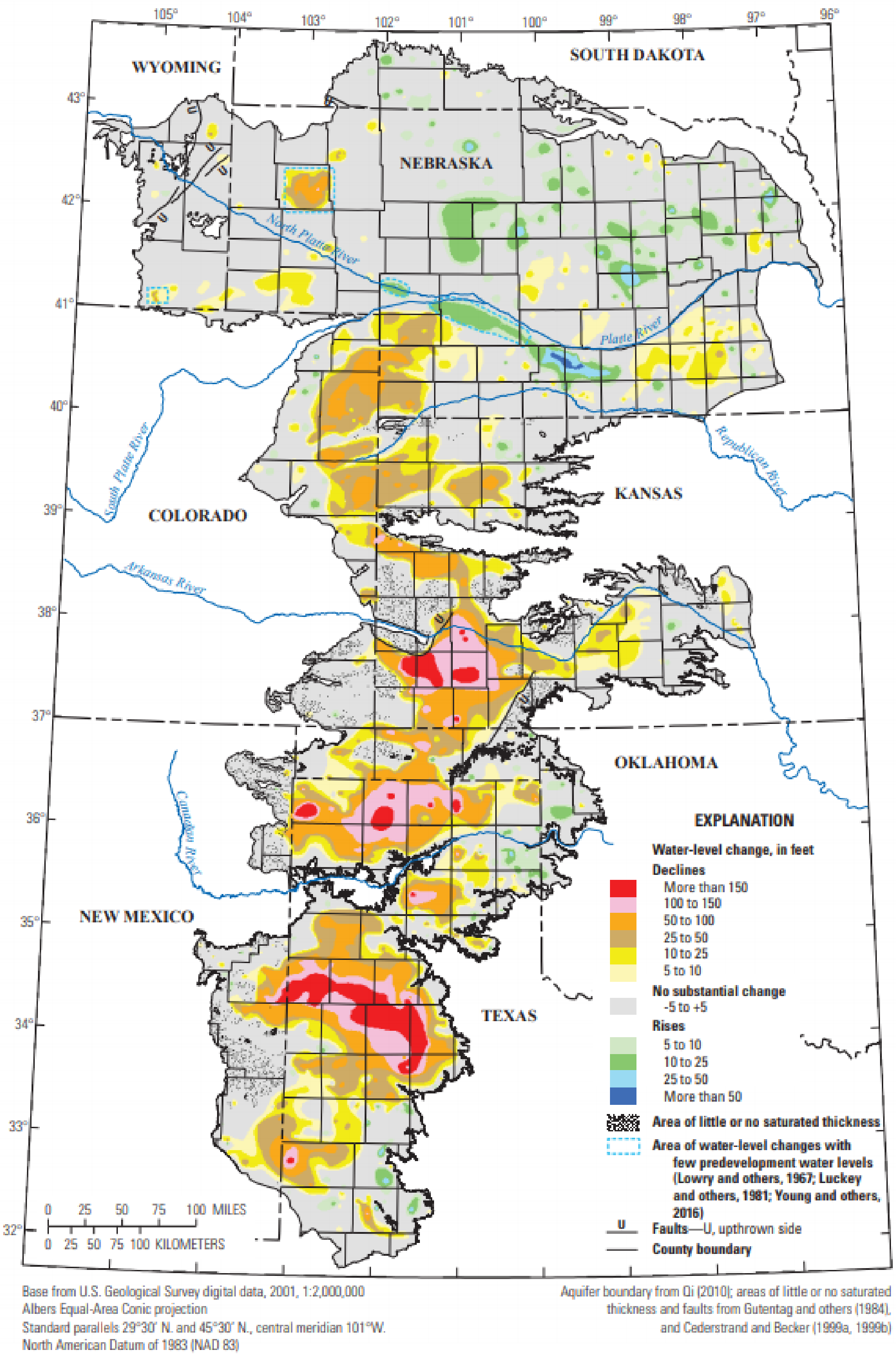


Figure 2.7 Water-Level and Recoverable Water in Storage Changes, High Plains Aquifer, Predevelopment to 2015 and 2013-15. Source: USGS, 2017, p.2

Significance of Agricultural Production and Water

As previously stated, agriculture is big business in the Llano Estacado region, and groundwater is the primary source for water. Texas leads the nation in cattle, cotton, hay, sheep, goats, and mohair production. Texas also leads the nation in the number of farms and ranches, with 248,800 farms and ranches covering 130.2 million acres (Texas Department of Agriculture 2019). Texas ranks number one nationally for selected commodities, including $1.6 billion in exports in cotton and cottonseed, $855 million in beef, and $431 million in hides and skins. Additionally, the state is the number two producer of seeds for planting valued at $244 million (Texas Department of Agriculture 2019). In the West Texas region, agriculture is not only an economic driver, it has become a cultural identity to many. West Texas is the United States' largest producer of cotton (Plains Cotton Growers, Inc. n.d.). To support this large-scale agricultural industry, a reliable, available water source is essential. The groundwater source that agricultural producers rely heavily on is the High Plains Aquifer. But, the situation is precarious as an estimated 124 million acre-feet have been lost through irrigation in Texas alone (McGuire, et al. 2003).

There is a remarkable relationship between agriculture and playas on the Llano Estacado starting when cattlemen first brought their cattle to range over the vast plains while utilizing the playas for water. Plants thriving in the annuals zone that form the playa edges were a vital source for forage for cattle in the dry season. The interaction of tillage agriculture with the Randall clay pan edge became an important part of increasing yields in some years, especially along the vast shallow basins. However, farmers that plowed the playas found it rather difficult to control some of the invasive species typically found in the bottom of playas. Farmers also considered some playas to be a liability, especially when they could not plow the basin because it held water most of the year. This created a problem when it came to profitability because the flooded basin was still subject to property tax even though it could not contribute to yield. Farmers turned to modifying the playas to reduce flooding issues and also increase their tillage area.

The evolution of agriculture from dry land to irrigated, created a new use for the playas; they could be utilized for irrigation instead of remaining a groundwater source, which was a costly alternative at the early stages (Steiert 1995). Playas became a primary source for irrigation during the mid-twentieth century. As a result, up to 85 percent of the larger playas in the area were modified for irrigation usage to help increase available water and productive tillage areas. Playas on the Llano Estacado have supplied up to 10 to 25 percent of the water for annual irrigation requirements (Steiert 1995, 48). Some 70 percent of playas 10 acres or larger have had pits dug in them to concentrate water for row-water (or furrow) irrigation. Road construction has also impacted playas with roads constructed in approximately one-tenth of playa basins (Texas Parks & Wildlife n.d.). Modifications for irrigation are no longer a method practiced across the Southern High Plains primarily because those most economically beneficial have already been modified, or are now protected as a wetland. However, the plow will have lasting effects on the Llano Estacado and conflicts between playas and their functions will continue to persist. Plows cannot tell the difference between Randall clay and other soils. But playas are resilient: even if they are plowed up, with one good rain they will return to their glory in a matter of hours. “Playas of the Llano can be ‘saddled’ by agriculture, but they will be only ‘green broke’” (Steiert 1995, 63).

Water Law/Rights in the State of Texas

In the vast plains of the Llano Estacado, there are few actual waterways. The nonlinear flow hydrology of the Llano Estacado playas makes it difficult to figure out the flow of water. Since 1899, the United States Army Corps of Engineers has been in charge of protecting the country’s waterways from encroachment and later maintaining water quality by regulating the discharge or fill material in coastal and inland waters and wetlands. Section 404 of the Federal Water Pollution Control Act Amendment of 1972 (PL 92-500) redefines the Army Core of Engineers’ role from that of protecting navigable waters to protecting all waters within the United States, and this amendment changes the government’s jurisdiction to include playa lakes (Steiert 1995).

In 1975 Section 404 was challenged in the federal court system in the District of Columbia by the Natural Resource Defense Council. The Court ruled that under PL-500 the Corps’ jurisdiction is all rivers, lakes, and streams to their headwaters, including contiguous and adjacent wetlands. The ruling went against a long-time ruling in Texas that stated the water in the playas are private property owned by landowners themselves. “It was counter to the reference in which Plains farmers and cattlemen hold private property rights, and to their fiercely independent mindset that, by God, what’s mine is mine, and what I do with it is nobody else’s damned business” (Steiert 1995, 67). In a public meeting in 1975, the Chief Legal Counsel of the Texas Water Rights Commission reaffirmed that the water in the playas is surface water owned by the property owner.

Many landowners did not associate playas with wetlands until the Food Security Act of 1985, a law that promoted reduction of soil erosion and retention of wetlands (Steiert 1995).

An understanding of the water law in Texas is important to this project. Water rights in Texas depend on whether the water is groundwater or surface water. While the State governs groundwater in Texas, the landowner has the right to utilize it, and this right is governed by the rule of capture. This gives the landowner the right to catch the water beneath their property. The water source in Texas is also understood as privately owned, meaning a landowner has the right to do what he/she wishes with the water under his/her property. It is essential to know that the landowner does not own the water, just the right to pump the water beneath their property. Limited regulation of groundwater came with the establishment of the Water Conservation Districts in 1949, and again in 1985. This gives each district general authority to promulgate rules to conserve, protect, recharge, and prevent waste of groundwater. In Texas, no permit is required for wells that withdraw 25,000 gallons or less a day (McGuire, et al. 2003, 44).

Surface water, on the other hand, is governed by the state and can be utilized by the landowner only with the state's permission. The Texas Commission on Environmental Quality (TCEQ) sets and implements standards for surface water quality to improve and maintain the quality of water in the state, including playas. The TCEQ requires a review process for any project that will impact a wetland greater than three acres, or if less than this threshold, those that are of significant ecological value (Texas Commission on Environmental Quality 2011). Understanding of water rights for independent landowners helps understand the complications that come with development and usage of playa lakes throughout Texas High Plains region.

Groundwater (Groundwater Footprints)

Groundwater refers to the water stored typically in underground geologic formations in cracks in rocks and spaces between soil, sand and rocks. It is the primary resource for millions of people around the world for access to potable water and irrigation use, including most people in the High Plains. If groundwater availability reaches a critical point of depletion, critical economic and social problems would result from a significant loss of a potable water source. “Groundwater footprint” is a term used to describe the longevity of food and human population growth throughout water-scarce regions on earth. Groundwater footprint is defined as, “the area required to sustain groundwater use and groundwater-dependent ecosystem services of a region of interest, such as an aquifer, watershed or community” (Gleeson, et al. 2012, 197). It is based on the rate of extraction, rate of recharge, and inputs from environmental streamflow. Groundwater footprint is the water balance between inflow and outflow of an aquifer. It is affected by the number of people utilizing the water source within the boundary of the groundwater footprint. This is important when attempting to understand the balance in water consumption in groundwater sources.

The High Plains Aquifer has the seventh largest groundwater footprint of all 783 aquifers found globally (Gleeson, et al. 2012). While some footprints for groundwater around the world are much larger, they can no longer be sustained for the long period of time due to the amount of withdraw that is occurring. Steps must be taken to understand the long-term and potentially irreversible effects of over-consumption of any groundwater resources. It is therefore important to place limitations on the amount of water being used while maintaining a constant path towards sustainability. A sustainable way of using groundwater sources around the world must be developed. The water that is being taken out must not be more than that which is recharging, or the system is no longer in balance. That is the primary focus for achieving water balance. This focus is directly related to the semi-arid landscape of the Llano Estacado, and it is crucial to understand that groundwater is a vital part of everyday life on the Llano and the High Plains. The potential to create more sustainable ways of utilizing the groundwater source could extend the usability of the groundwater.

Lubbock

Human developments have always located around water sources, and Lubbock is no different. The City of Lubbock was officially founded on March 16, 1909 (Graves 2010)The location of today's downtown lies near the original headwaters of the North Fork Double Mountain Fork Brazos River. Water flowing in the North Fork carved out Yellow House Canyon, one of three major canyons along the east side of the Llano Estacado. Today, this Fork is contained within a system of dammed lakes known locally as the Canyon Lakes. Today's downtown was at one time the center of town. However, a devastating category-5 tornado in May 1970 leveled much of the downtown. Rather than using funds to rebuild in the original location, city leaders invested in developing in new, outlying areas to the southwest, anchored by the South Plains Mall. This trend has only accelerated, and new growth continues spreading outward, leaving downtown Lubbock plagued with high vacancies and little to no residential uses. As a result, Lubbock does not have a well-defined city center with emanating suburbs as some communities do. However, downtown Lubbock is experiencing some rebirth as major arts, culture, and civic venues have been, and are currently being built throughout. Historic hotels have been converted to apartments, and a mix of uses is bringing needed life to the core area.

Development throughout the city is highly automobile-centric, with wide, straight corridors designed for vehicular use only dominating the landscape. Major thoroughfares run north to south and east to west with road widths varying from five to seven lanes. The 289 Loop, the Marsha Sharp Freeway (SH62/82), and Interstate 27 are the primary state thoroughfares. Each are six-lane, limited-access highways with a divided concrete median. The City of Lubbock was designed on a grid with most major intersections occurring every mile, or development made in sections at a time, that contain either a gas station, fast food restaurant, bank, or drug store. Typical Lubbock residential development has occurred in quarter-acre lots with either large houses on small lots, or smaller houses with large lawns. Another noticeable trend is the high number of strip malls throughout the city accompanied by copious amounts of parking. Parks and green spaces tend to be located around previously known playa lake locations that have been converted to stormwater management detention ponds. A majority of the playas that were once located throughout the city have either been filled in for development or dugout to hold more water to accommodate the high-density development trends. Newer residential development in Lubbock consists of parcel sizes ranging from 1/15th of an acre to a quarter acre with no open spaces provided. These areas are most noticeable on the southern and southwestern parts of town, but also include the older neighborhoods in and around the downtown area and Texas Tech University.

City of Lubbock Storm Water Management

Stormwater management in the city tends to be handled in a way that differs from traditional inlet and pipe conveyance systems. Due to the area's flat terrain and infrequent rain events, decisions were made to rely on the street network as a main system to handle runoff through curbs and gutters. Sites are therefore sloped to drain to the street, which become de-facto holding ponds. As development has increased, however, severe flooding (especially in streets) is a common occurrence following storms. Past and current development trends throughout the city continue to put a strain on the playa system that is being changed more and more from pasture and agriculture to urban development. The increase of impervious surfaces, in turn, requires an increase in stormwater infrastructure. However, if development patterns are adopted that minimize runoff, the increase for stormwater-related infrastructure would potentially decrease drastically. Presenting alternative development patterns and agriculture and suburban design is the purpose of this study.

Most stormwater measurements and calculations are based on stream and river flows. As Lubbock is unique and largely does not have stream and river system flows, chosen methods depend on the designer's familiarity with the method and the size of the area of in question and guided by the City of Lubbock Stormwater Guidebook.

Multiple methods can be used for determining stormwater runoff with each having a limitation. The Stormwater Guidebook uses three methods: The Rational

Method, Graphical/Tabular Method (TR-55), and Unit Hydrograph Method (HEC-1, TR-20). The guide states that any site smaller than 200 acres is suitable to use the rational method. Sites greater than 200 acres should use TR-55, HEC-1, TR-20, and Soil Conservation Services (USDA 1986). There is an exception for using the rational method when creating storm sewer networks that do not also serve as an outfall for a playa lake. However, if the storm sewer is a gravity drain outfall for playa lakes, then a hydrograph method must be used since the playa lakes storage-elevation is at which point discharges occurs. The second exception to the rule is for calculating the peak discharge versus the overall capacity of water the street can hold (City of Lubbock 1997).

Water Sources: Lubbock

The primary source of water in West Texas is the High Plains Aquifer groundwater. The City of Lubbock's water comes from the High Plains Aquifer as well as Lake Allen Henry (2,880-acre reservoir), and Lake Meredith (a 7,349-acre reservoir) (City of Lubbock 2017). Lubbock has obtained, and developed water rights for surface water from Lake Meredith located 160 miles north of Lubbock on the Canadian River. Currently, the city utilizes the reservoir for about 10% or 3.6 AFY, according to the (City of Lubbock 2017). The reservoir is at 38.1% capacity (December 19, 2018 TWDB). Lake Alan Henry is the second surface water reservoir the city utilizes, located 66 miles southeast of Lubbock on the Double Mountain Fork Brazos River, supplying 19% or 6.87 AFY (City of Lubbock 2017), and is at 87.5% capacity (December 19, 2018 TWDB). The High Plains Aquifer groundwater well fields in Bailey and Roberts Counties combined makeup 71% of the city's water source, with Bailey County supplying 13% or 4.8 AFY, and Roberts County 58% or 21.4 AFY (City of Lubbock 2017).

Growing Population and Water Use

Population and urban center growth increases the demand for potable water for human, agricultural, and landscape uses. From the years 2000-2010, population in the state of Texas increased by 20.6%. (Texas Demographic Center 2018). In Lubbock population has grown by 10 percent since 2010 (World Population Review 2019). Lubbock is also known as the "Hub City," with an economy that consists of agriculture, wholesale, manufacturing and retail trade services, as well as government, education, and health care. Its current population is 252,506 making it the 11th largest city in the State of Texas and the second largest city west of Interstate 35 (Lubbock Economic Development Alliance 2019). Lubbock is home to Texas Tech University and Texas Tech University Health Sciences Center, and is the only city in the nation with a comprehensive university, a health sciences center, an agriculture college, and a law school in one location. Combined with Lubbock Christian University, Lubbock County has more than 50,000 college students. (Lubbock Economic Development Alliance 2019)

According to the City of Lubbock's 2018 strategic water supply plan, Lubbock supplies water to the following cities: Lubbock (229,573 people), Shallowater (2,484 people), Ransom Canyon (1,096 people), and Buffalo Springs Lake (453 people). The city's plan contains two growth prediction models: Expected Growth (a more conservative estimate) and Accelerated Growth. These two scenarios depict different but similar population predictions. The Expected Growth scenario derives population growth for the city of Lubbock by working closely beside the Planning Department. A 1.20% population increase per year up to year 2038 is the basis for the Expected Growth scenario. The growth rate then drops to 0.80% and declines 0.10% every decade until

2079, and from this point onward the growth rate stays constant at 0.40% per year. The Accelerated Growth scenario depicts the next 20 years' growth rate remains constant through 2038 at 1.20% and then increases by 0.10% every year until it reaches 1.70%. After 2038, the growth rate falls to 1.20% per year for a decade and then 10% per decade from 2058 through 2098; and the last two decades, the rate is 0.15% (Figure2.8).

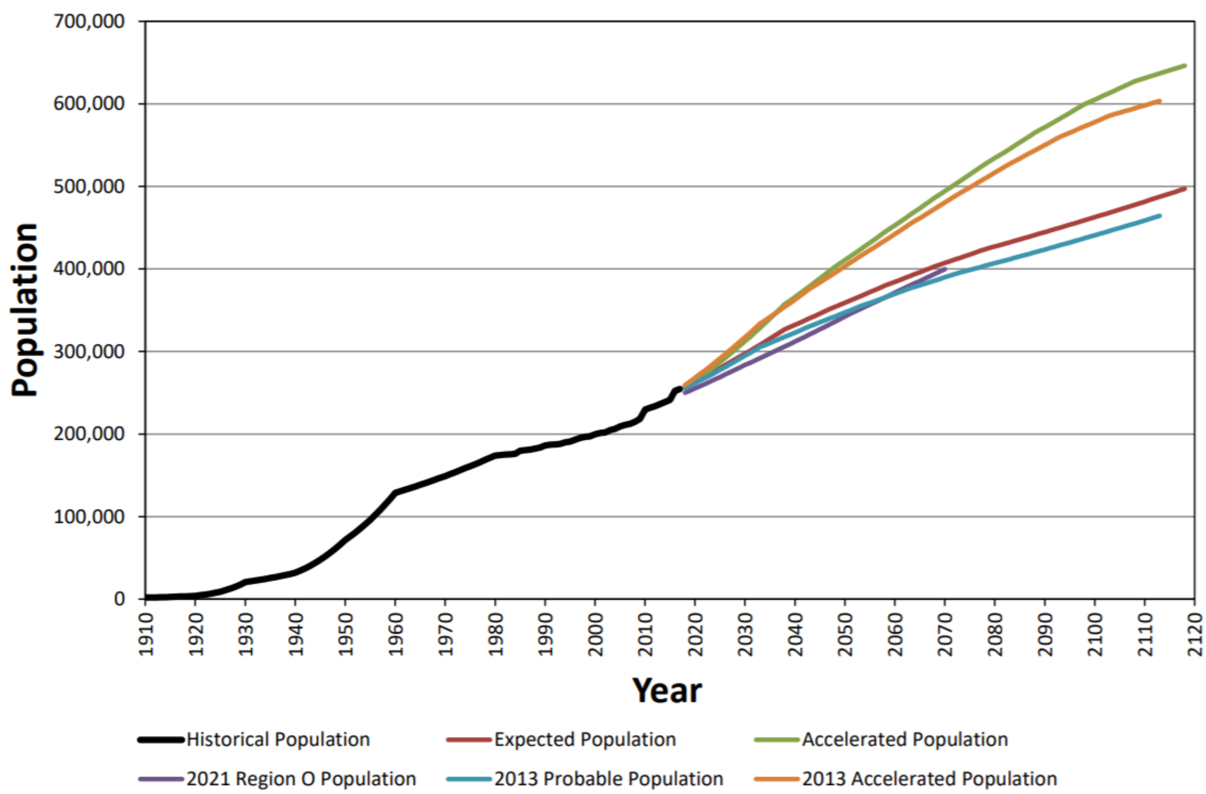


Figure 2.8 Historic and Projected Per Capita Water Consumption. Source: (City of Lubbock, 2018, 2.2)

The per capita consumption rate followed by The State of Texas Water Conservation Task Force is a recommended individual consumption of 140 gallons per capita per day (gpcd) (City of Lubbock, 2018). The total percent recommended decline per year is based on a five-year rolling average until the goal of 140 gpcd or lower is met, but in the Llano Estacado region, officials found a one percent reduction every year to be too aggressive and recommends a 0.5 percent reduction annually (City of Lubbock 2018). The 2018 City of Lubbock Strategic Water Plan compared two scenarios of water usage for future planning: drought consumption and conservation consumption. The drought scenario starts at 171 gpcd, a number generated from the 2011 drought which was the worst ever recorded with an annual rainfall total of 6.07 inches (Texas Tech University 2019). In 2011, the average individual water use was in Lubbock 178 gpcd, a rate above the recommended base consumption of 171 gpcd and significantly above the State of Texas' recommended individual use of 140 gpcd, and a national recommendation of 130 gpcd (City of Lubbock 2018). This increased consumption may indicate that the lack of precipitation in times of drought caused people to use more water on their lawns as it can be reasonably assumed that household water use is not affected by rain levels. Lubbock's water plan calls for declines at 0.54% per year until 2038 when it reaches its 20-year goal of 155 gpcd used. It will then decline at a rate of 0.13% to reach a 100-year goal of 139 gpcd by 2118. The conservation consumption scenario is based on a five-year rolling average of water provided by the city of Lubbock, which was determined from 2012 to 2016. In this scenario, the city has set the standard lower than the state's suggested amount and looks to reach a water use rate of 140 gpcd by 2022, and from there decline at a slower rate of 0.149% per year to reach a 100-year goal of 118 gpcd by 2118 (City of Lubbock 2018).

Annual water demand was determined by utilizing the projected population and per capita consumption scenarios given three different conditions:

- expected drought demand = expected growth x drought consumption,

- conservation demand = expected growth x conservation consumption, and
- accelerated growth demand = accelerated growth x conservation consumption.

The annual water projections for each scenario are in acre-feet per year for the years 2018, 2028, 2068, and 2118. Expected drought scenario annual water demand for 2018 (49,344), 2028 (52,878), 2068 (67,180) and 2118 (77,625) per year (City of Lubbock 2018) (Figure 2.9).

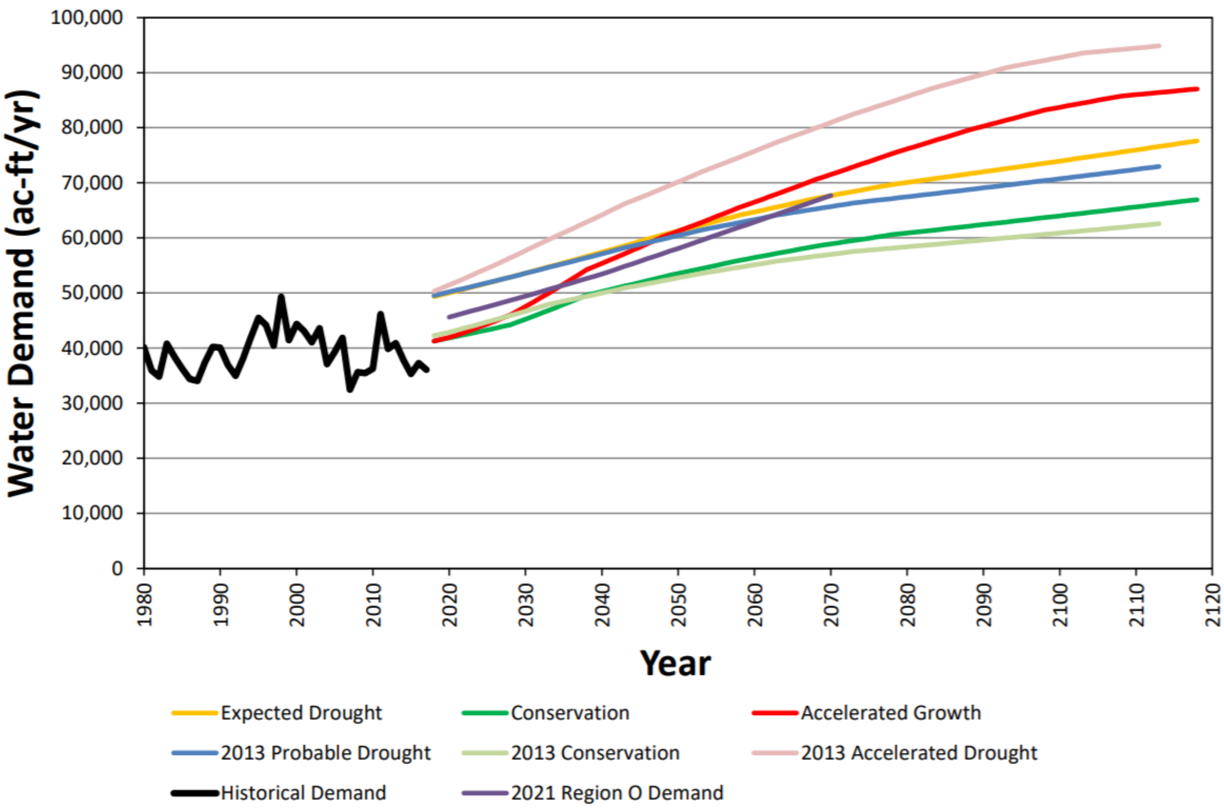


Figure 2.9 Historic and Projected Water Demands. Source: (City of Lubbock, 2018, 2.5)

The increase in population can increase urban landscape irrigation water demand. The continued growth in population and same landscape practices will only increase the overall demand for water in urban settings, however could reduce agricultural irrigation demand as land use changes from agriculture to urban. If alternative designs consider stormwater infiltration to increase soil moisture could reduce urban irrigation demand compared to current practices.

Smart Growth Communities

"Smart growth" is a term describing an approach to land development in the U.S. that is based on planning for sustainable growth.

> It encourages a mix of building types and uses, diverse housing and transportation options, development within existing neighborhoods, and community engagement… [A stated goal of] smart growth is to build cities, towns, and neighborhoods that are economically prosperous, socially equitable, and environmentally sustainable (Smart Growth 2019).

Smart growth communities seek to make the most of what nature has provided by protecting and preserving its natural benefits. From this perspective, an important focus in smart growth communities is protecting natural drainage ways and wetlands from development impacts through the implementation of adjoining buffers. Smart growth communities also take into consideration the changing climate by protecting area topsoil and decreasing water needs.

When the development of a site is under consideration, all significant natural features must be protected from development. Noted architect and design theorist Christopher Alexander urged, "Buildings must always be built on those parts of the land which are in the worst condition, not the best" (Duany, Speck and Lydon 1976). A sense of place is often achieved through the presence of a natural feature, and natural features also help increase property values throughout the development (Duany, Speck and Lydon

1976). Developments should not cut off the natural features of the site but embrace what they have to offer. For example, creating views and corridors that access the natural feature instead of cutting it off from use can do this. Significant natural features should be preserved as public spaces that can be used by all and not sold to private developers. In this way important natural features become the focal points of a site.

Developers should strive also adhere to development practices that cause the least amount of damage to natural features. This is not only the environmentally responsible approach to development, but it is often the most cost-efficient. For example, following the natural contours of the site can dramatically cut down on the cut and fill needed to construct a project. Locating development on the flattest areas of the site reduces disturbance and also minimizes cut/fill. Healthy soils should be kept in their native states. During construction, compaction should be limited to the areas that require it, and erosion control implemented to mitigate any adverse effects it may have on the natural systems in place.

Proper managing of post-development stormwater allows flow to continue in the natural drainage and infiltration zones as close as possible to the pre-development state. To help mitigate stormwater runoff, the amount of impervious surface should be limited as much as possible. Another way to manage stormwater is to not to develop over known porous soils, so they can still function as they would in their natural state. Environmental standards typically do not allow development to accrue in and around wetlands. Buffers are needed to protect the wetlands from increased storm runoff and sedimentation caused by development. Artificial wetlands and detention/retention ponds are effective ways to help mitigate the increase in storm runoff, and filter buffers can also be used to control sedimentation. Residential landscapes can also help mitigate the effects of storm runoff by collecting water onsite, which can decrease the need for supplemental irrigation demands.

In contrast to smart growth, "sprawl" development is characterized by highly consumptive land uses that are automobile-dependent and separated (i.e. residential and commercial uses do not mix). One of the many negatives to sprawl is the distance between urban areas and open or green spaces. Most people that live in sprawl developments lack readily available green spaces that promote engaging with nature. Playas in this area are a unique opportunity to create available green spaces for the community to utilize as a whole. They also work as a functioning ecosystem that is dependent on native stormwater runoff amounts. However, managing stormwater to an excessive amount can be detrimental to the ecosystem functions if sufficient water does not reach the playa.

Green Infrastructure and Low Impact Development Strategies

Green infrastructure is another approach to help stabilize the natural system after development has occurred. Green infrastructure is a cost-friendly approach to maintain stormwater impacts that provide ecological benefits, by using vegetation, soil, and other alternatives to managing stormwater (United States Environmental Protection Agency 2019). There are many different ways to implement green infrastructure in the urban landscape such as rainwater harvesting, rain gardens, planter boxes, bioswales, permeable pavements, green streets and alleys, green parking, green roofs, urban tree canopy, and land conservation (United States Environmental Protection Agency 2019). Some commonly used green infrastructure techniques are described below.

Rainwater harvesting is designed to collect the water and use it at a later date for irrigation needs, or even potable water if it is properly treated. This is typically practiced in arid regions around the county to increase water availability for dryer parts of the year. *Rain gardens* are designed shallow depressions that temporarily store water and allow it to slowly be absorbed through the soil. They can typically be installed in any open space and use a variety of plants with dense root systems to help filter and absorb stormwater runoff through infiltration, transpiration, and evapotranspiration. They work best with native or native-adapted plants that can tolerate wet or dry conditions. *Planter boxes* are used for directing runoff from roofs or other sources into planter areas for irrigation. *Bioswales* are mulched and vegetated swales used for retention and treatment while moving water from one place to another. Their linear nature means they are typically found adjacent to parking lots and streets and are very effective at filtering the water through vegetation.

Permeable paving can also be used for decreasing stormwater runoff, as it allows runoff to seep directly back into the ground below. It is most cost-effective where land values are high and flooding tends to be an issue. *Green streets and alleys* are used to create areas that hold and filter stormwater through infiltration, transpiration, and evapotranspiration. *Green parking* can be integrated into most parking lots without many even noticing a difference. Placing rain gardens in medians to capture stormwater can also do this. *Green roofs* cover the roof with vegetation that will hold and filter water before releasing it. The *urban tree canopy* can be used to control stormwater by collecting precipitation on the leaves and branches of street trees, trees planted in yards, and in open spaces. This slows down the amount of water making it to the ground in the form of runoff. Many cities also benefit from trees' ability to reduce the urban heat island effect, in addition to their function for stormwater management. *Land conservation* is a strategy to protect from the flooding impacts of stormwater by setting aside land for protection from development and its effects on natural wetlands and sensitive natural areas (United States Environmental Protection Agency 2019) (Figure 2.10).

Figure 2.10 Native Landscape Systems University Research Park Madison, Wisconsin. Source: Conservation Design Form

Summary of Literature

Dramatic changes to the environment throughout the history of the Llano Estacado have occurred. Surface water in the Llano Estacado region is very limited due limited precipitation and only three major river systems: North Prairie Dog Fork of the Red River, Double Mountain Fork Brazos River, and the Colorado River. The region's extensive playas are a vital source for recharge of the High Plains Aquifer with as much as 95 percent of the water collected and filtered into the aquifer through playas (Texas Parks & Wildlife n.d.). Historically, Native Americans communities survived and thrived by hunting bison, growing essential crops, and trading via their created trade routes. These native populations eventually gave way to homesteaders, who struggled to survive on the High Plains until the discovery of groundwater, and the invention of the turbine pump. Together these discoveries allowed mass consumption of water from the High Plains/Ogallala Aquifer for both human potable water and agricultural irrigation creating more reliable water sources, crop yields and economy. High reliance on this groundwater source makes today's global-scale agricultural and oil production possible. If depletion rates for the High Plains Aquifer are not addressed in the near future the potential ramifications could lead to completely depleting the water source (Brooks, et al. 2000).

Cities in West Texas including Lubbock, Amarillo, and Midland have been growing steadily due to a variety of expanding industries including petroleum, higher education, medical services, and energy producers. With this increase in population it is essential to understand the way water is being utilized in West Texas and seek ways to conserve water resources. The impact of unsustainable land use practices and a changing climate, coupled with increased water use, have created notable shifts in attitudes, approaches, and technology to address the region's long-term water needs.

Playas are threatened by urban and suburban development, which leads to an increase in runoff, sedimentation, and impacts from artificial fertilizers used on lawns and agricultural fields. The development of playa basins can also compromise the delicate balance of the playa ecosystem. Conservation of playas is of the upmost importance to the region—both in terms of their ecological function and the role they play in forming the region's unique identity. As land use changes occur, how can both urban and agricultural landscapes be planned and designed to: 1) maximize the beneficial use of precipitation, minimize the consumptive use of water from the finite High Plains/Ogallala Aquifer, and 2) preserve/conserve/protect the playas critical to aquifer recharge and migratory waterfowl and other native species? Landscape Architecture uniquely equipped to address this challenge of traditional development patterns and determine design alternative to protect the playa lake system from the negative effects of development.

CHAPTER 3

METHODS

Project Approach

To understand the current development challenges in Lubbock, Texas in relation to water resources and land use transitions from agriculture to suburban, a traditional approach to site inventory and analysis in the landscape architecture design process could be used. However, to understand the impacts of design alternatives, the traditional design process employed in landscape architecture was coupled with the Geodesign process which seeks to understand the impacts of alternatives.

Landscape Architecture Design Process

The landscape architecture design process is best summarized in the diagram by Kurt Culbertson of Design Workshop, Inc. (Design Workshop, Inc. 2007) (Figure 3.1). This sketch helps demonstrate that the process of design decision making is interactive and not always a straightforward approach. The design process begins with answering key questions related to knowledge of the client, site, context, economics, the users and design precedents. Once key questions are answered design alternatives can be created via an iterative process.

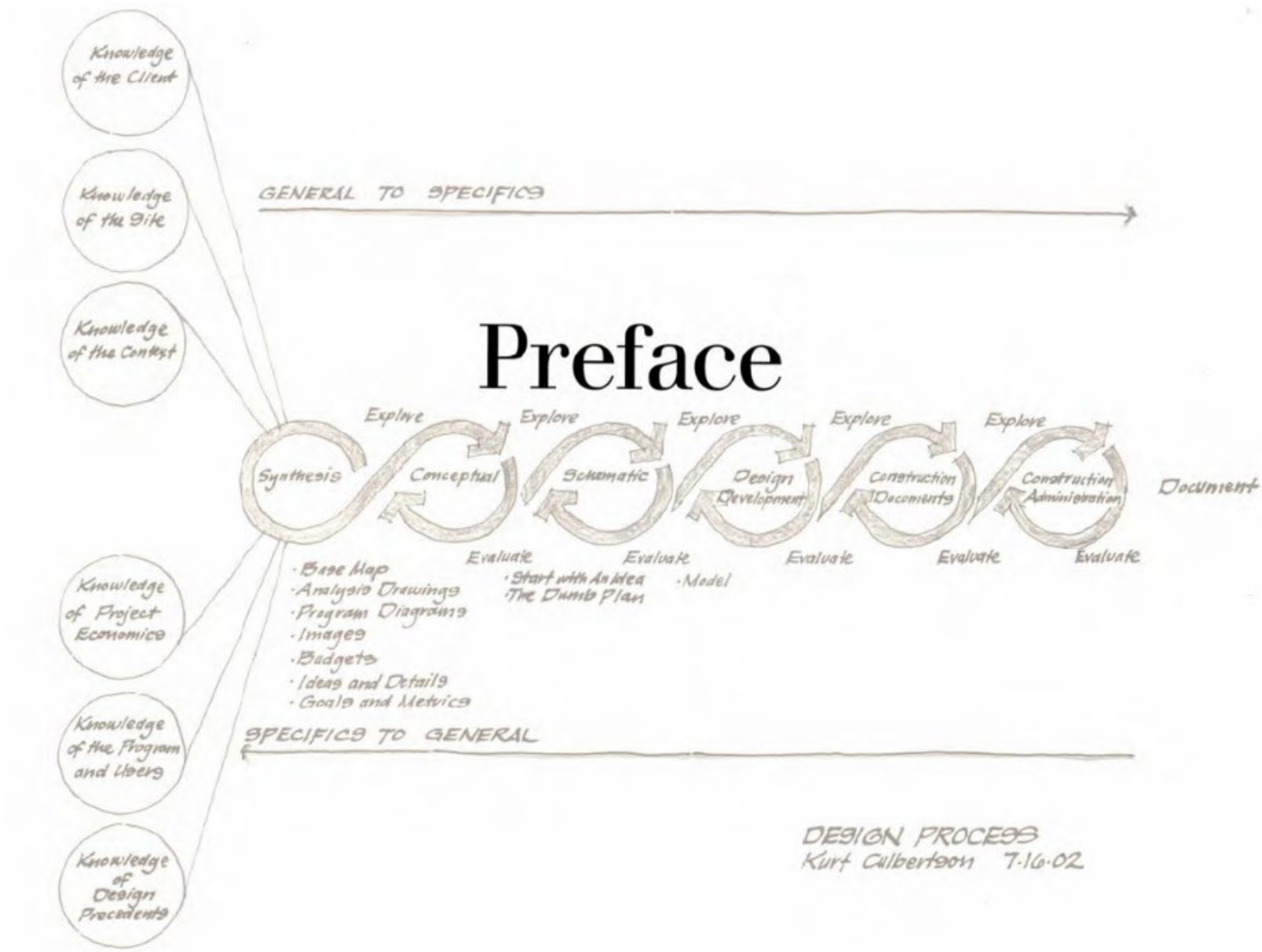


Figure 3.1 Kurt Culbertson, CEO of Design Workshop, Inc. Source: Toward Legacy.

Using the six knowledge questions illustrated in this landscape architecture design process helps guide the exploration and evaluation of the conceptual, schematic, design development, construction documentation and administration phases of the project by providing focus on the important elements of the project. In this case the client is developers and the community at large who without knowledge can undermine playa basin functions and services which are essential to the short and long-term sustainability and economy of the region. Smart Growth and green infrastructure approaches presented can provide important precedents for alterative design approaches that minimize, or mitigate development impacts on playas and reduce water use in agricultural and urban landscapes.

Geodesign

The framework for the geodesign process asks six key questions illustrated Figure 3.2 (Steinitz 2012). The six questions were developed to aid understanding the context of a project and different points of view, by describing the landscape, how it functions, how it could be changed and what change impacts might be, to determine if the landscape should be changed.

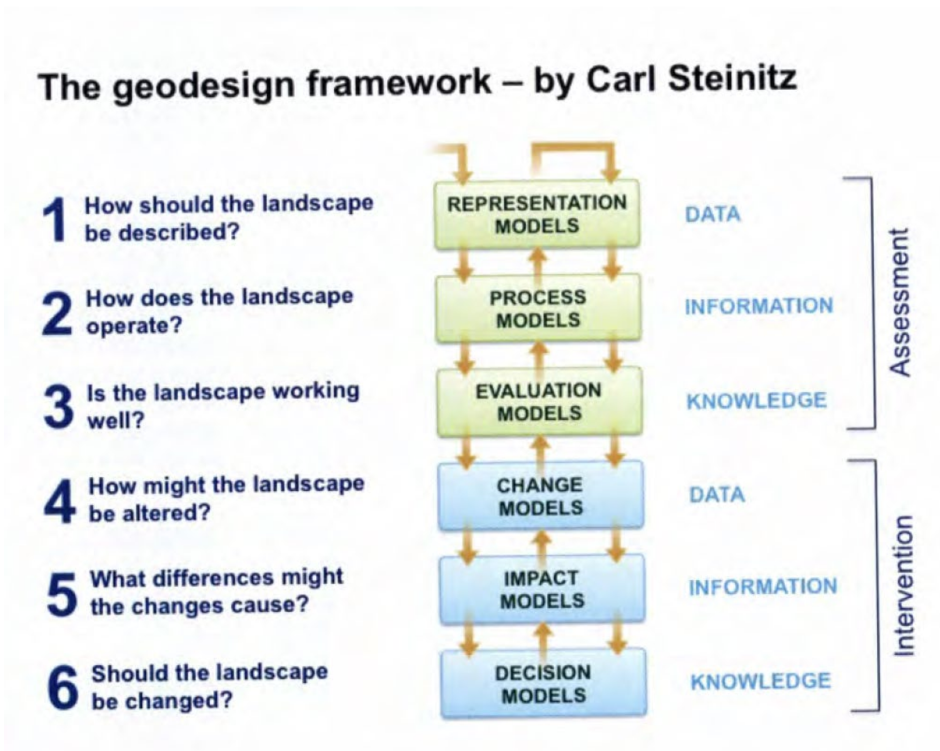


Figure 3.2 Framework - by Carl Steinitz. Source: Steinitz 2012

When employing the framework, the first iteration is very linear and straightforward. Asking the questions in reverse order offers a very different perspective and opens the door for new ideas that will not always lead to results, but rather to dead ends and unanticipated issues. The framework is helpful in understanding the project as a whole and in leading to questions that were not always obvious at the start of a project (Steinitz 2012). The six geodesign questions are very helpful when considered in conjunction with the landscape architecture process delineated by Culbertson. For instance, the six knowledge areas in the landscape architecture process are key elements of understanding the first geodesign question aimed at describing the existing landscape. The synthesis step closely aligns with second geodesign question to understand how the landscape is operating and working well. The conceptual, schematic, design development, construction documentation and construction administration steps in the landscape architecture process can benefit from asking geodesign questions 4-6. The following are quick first responses to the six geodesign questions by the author.

1) *How should the study area be described in context, space, and time?*

a. The case study playa basin was once a part of a vast shortgrass prairie ecosystem and was surrounded by thousands of other playas with similar low sloping topography. Habitation of the Llano Estacado has been challenged by limited surface water resources and became consistent when groundwater pumping offered a reliable water source. The PLSS grid system and subsequent road network, agricultural and urban developments have not respected playa hydrologic or ecologic functions and services including the study playa. First the study area transitioned from shortgrass prairie to cultivated agriculture, and now is facing intense pressure to transition from agriculture to suburban development. The playa floodplain is bisected on the north from the county road on the PLSS section grid. Current agricultural practices involve straight row, contour and terracing around the existing playa where cotton is the primary crop. Single family residential development has begun in the northern part of the playa basin, where a school and church have also been constructed.

2) *How does the study area operate?*

a. The current area operates as a mix of productive agricultural lands transitioning to suburban development in the northern portions of the site. The type of agriculture is dominated by cotton, while suburban development is high-density median income households. The playa lake currently supports ecosystem functions for migratory waterfowl throughout the migratory seasons. By providing food, water and shelter for the migratory species as farming practices have largely not impacted the typical floodplain. The transition to agriculture and now suburban development from native shortgrass prairie has increased stormwater runoff, erosion and sedimentation in the playa Randall clay pan as evidenced in site visits.

3) *Is the current study area working well?*

a. The current agriculture management for cotton is typical, bare soil covering large portions of the site from November to Mid-May and emerging cotton plants from the end of May to early June. The terrace and contour farming practices show less erosion signs than the straight row tillage practices typical in the area, and the fact that the clay pan area and annulus area is not currently tilled and planted is important to the playa's functions and services. The suburban development in the northern part of the playa basin follows typical single family development practices in Lubbock's southwest area of growth just north of the site. Soil erosion from water and wind are noted as the developed area was over lot graded without erosion prevention practices in place. These impacts are now making their way to the northern edge of the original playa cut off by the county road that bisects the northern edge of the historic annulus and floodplain.

4) *How might the study area be altered?*

a. The area could remain agricultural with typical, or best practices still respecting the playa floodplain, transition to typical suburban development not respecting the historic playa floodplain and ecosystem functions and services, or could be partially restored to native prairie and usable green space given population growth and development pressures surrounding the site.

5) *What differences might the changes cause?*

a. Land use and land cover changes can negatively impact the playa's hydrologic and ecologic functions by: increasing water depths, not allowing the clay pan to dry out, filling the clay with erosion material from agricultural or development construction, or increased runoff concentrated to create gully erosion. Altering the design of typical development patterns can help ecosystem functions by controlling and maintain stormwater runoff from the new development. The proposed development could increase green space and stormwater storage capabilities on managing stormwater on a lot-by-lot basis. Infiltrating stormwater on lots could increase soil moisture and decrease irrigation demand and aquifer water use. A development that includes green space and maintains the playa biodiversity could potentially encourage people to venture out into nature. Changes would impact environmental, social, and economic factors as benefits or detriments.

6) *How should the study area be changed?*

a. The proposed development should encourage the creation of green corridors that have connection points to larger green spaces used to capture and infiltrate stormwater to reduce impacts on playa functions and decrease irrigation water use. Development should provide for recreational space and mitigate and control stormwater runoff from reaching and exceeding the predevelopment 500-year flood boundary of the playa basin.

Fusing the six knowledge areas with the six geodesign questions helped to quickly formulate understanding of the site and important considerations for alternative design options for agricultural and suburban development in the study area playa basin on the Llano Estacado. The fusion of the two processes is used throughout the project and aided design decision making. The remainder of the section provides details about the site and methods used to describe and evaluate existing conditions and design alternatives.

Project Location: Lubbock, County.

Rapid suburban expansion since the 1970s has changed the hydrology and ecosystem functions and services of Lubbock's playa basins. The playa basin study area selected for this project is mostly in agricultural crop production with limited playa modification and tillage. The basin is located in a high-risk area for near-term future development, based on current land use plans and rapid expansion of suburban development all around it. The basin is located west of County Road 1600, also known as Upland Avenue, and between County Road 7200 (98th Street) and County Road 7400/Farm-to-Market Road 1585, which is currently in design and land acquisition phases for a new outer transportation loop. The study area has been defined by a single delineated watershed boundary for a playa basin using digital elevation model data obtained from the City of Lubbock and the USGS (Figure 3.3).

Determining the playa basin boundary was vital to help further understand how much water is making it to the playa from its upland basin. The site was then analyzed using geographic information systems (GIS) and commonly practiced stormwater management calculations for three different storm events: 1-year, 100-year, and 500-year flood.

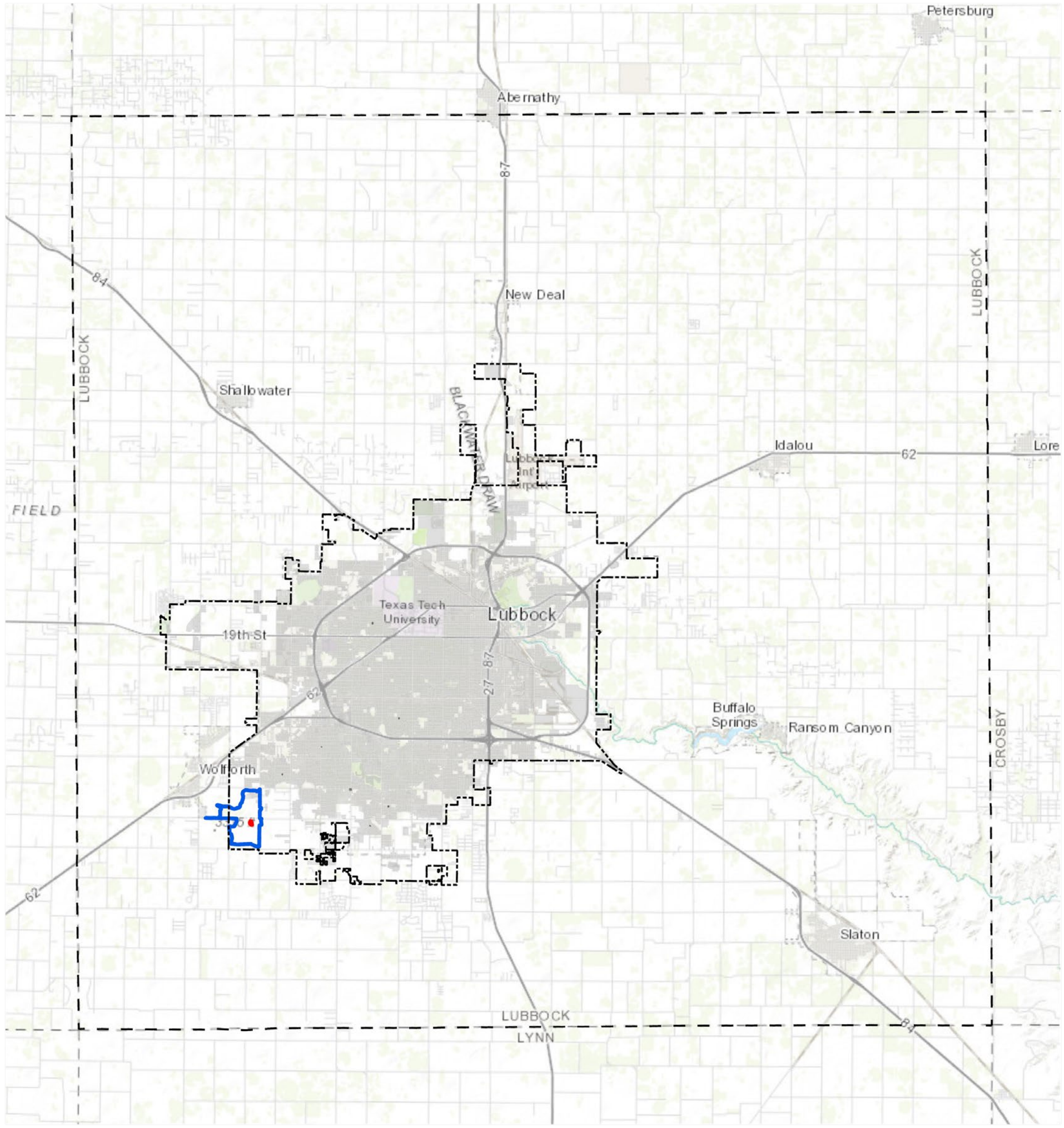


Figure 3.3 Case Study Playa Basin. Source: Tyson Watson

Delineating the Playa Watershed

Digital Elevation Models (DEMs) based on existing elevations were used to delineate a watershed boundaries for the study area playa and surrounding playas for context (USGS 2019). Three publicly available DEMs with different resolutions were used to determine the boundary for the playa basin. The approach used the different cell size of the DEMs, to understand differences in boundary areas and potentially with courser resolution DEMs be able to understand a pre-development watershed area. The three types of DEMs were: (National Elevation Dataset (NED)), 30 and 10 meter surface cells (USGS 2019), and (Light Detection and Ranging (LiDAR)), or laser measured point derived three-foot surface cells (City of Lubbock 2011).

Surface cell size refers to the size of grid cell edges that represent the land surface. A NED 10-meter surface means that the land surface is represented by a grid of cells, each measuring 10 x 10 meters on a side, or 100 square meters each (1076.39 square feet, 0.025 acres). A NED 30 meter surface is a grid of cells each measuring 30 x 30 meters on a side, or 900 square meters (9687.52 square feet, 0.22 Acres). The LiDAR DEM data is available for the City of Lubbock area and was created using laser scanned elevation points at a maximum spacing of 1.4 meters. The 2011 LiDAR bare earth elevation point measurements, provided by the City of Lubbock GIS Department, were interpolated into DEM with a cell size of 3 x 3 feet (approximately 1 square meter, 9 square feet, 0.0002 Acres) in the Texas Tech University Department of Landscape Architecture, using the LP360 extension to ArcGIS ArcMap 10.x. The LiDAR-derived DEM is the most accurate DEM of present-day conditions and illustrates curbs and crowns in the road, which the NED10 and 30-meter surfaces smooth out. The goal of using these differing resolution surfaces was to determine the playa basin, or watershed pre-development (NED 30 or 10 meter), and present day as developed (LiDAR 3 foot). The following (Figure 3.4) illustrates the playa basin in NED 30m, NED 10m and LiDAR 3 foot cell resolution surfaces.

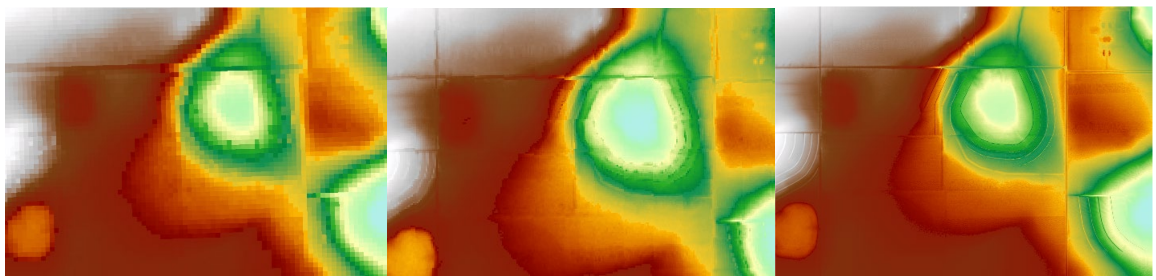


Figure 3.4 Digital Elevation Models (DEMs) 30m, 10m and 3FT LiDAR. Source: Tyson Watson

Delineating the watershed the case study playa basin required that other playas in the vicinity be located because the ridgeline, or watershed boundary exists between playas. Playa locations can be determined from aerial imagery, the Playa Lakes Joint Venture GIS data, and also Randall Clay soil polygons available from the Web Soil Survey (WSS) maintained by the Natural Resources Conservation Service (NRCS). ArcGIS Pro 2.3.x was used to overlay aerial imagery with playa lake polygons (PLJV) and Randall clay soil polygons (WSS) features as overlays along with the NED 30m and NED 10m (USGS), and LiDAR 3ft surfaces (City of Lubbock and Texas Tech University Department of Landscape Architecture).

ArcGIS Pro 2.3.x was used to digitize polygon watershed boundaries using the NED 30m, NED 10m, and LiDAR 3ft DEMs. Digitized polygon features were stored as Feature Classes in a project file geodatabase. Feature classes represent landscape features with points, lines, or polygons. After creating empty feature classes to store the playa basin, or watershed boundaries, for the 3 DEM resolutions, the symbology of the DEMs was adjusted to illustrate color bands of elevation change, and the DRA (Dynamic Range Adjustment) function was activated to force the maximum color range chosen for just the cells shown on screen; this function makes subtle changes in elevation and watershed boundaries more legible. When DRA is turned on, it facilitates the process of delineating the watershed by allowing the high points not noticeable by the eyes to be seen when zooming in and out (Figure 3.5).

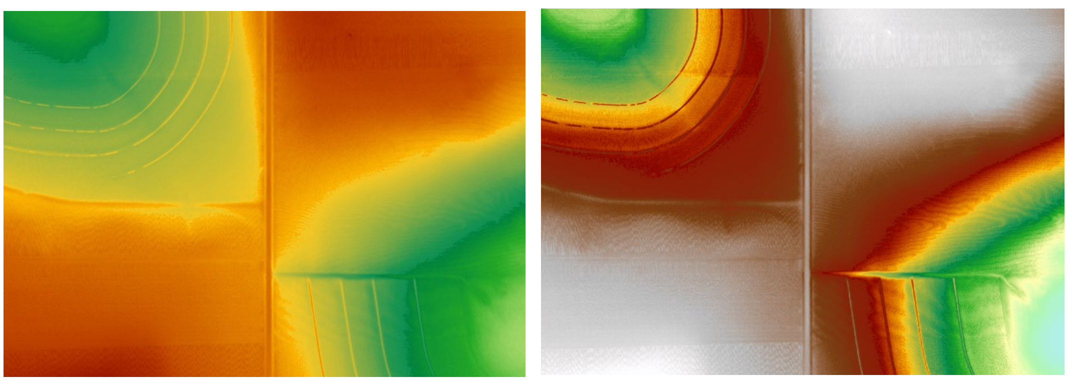


Figure 3.5 Screen captures of illustrating DEM without Dynamic Range Adjustment (DRA) on left and with DRA applied on right. Note the full color range shown on right for just the area on screen where white is high elevation and blue is low elevation. Source: Tyson Watson

The ArcGIS Pro contour geoprocessing tool was used to create contours from the DEMs to enhance the understanding of subtle grade changes that impact the watershed boundary delineation. Note that the LiDAR DEM was in a Texas State Plane NAD 1983 projection with US Feet units and did not require a conversion factor, while the NED 10 and 30-meter DEMs required a meters to feet conversion factor of 3.28084. If the conversion factor is not applied contours will be drawn as 1-meter contours, not 1-foot contours as intended (Figure 3.6).

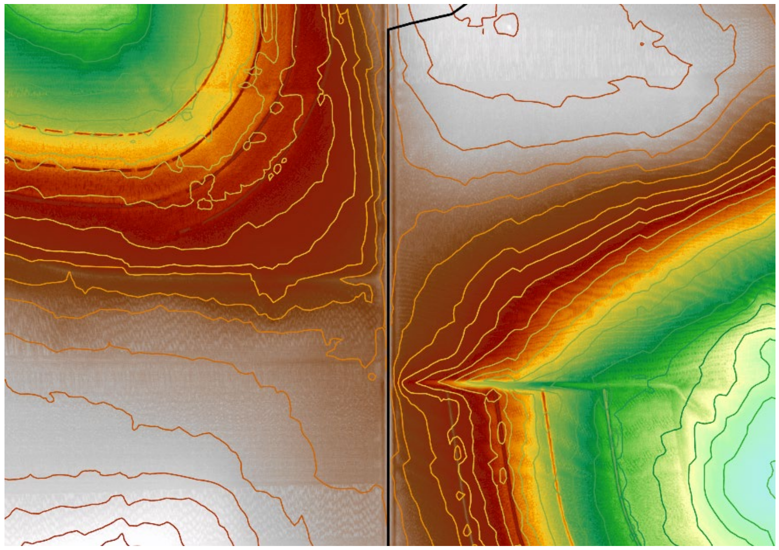


Figure 3.6 One Foot Contours derived from DEM Surface. Source: Tyson Watson

Typical Lubbock Single Family Suburban Development Types

Representative subdivions, refered to as neighborhoods in the City of Lubbock were selected from City of Lubbock Subdivision GIS polygons (City of Lubbock GIS 2018) based on lot size variations, road layout and right-of-way areas representative of typical development patterns. Parcels or lots were randomly selected within the representative subdivisions to be digitized to produce stormwater runoff calculations. ArcGIS Pro was used to generate a random point distribution within subdivison areas. Random points were then selected via random number generation to select a single land parcel to be digitized at a high level of detail for land use, land cover and surface material. GIS parcel polygon data was obtained from the Lubbock Central Appraisal District (Lubbock County Appraisal District 2019).

The five sample parcels were exported from ArcGIS Pro into shapefiles (.shp) and imported into AutoCAD Civil 3D 2019 (AutoCAD C3D) with the same Texas State

Plane coordinate system and projection as ArcGIS Pro to expedite digitizing based on personal preference. ArcGIS Pro could have been used to digitize land use, land cover, and material areas. After the parcels were individually digitized in CAD, they were added back into ArcGIS Pro as .dwg data, then added back into the project geodatabase as line feature classes. Polylines were then converted to polygons using the Feature to Polygon geoprocessing tool. This step makes clean polygon areas and calcuates each polygon area in square feet based on the coordinate system and projection.

The attribute table from the ArcGIS created polygons was exported to Microsoft Excel 2016 (Excel). New fields and columns were created to create drop down lists, similar to Domains and Subtypes in ArcGIS geodatabases. Excel tables were created from coefficent described land use, land cover, and materials based on common and City of Lubbock watershed calcuation methods.

Stormwater Calculations

The Rational Method (RM) method was used for calculating stormwater runoff for this project based on the approach to understand runoff on a lot-by-lot basis, the City of Lubbock exception for single playa basins that do not provide overflow conveyance systems, and the Modified Rational Method (MRM). The RM is used for calculating small drainage areas and peak runoff rates for areas typically less than 200 acres (City of Lubbock provides an exception to this rule for single playa basin calculations). RM is calcuated using the equation

$$q = CiA$$

where (q = peak runoff rate, cubic feet per second), (C = a dimensionless coefficient between 0 and 1), (i = Rainfall intensity per hour) and (A = Area of drainage area).

The RM was also used for digitzed representative single family lot types. These equations formed the basis for calculating the amount of water that could potentially be stored on site and not allowed to run off.

Runoff coefficients listed in *Site Engineering for Landscape Architecture* (Nathan and Woland 2013), were added to Excel and compared to those in Chapter 4 of the City of Lubbock's Stormwater Guide (Lubbock 1997), which were also added to an Excel table. Many of the same coefficients are listed in both sources. Runoff coefficients were also added to the Excel table from Technical Release 55 (TR-55), created by the USDA NRCS (USDA 1986). All commonly used coefficents inventoried from the three sources were evaluated based on the land use, land cover, material, soil, slope and land cover condition. Separate fields were created for land use, land cover, material, soil, slope and land cover condition and descriptions provided by coefficient sources were evaluated to populate a consistent values for land use, land cover, and material. Note that soil, slope and land cover condition are used only in TR-55 coefficients. The Site Engineering and City of Lubbock coefficients were identical, while the TR-55 coefficients were much more detailed for agricultural land use, and conservation practices like terracing, tillage practices and crop types that are not included in the other sources. It should be noted that coefficients can range from 0 to 1.0, where 0 = no runoff, 0.5 = 50% runoff, and 1.0 = 100% runoff.

Watershed calculations can account for multiple types of water flow, including surface flow, surface flow with transmission losses, quick return flows and base flows (Figure 3.7), this project focuses on surface flows and assumes all areas contribute based on the their applied coefficient to surface flow. This method accounts for the maximum potential total volume of water entering the playa lake based on upland land use, land cover and material.

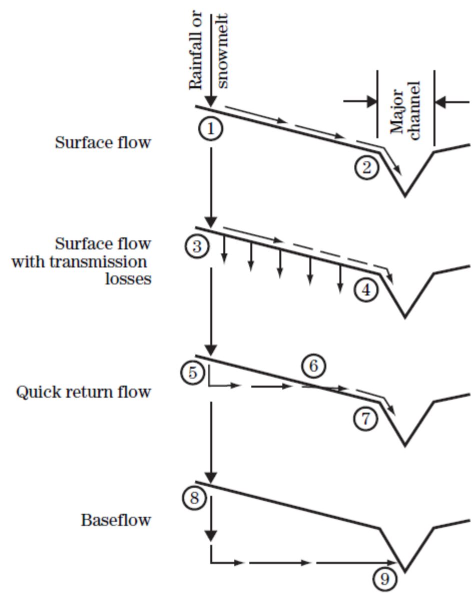


Figure 3.7 Types of Flow. Source: (USDA 2010)

The Excel coefficient table for all types of land use, land cover, and material, was used to create drop-down, selectable lists to assign a specific land use, land cover, and material to each polygon digitized area. The land use, land cover, and material (LU-LC-M) entries were concatenated, or combined, into a single cell and compared to the same concatenated values in the combined sources coefficient table. An Excel look-up algorithm was created to assign the appropriate coefficient to each polygon by comparing the LU-LC-M values determined for the polygon to corresponding LU-LC-M in the coefficient table (Figure 3.8).

Category	Sub Category	Sub Sub Category	R.O Coefficient							
			Range		Soil			Slope		
			Min	Max	Sandy Loam	Clay/Silt Loam	Clay	2%	2-7%	7%
Site Engineering of Landscape Architects 6th Ed. Pg 206 Table 12.1										
Urban Areas										
	Downtown Business		0.7	0.95						
	Neighborhood Business		0.5	0.7						
	Single-family Residential		0.3	0.5						
	Detached Multi-unit Residential		0.4	0.6						
	Attached Multi-unit Residential		0.6	0.75						
	Suburban Residential		0.25	0.4						
	Apartment		0.5	0.7						
	Light Industrial		0.5	0.8						
	Heavy Industrial		0.6	0.9						
	Parks, Cemetaries		0.1	0.25						
	Playgrounds		0.2	0.35						
	Railroad Yards		0.2	0.35						
	Unimproved		0.1	0.3						
Urban Surfaces										
	Roofs		0.8	0.95						
	Asphalt and Concrete Pavments		0.75	0.95						
	Gravel		0.35	0.7						
Rural and Subrurban Areas										
	Woodland									
		Flat (0-5%)	0.1	0.4	0.1	0.3	0.4			
		Rolling (5-10%)	0.25	0.5	0.25	0.35	0.5			
		Hilly (10-30%)	0.3	0.6	0.3	0.5	0.6			
	Pasture and Lawns									
		Flat (0-5%)	0.1	0.4	0.1	0.3	0.4			
		Rolling (5-10%)	0.16	0.55	0.16	0.36	0.55			
		Hilly (10-30%)	0.22	0.6	0.22	0.42	0.6			
	Cultivated or No Plant Cover									
		Flat (0-5%)	0.3	0.6	0.3	0.5	0.6			
		Rolling (5-10%)	0.4	0.7	0.4	0.6	0.7			
		Hilly (10-30%)	0.52	0.82	0.52	0.72	0.82			

Figure 3.8 Example of Coefficient Table Used. Source: (Nathan and Woland 2013)

The City of Lubbock design storms table was entered in Excel based on inches in a 24 hour period for 1, 2, 5, 10, 25, 50, 100, 500 and 1000 year storm events. These values were converted to Inches Per Hour (IPH = i) used in the RM equation by dividing the inches in 24 hours by 24 in Excel.

Excel was then used to calculate RM runoff using Q= CiA for each polygon digitized area and assigned land use, land cover, and material, which corresponded to a coefficient C, a drop-down selected storm intensity (i), and the ArcGIS Pro geodatabase calculated area in square feet divided by 43,560 (square feet in acres) to convert to area in acres as required.

This method was used to calculate runoff for the watershed prior to development, with different types of agricultural development and single family, commercial, and school public building types to determine the baseline volume of water likely collecting in the playa pre and post development. As described, the developed Excel tables created a relationship between a polygon and its corresponding LU-LC-M classification. These numbers were used to automatically determine coefficients and then calculate runoff rates and amounts for each type of development. The table is easily editable, so if the land use, land cover, or material changes, the coefficient will immediately update to the correct coefficient value and the runoff be recalculated.

The runoff rates determined for each of the single family lot types were then used to determine runoff for the case study playa basin. Than that lot type and corresponding runoff rates were applied to the entire watershed area including the playa basin, based on each subdivision type's dwelling units per acre (DU/AC). The runoff amounts per parcel were multiplied by their corresponding density to estimate that typical Lubbock development being applied to the watershed area. Results were then compared to pre-development runoff based on a coefficient of 0.1 (C=0.1) for native prairie in good condition. The RM calculated Q values representing peak runoff rate in, cubic feet per second were multiplied by 86,400 seconds (in 24 hours) to determine a total runoff volume in cubic feet. Runoff cubic feet were divided by 27 to convert from cubic feet to cubic yards which correspond to volume calculations between surfaces—LiDAR land surfaces and water elevation surface when using AutoCAD C3D surfaces analysis tools.

Modeling Water Storage Capability in a Playa

The LiDAR surface from ArcGIS Pro was recreated in AutoCAD C3D to help understand water storage capabilities for the playa basin. AutoCAD was used to determine the water level of the playa pre-development based on runoff volumes in cubic yards and using native prairie grass (C= 0.10) for 1, 10, 100, 500 and 1000 year storms. A flat surface representing the water elevation based on elevation above sea level was created. As the elevation of the water surface is changed up or down, first at specific elevations in 1-foot increments starting at the playa bottom plus1 foot (ex. 3276.00, 3277, etc.). The volume was calculated between the existing land surface and water elevation surface to determine storage volume and then compared to the runoff calculated for each design storm. Once the volume levels were calculated for each storm, the development scenarios were applied against the known volumes to determine the increase in water volume needed to be stored elsewhere and not allowed into the playa basin. This same technique was applied to the individual parcels to determine how much water could be stored on each type of development by grading depressions in the pervious areas outside a 5-foot sloping buffer of the building footprint.

The following presents the findings employing the process of landscape architecture coupled with geodesign to understand design alternatives for the case study playa basin and their impacts.

CHAPTER 4

FINDINGS

The findings begin with describing the study area in detail, understanding how the playa watershed currently works, options to typical approaches for development, potential impacts of typical and alternative approaches, and recommendations for change. The first step is to understand the playa basin and how it is currently operating.

Delineation of the Playa Watershed Boundary

The HU12 (Hydrologic Unit 12-digit watershed USDA NRCS) watershed boundary for the case study is the City of Farm Center (Figure 4.1). This watershed boundary spreads between Lubbock and Hockley counties and contains no mapped stream or river in the National Hydrography Dataset (NHD). The HUC12 watershed area within Lubbock County contains 34 playa lakes according to the NRCS SSURGO (WSS) Randall clay soil polygons for Lubbock County and the PLJV playa lakes GIS polygon layer. As noted, shallow, small basin area playas have the potential to overflow and interact with other playas depending on the duration and intensity of the storm event. The case study playa under pre-development conditions would not overflow into any other playa lakes due to depth and size of the basin.

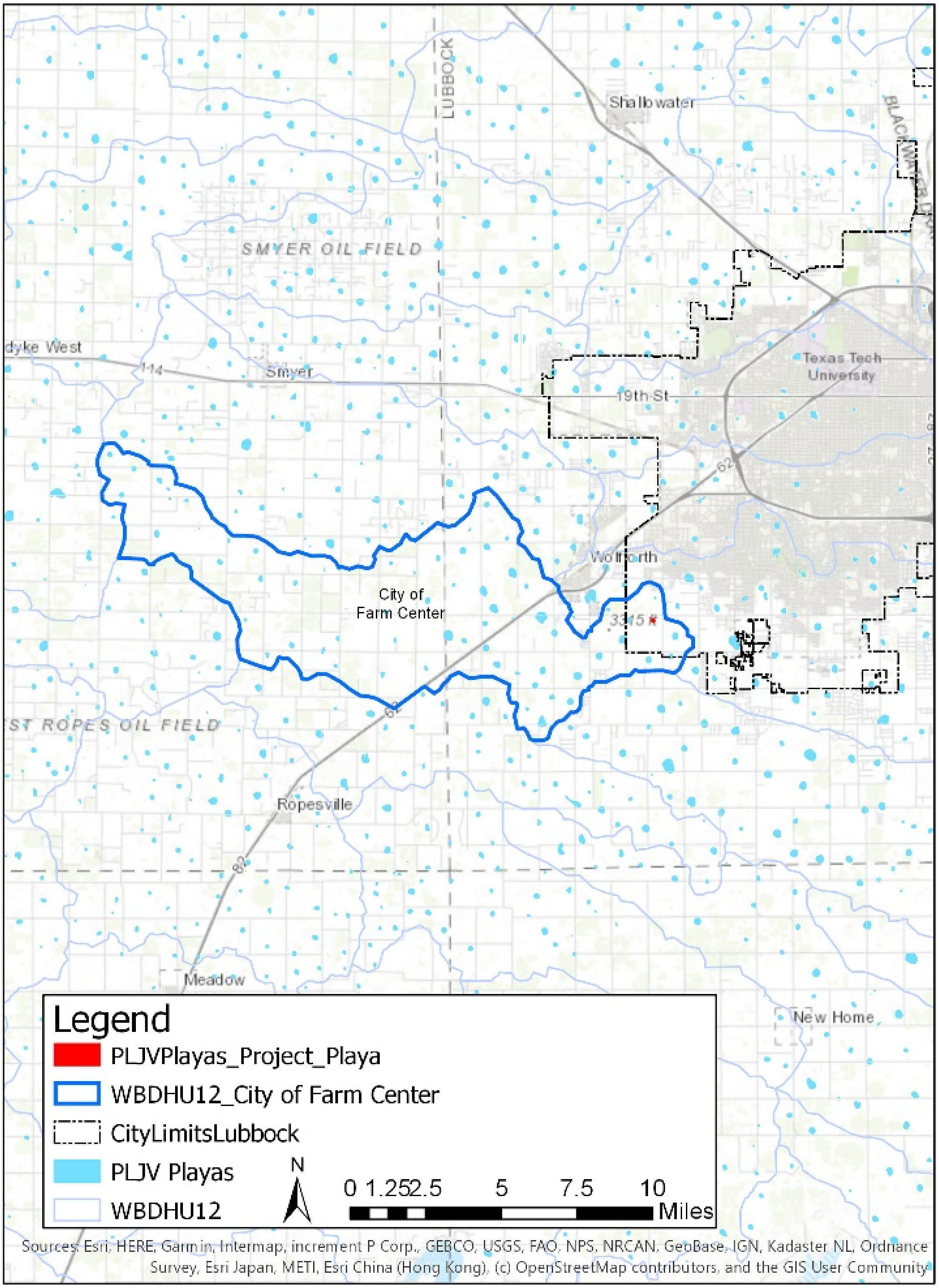


Figure 4.1 HUC12 Watershed Boundary for the City of Farm Center. Source: Tyson Watson, USDA-NRCS

The delineated watershed boundaries for the three types of digital elevation models (NED 30 and 10 meter, and 3ft LiDAR) varied in shape and size. The watershed boundary delineated using the NED30m is the closest to predevelopment limits as it smooths out road features that change drainage patterns given the 30 m cell size. The NED 30m delineated watershed boundary was calculated at 1012.38 acres (Figure 4.2). The NED10m delineated watershed shows increased detail and general development patterns including roads and general landforms. In contrast to the NED30m delineated watershed boundary, the NED10m was calculated at 937.26 Acres (Figure 4.2). The LiDAR surface delineates the most accurate watershed boundary for the project playa depicting crowns in the road along with the curbs and even agriculture terraces and rows. Since the LiDAR has the ability to depict crowns in the road, accurate understanding of the road surface and bar ditches is captured that are commonly used in the area for stormwater management as surface conveyance systems. Given the very low valued slopes, these systems can extend for great distances. As such, the LiDAR DEM delineated boundary was the largest at 1014.97 acres, and is the closest to the NED30m surface in this case (Figure 4.2).

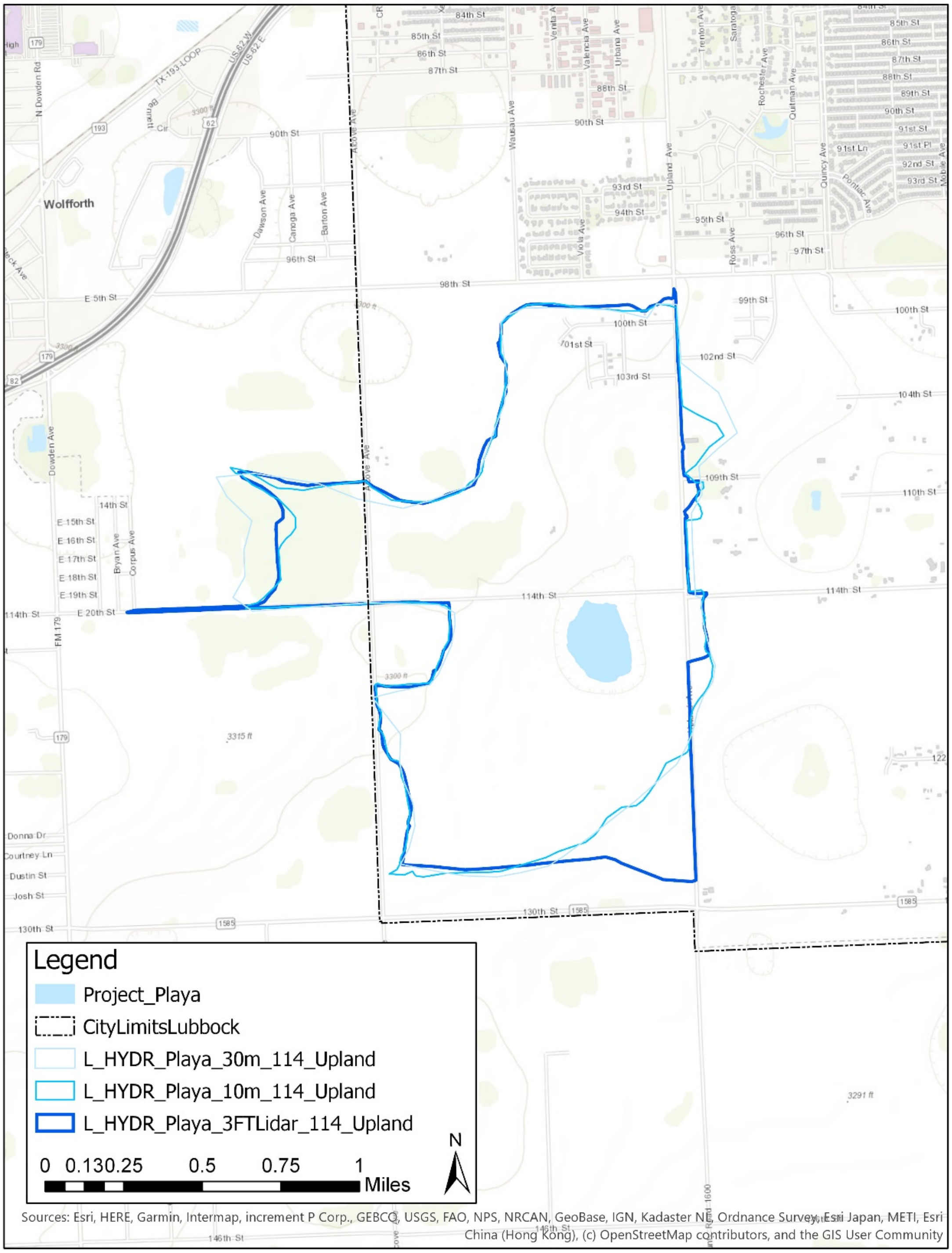


Figure 4.2 Playa Lake Watershed Delineation 30m, 10m and 3FT LiDAR. Source: Tyson Watson

The LiDAR boundary shows the effects that development, primarily of road systems, has had on the playa basin watershed boundary. The LiDAR surface is the current and most accurate surface for completing the stormwater runoff calculations for the project and was used for all calculations. It should be noted that any increase to the watershed boundary area would change the amount of stormwater entering the playa lake area and could potently cause harm to the playa's ecosystem.

Pre-development Playa Flood Levels

Urbanization is widely known to increasing stormwater runoff over predevelopment conditions due to impervious land covers and materials. This case study investigates increases in runoff based on typical and alternative agricultural crop production and suburban single-family design types to demonstrate the change impacts development from native prairie conditions. The goal is to understand how design alternatives can be implemented to meet pre-development playa flood levels based on the following 24 hour storm events: 1 year = 2.19 inches; 10 year = 4.22 in; 100 year = 6.85 in; and 500 year = 9.12 in (NOAA 2017).

To determine the baseline pre-development flood plains, the following were used:

RM equation $Q=CiA$, where

$C= 0.10$ for short-grass prairie

$i=$ IPH for the 1, 10, 100, 500 and 1000-year events =

0.09125, 0.175833, 0.28541667, 0.3245833, 0.38, and 0.425 respectively

$A= 1014.97$ acres = LiDAR delineated watershed boundary area

Predevelopment Q = Runoff CFS

Predevelopment Volume = Q * 86,400 seconds in 24 hours = cubic feet / 27 = cubic yards

Under the native short-grass prairie predevelopment condition, following runoff CFS, 24 Hour volume, and estimated flood elevation in feet above mean sea level were calculated: (Table 4.1)

Table 4.1 Native Prairie Predevelopment Watershed Calculations

1-year storm	800,201.09 CFS	29,637 yd^3	Flood Elevation 3274 ft
10-year storm	1,541,940.00 CFS	57,108 yd^3	Flood Elevation 3274.25 ft
100-year storm	2,502,912.09 CFS	92,700.45 yd^3	Flood Elevation 3275.60 ft
500-year storm	3,332,344.27 CFS	123,420.16 yd^3	Flood Elevation 3276.15 ft
1000-year storm	3,726,963.90 CFS	138,035.70.16 yd^3	Flood Elevation 3276.40 ft

Runoff volumes were modeled in Civil 3D with a volume surface comparing a level water surface set a specific elevation to the LiDAR DEM existing land surface. A visualization of the resulting flooded areal extent to achieve the required runoff volume is on the following page and illustrated with a light blue filled polygon. Note that modeling the water level planar surface also allowed the pour point elevation, or maximum volume of the playa basin to be determined and is illustrated with the blue line in the following rendered models (Figures 4.3-4.7). Predevelopment flood elevations now determined the goal is to limit the increase of stormwater runoff to the 500-year boundary while leaving the 1000-year flood boundary as an overflow.

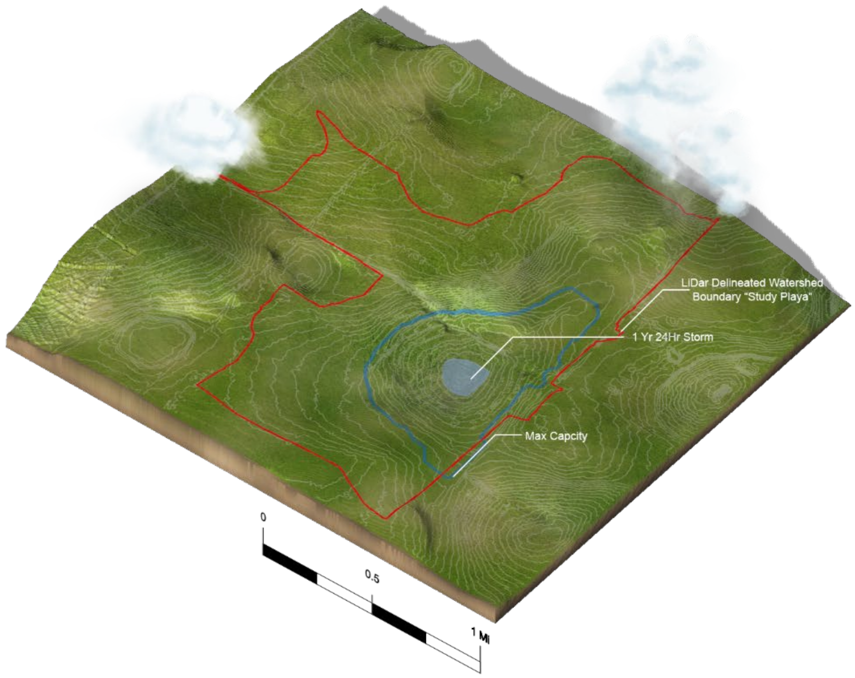


Figure 4.3 Native Prairie Runoff Volume Estimated Extent by 1-Year Design Storm.
Source: Tyson Watson

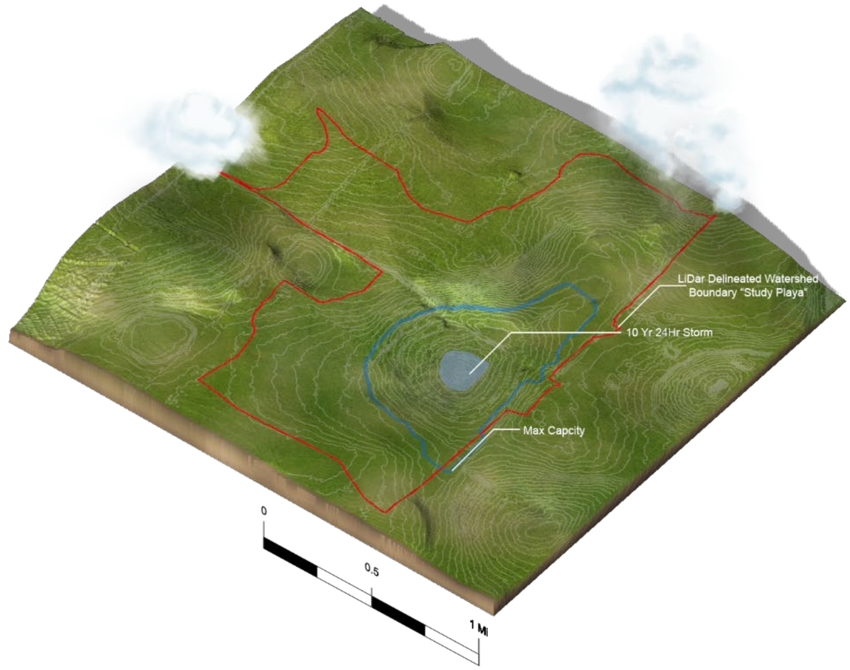


Figure 4.4 Native Prairie Runoff Volume Estimated Extent by 10-Year Design Storm. Source: Tyson Watson

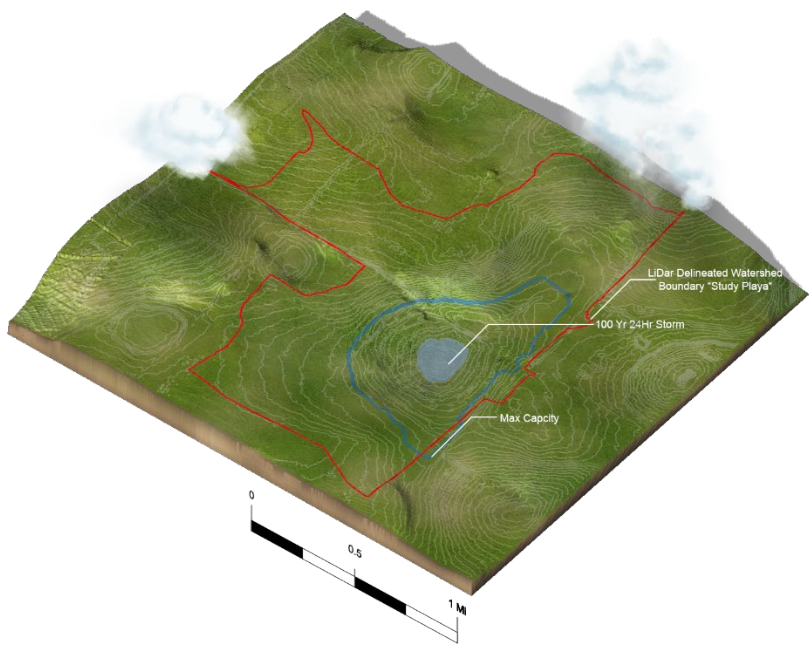


Figure 4.5 Native Prairie Runoff Volume Estimated Extent by 100-Year Design Storm. Source: Tyson Watson

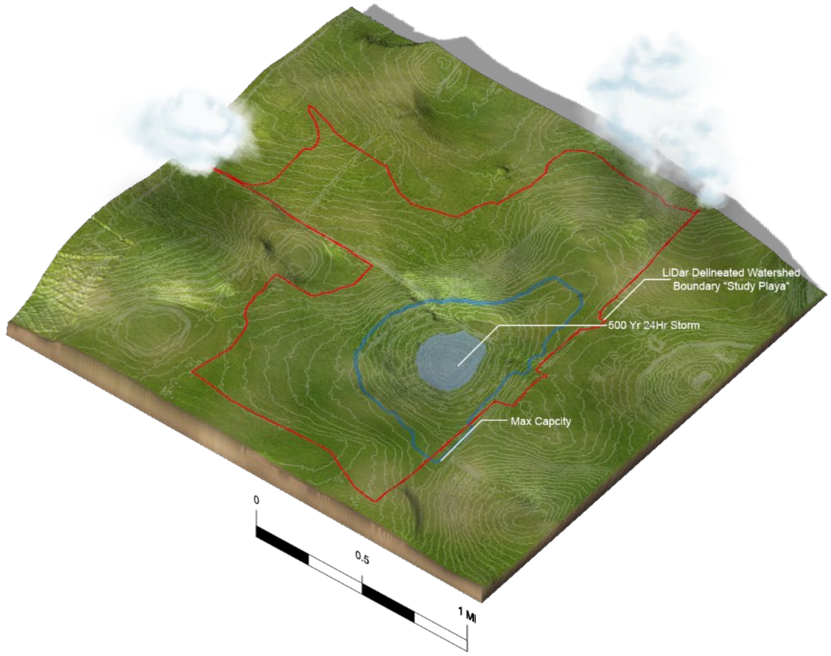


Figure 4.6 Native Prairie Runoff Volume Estimated Extent by 500-Year Design Storm.
Source: Tyson Watson

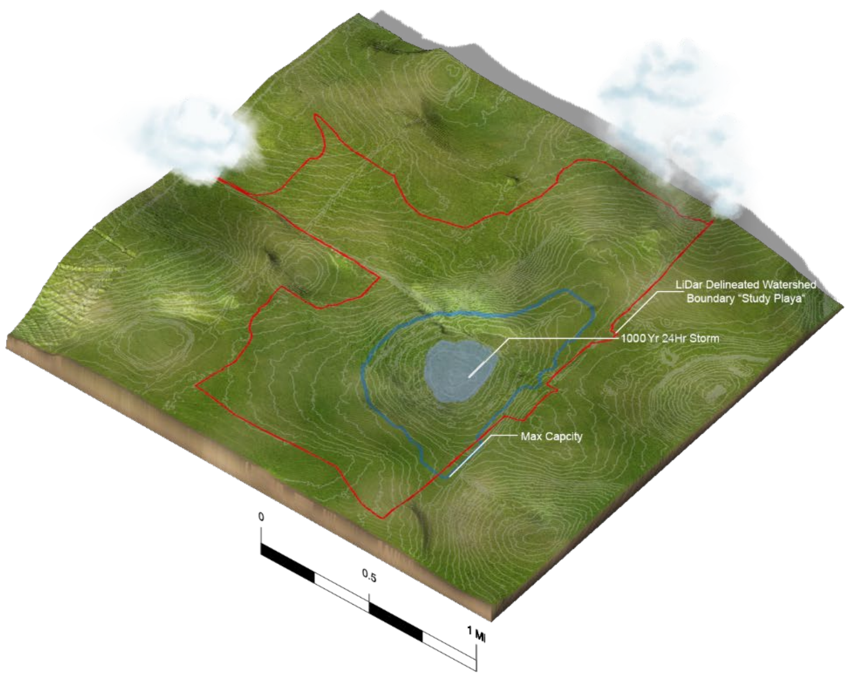


Figure 4.7 Native Prairie Runoff Volume Estimated Extent by 1000-Year Design Storm.
Source: Tyson Watson

To determine baseline agricultural crop production runoff rate based on typical conditions found in the region, and within this playa basin, the following were used:

RM equation Q=CiA, where

C= 0.30 for cultivated with no plant cover

i= IPH for the 1, 10, 100 and 500-year events =

0.09125, 0.175833, 0.28541667, 0.3245833, 0.38, and 0.425 respectively

A= 1014.97 acres = LiDAR delineated watershed boundary area

Predevelopment Q = Runoff CFS

Predevelopment Volume = Q * 86,400 seconds in 24 hours = cubic feet / 27 = cubic yards

Under typical agricultural crop production conditions, the following runoff CFS, 24 Hour volume, and estimated flood elevation in feet above mean sea level were calculated: (Table 4.2)

Table 4.2 Agriculture Development-Cultivated no Plant Cover Watershed Calculations

1-year storm	2,400,603.27 CFS	88,911.23 yd^3	Flood Elevation 3275.40 ft
10-year storm	4,625,820.01 CFS	171,326.67 yd^3	Flood Elevation 3276.75 ft
100-year storm	7,508,736.26 CFS	278,101.34 yd^3	Flood Elevation 3278.40 ft
500-year storm	9,997,032.81 CFS	2,370,260.47 yd^3	Flood Elevation 3279.00 ft

For this project the goal for stormwater runoff is to be limited within the predevelopment 500-year flood boundary and limiting development to occur within the 1000-year flood boundary. Resulting volume models are presented on the following page (figures 4.8-4.11).

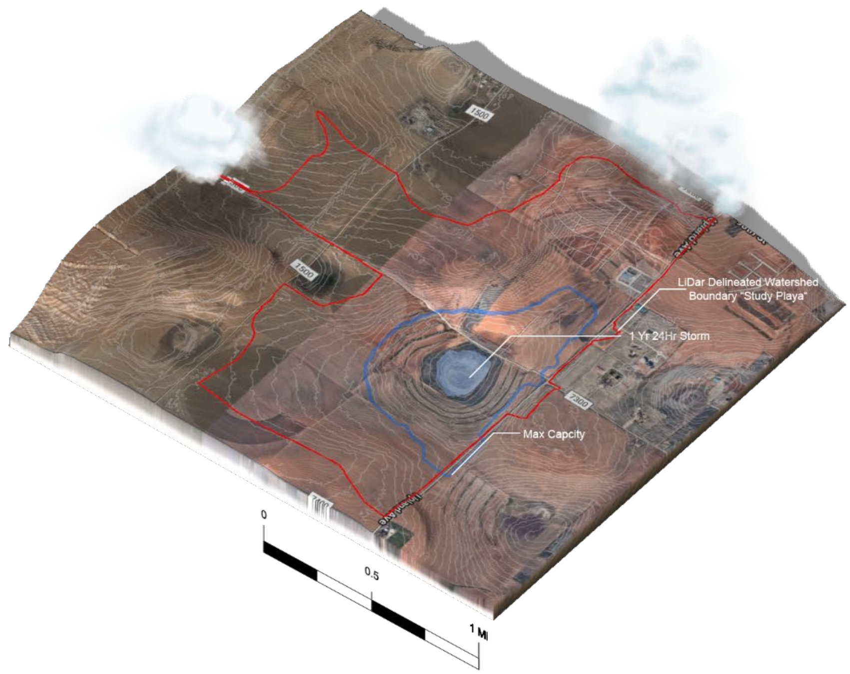


Figure 4.8 Cultivated No Plant Cover Runoff Elevation Extents for 1-Year Design Storm.
Source: Tyson Watson

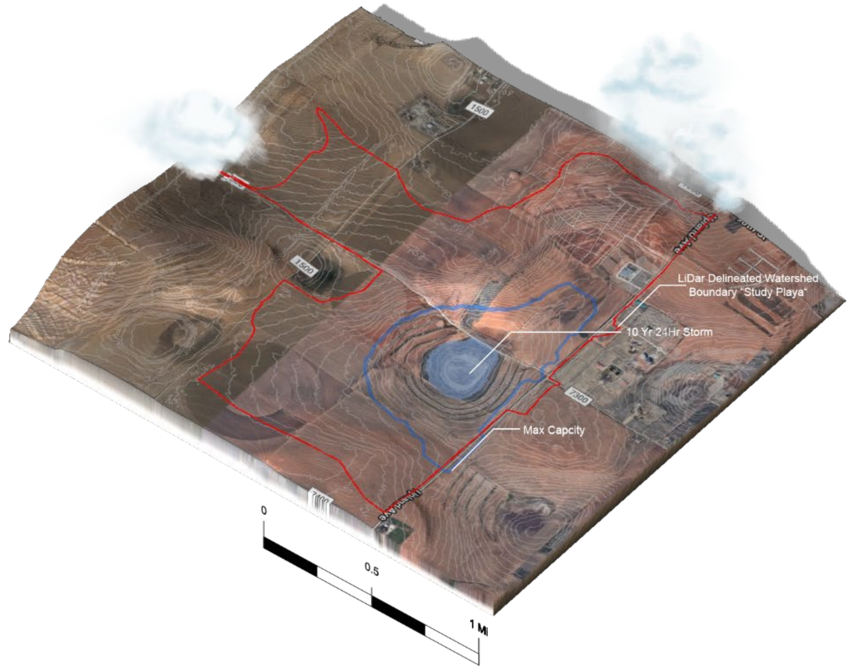


Figure 4.9 Cultivated No Plant Cover Runoff Elevation Extents for 10-Year Design Storm. Source: Tyson Watson

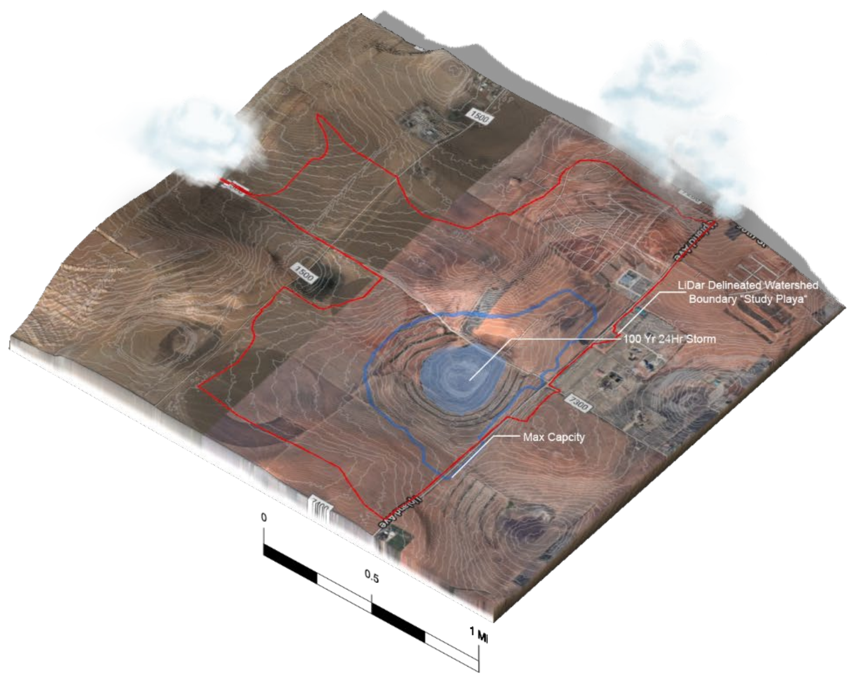


Figure 4.10 Cultivated No Plant Cover Runoff Elevation Extents for 100-Year Design Storm. Source: Tyson Watson

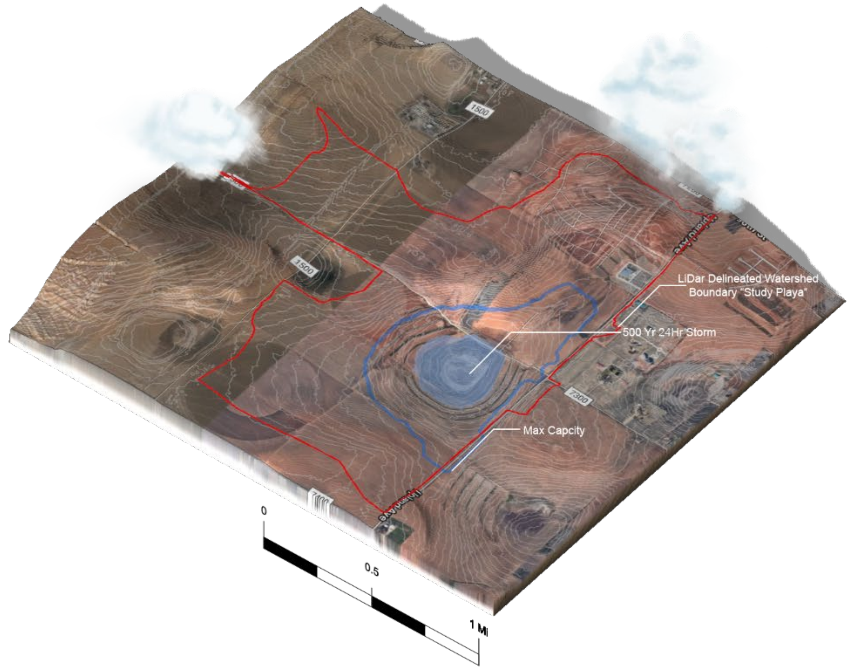


Figure 4.11 Cultivated No Plant Cover Runoff Elevation Extents for 500-Year Design Storm. Source: Tyson Watson

To determine the existing watershed runoff rate as developed in the playa basin by existing land use, cover, and material, 2018 aerial imagery was used to digitize and assigned the land use, land cover and material which were then used to assign the coefficient. The following formula was used:

RM equation Q=CiA, where

C = 0.60 for cultivated with no plant cover

C= 0.60 for the development to the north

i= IPH for the 1, 10, 100 and 500-year events =

0.09125, 0.175833, 0.28541667, 0.3245833, 0.38, and 0.425 respectively

A= 1014.97 acres = LiDAR delineated watershed boundary area

Predevelopment Q = Runoff CFS

Predevelopment Volume = Q * 86,400 seconds in 24 hours = cubic feet / 27 = cubic yards

Under typical agricultural crop production conditions, the following runoff CFS, 24 Hour volume, and estimated flood elevation in feet above mean sea level were calculated: (Table 4.3)

Table 4.3 Current Conditions Watershed Calculations

1-year storm	2,478,526.83 CFS	91,797.29 yd^3	Flood Elevation 3275.40 ft
10-year storm	4,775,990.31 CFS	176,888.53 yd^3	Flood Elevation 3276.75 ft
100-year storm	7,752,469.77 CFS	287,128.51 yd^3	Flood Elevation 3278.40 ft
500-year storm	10,321,533 CFS	382,279.00 yd^3	Flood Elevation 3279.00 ft

For this project the goal for stormwater runoff is to be limited within the predevelopment 500-year flood boundary and limiting development to occur within the 1000-year flood boundary. Resulting volume models are presented on the following page (Figures 4.12-4.15).

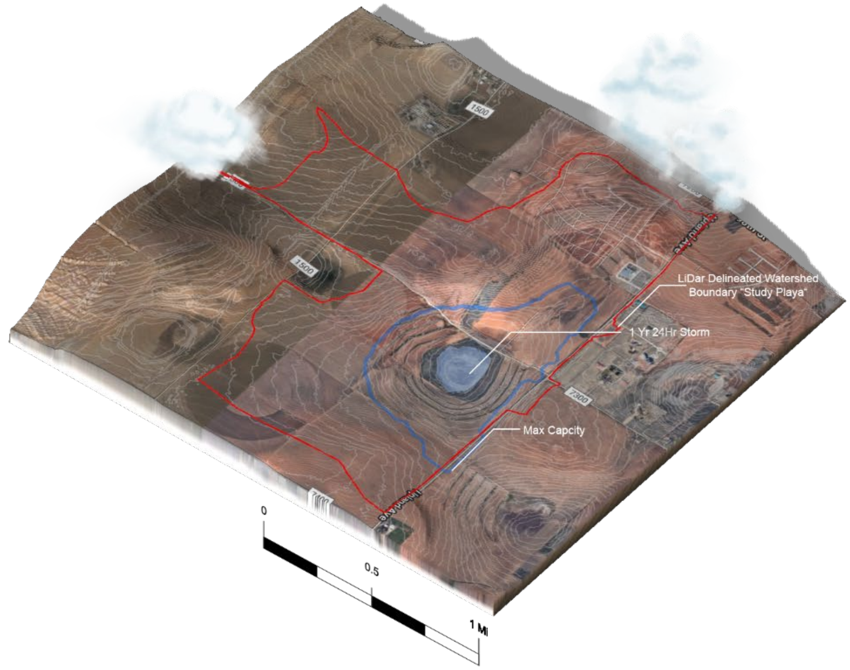


Figure 4.12 Current Condition Runoff Elevation Extents for 1-Year Design Storm.
Source: Tyson Watson

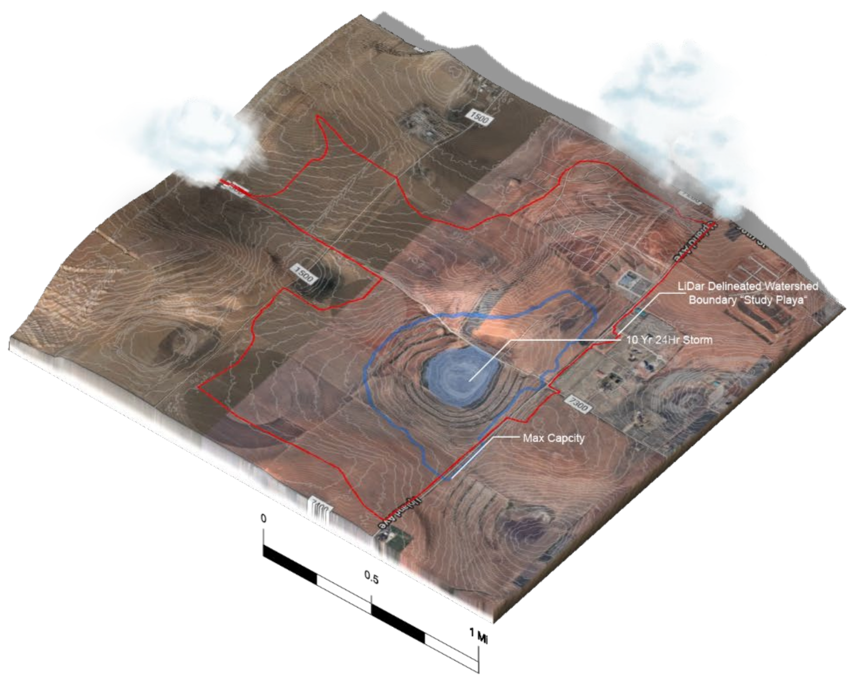


Figure 4.13 Current Condition Runoff Elevation Extents for 10-Year Design Storm.
Source: Tyson Watson

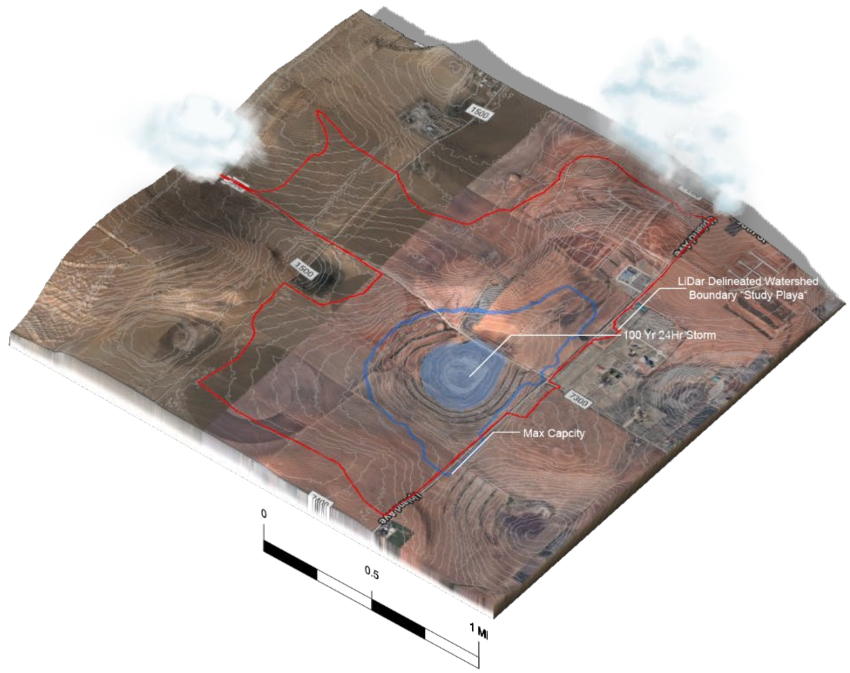


Figure 4.14 Current Condition Runoff Elevation Extents for 100-Year Design Storm. Source: Tyson Watson

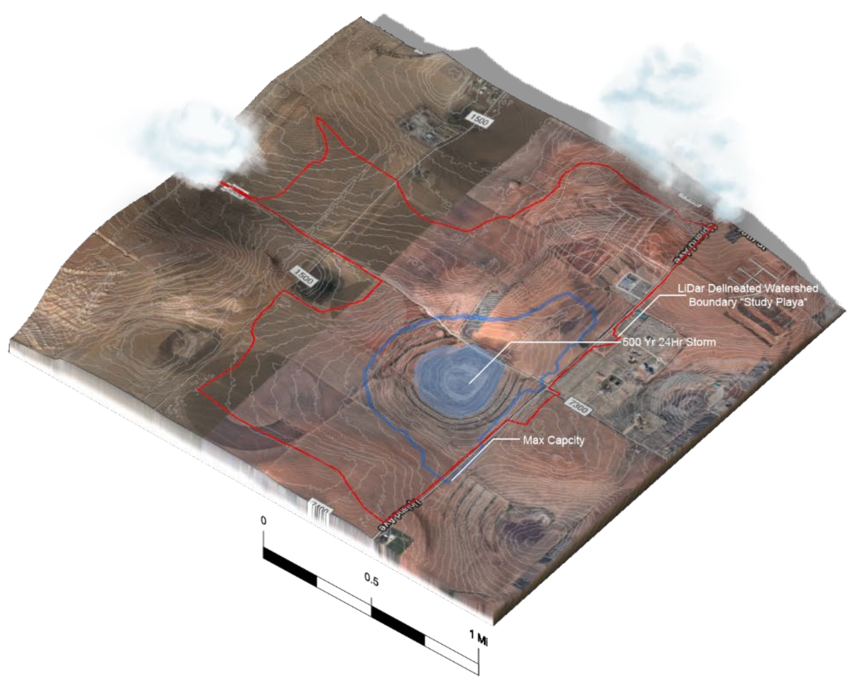


Figure 4.15 Current Condition Runoff Elevation Extents for 500-Year Design Storm. Source: Tyson Watson

Agriculture Tillage Practices

There are different techniques when it comes to tillage practices for agriculture such as Strait row (SR) (C=0.72), Contoured (C) (C=0.7), Contoured & Terraced (C&T) (C=0.61), and No-till (C=0.30). These coefficients for tillage are used in the TR-55 watershed calculator for stormwater runoff (United States Department of Agriculture 1986, 2.5-2.8). The TR-55 coefficients for each of these are dramatically higher than the cultivated no plant cover (C=0.30) from Site engineering for Landscape Architects (Nathan and Woland 2013). Each of these tillage techniques offer different design or implementation opportunities and challenges. Strait row tillage runs in one direction and does not take into consideration the terrain of the land. This can cause an increase in stormwater runoff and erosion while also creating pooling in low areas that then can cause erosion problems (Figure 4.16). This method of tillage is a direct path for runoff from agriculture fields into playa basins compared to contoured tillage.

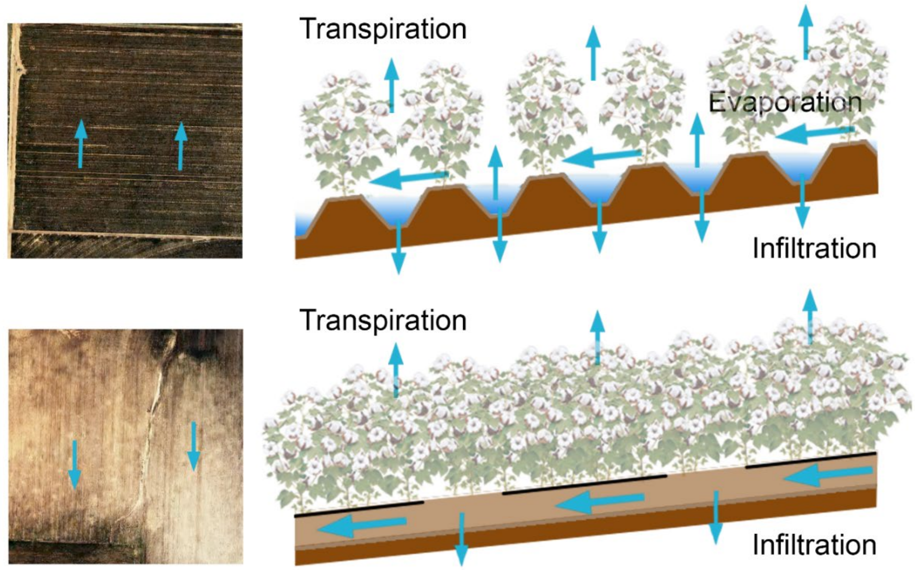


Figure 4.16 Strait Row Tillage. Source: Tyson Watson

Contoured tillage is created when crop rows follow the existing contours of the landform or terrain (Figure 4.17). This design and implementation approach to tillage decreases the amount of runoff depending of the percent of slope it is associated with.

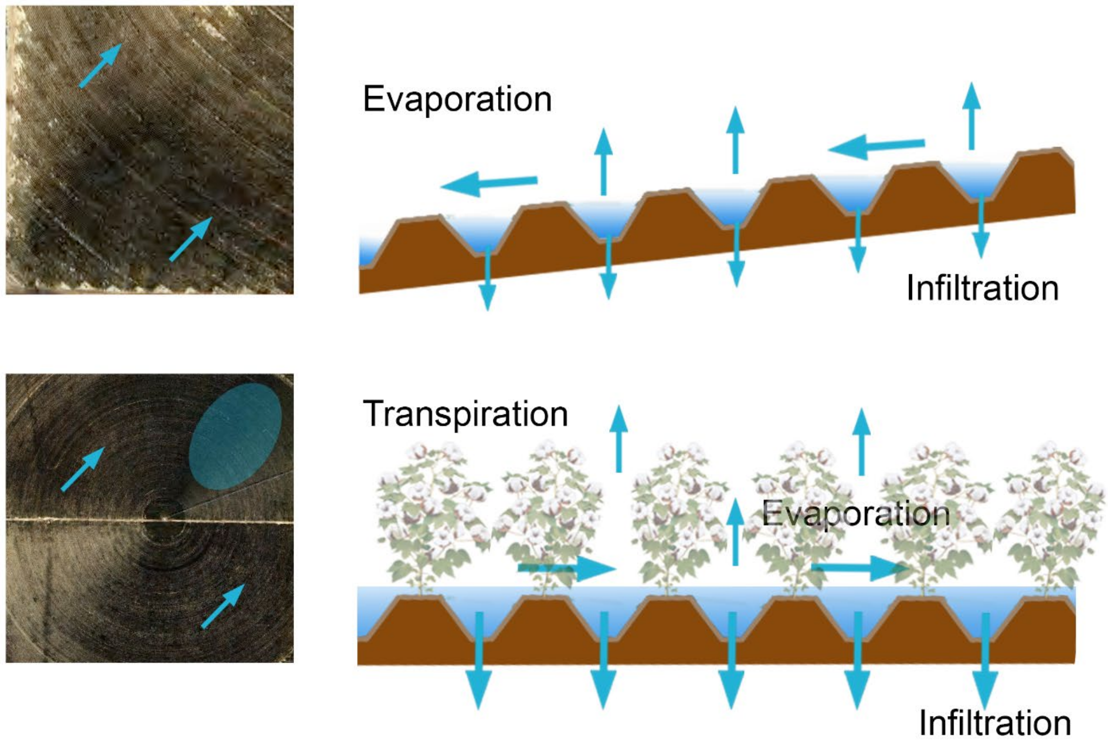
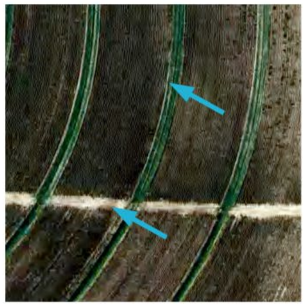


Figure 4.17 Contour Tillage. Source: Tyson Watson

The combination of contoured rows with terraces following contours is the best alternative to control the amount of stormwater runoff from agricultural crop production land uses. Terraces are used to control erosion in steeper terrain areas. The combination of contoured rows and terraces are the best method for controlling runoff and increasing soil moisture (Figure 4.18).



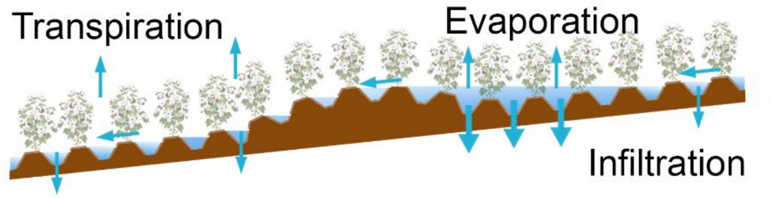


Figure 4.18 Contour and Terraced. Source: Tyson Watson

No-till farming is an up and coming practice in this region that does not involve high disturbance of the soil like traditional tillage practices (Figure 4.19). This practice tends to have a cover crop of some type that helps hold down the soil and helps control stormwater runoff. Appendix-A shows the increase in stormwater runoff based on the five tillage practices if each method of tillage was replicated over the entire watershed.

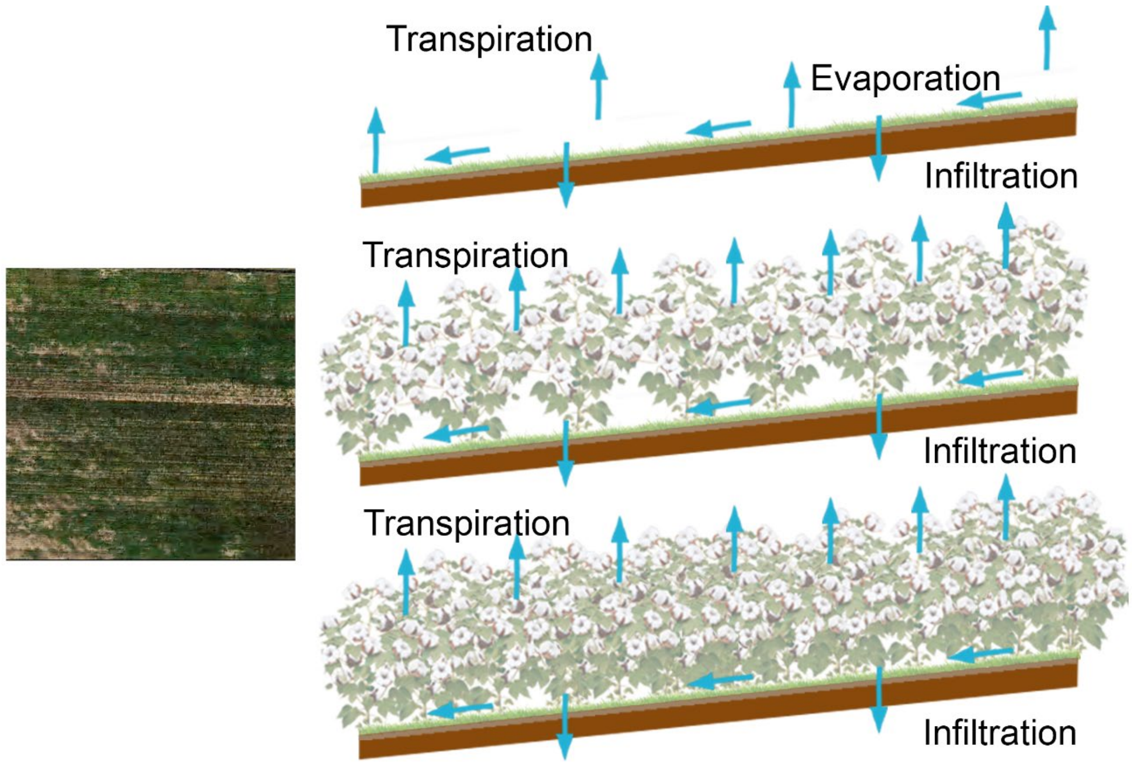


Figure 4.19 No-till Farming. Source: Tyson Watson

Typical Single Family Lot Types and Runoff Calculations

Transitioning from agriculture to urban development has effects on stormwater runoff. Five Lubbock subdivisions were selected for project precedents throughout the City of Lubbock. The five subdivisions are Melonie Park 179.04 acres (ac), Monterey150.78 ac, Rushland Park 155.99 ac, Vintage Township 54.97 ac, and Orchard Park 94.23 ac (Figure 4.20). These five subdivisions demonstrate different lot sizes from 0.10 acre to 0.50-acre lots. The Parcels that were selected within the five subdivisions for study prototypes were digitized by pervious and impervious surfaces. Once digitized each polygon was assigned a land use (LU)/land cover (LC) which has a different runoff coefficient (Nathan and Woland 2013, 206).

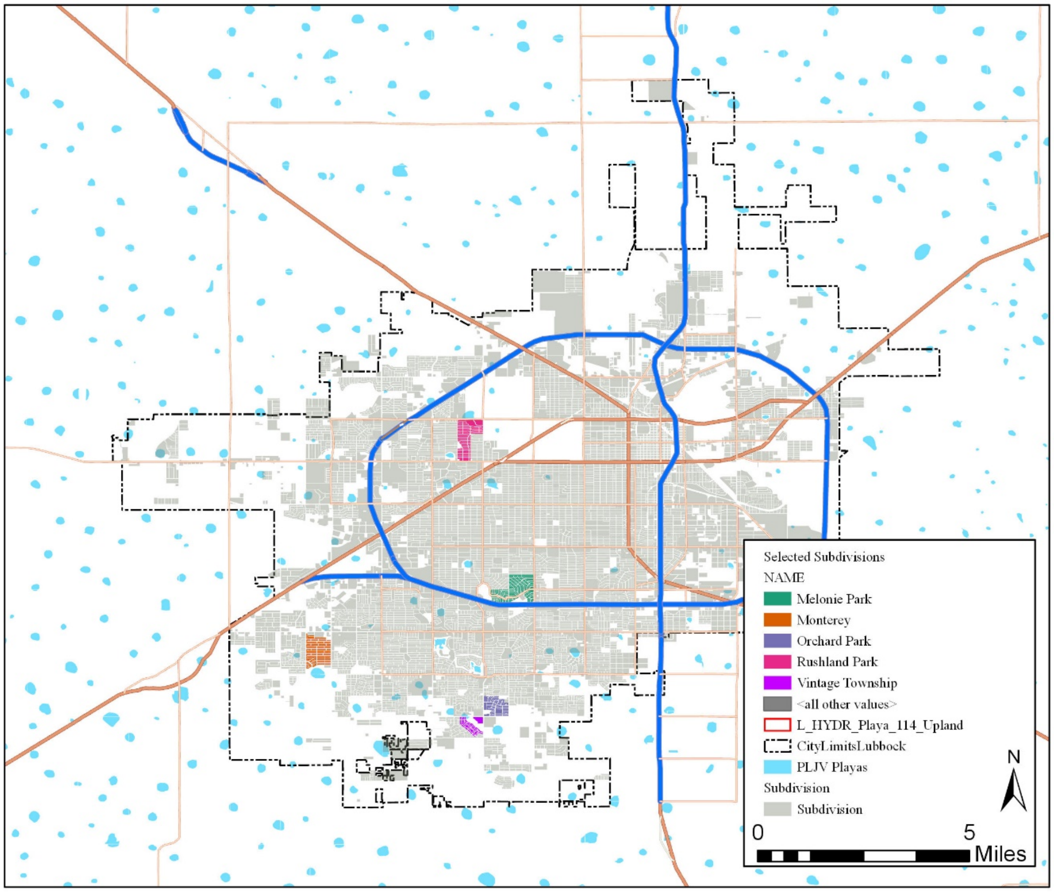


Figure 4.20 Study Subdivision Locations. Source: Tyson Watson, City of Lubbock

In each of the five subdivisions, a parcel was randomly selected using ArcGIS Pro to generate a random point distribution and a random number generator used to determine the point to select the lot. Each selected lot was then exported from ArcGIS Pro and digitized in AutoCAD C3D. Starting with Melonie Park, the lot digitized is a 0.18 acres (ac) lot considering the area inside of the parcel boundary, and does not include the Right-of-Way (ROW) space. When the ROW is included the total amount of land accounted for is 0.24 ac. In the subdivision of Monterey, the parcel digitized is a 0.18 ac. When the ROW is included the total amount of land accounted for is 0.24 ac. In Rushland Park, the parcel that digitized is a 0.38 ac lot, with a ROW included total of 0.48 ac. The Vintage Township parcel is a 0.12 ac lot, and 0.15 ac when including ROW. In the subdivision of Orchard Park, the parcel digitized is 0.24 ac and with ROW included 0.31 acres.

These five parcels were used as prototypes representing typical Lubbock developments with varying density, land use, land cover, materials, and street widths. With the prototypes digitized, land use (LU), land cover (LC) and material (M) was determined and attributed for each digitized polygon so a runoff coefficients from (Nathan and Woland 2013, 206) be applied to calculate the current runoff amounts for each parcel. The prototypical parcels for each subdivision are replicated over the entire watershed by the dwelling units per acre (Du/Ac) to determine playa water level changes under design storm events. Melonie Parks Du/Ac is 3.25, Monterey 5.0, Rushland Park 1.3, Vintage Township 5.0, and Orchard Park 2.65.

Typical Development Implications on Playa

To understand the increase in stormwater runoff from each type of development a scenario will be run for each type of subdivision and corresponding Du/Ac. This is taking the amount of stormwater runoff from each prototype and replicating it over the entire watershed including the playa basin area. By doing this, it will replicate a worst-case scenario for the development of the playa and demonstrate the increase in stormwater runoff compared to native shortgrass prairie conditions for each of the designed storms.

The scenarios for each development type based on the following du/ac for each lot type resulted the following potential number of parcels within the playa basin watershed boundary. (Table 4.4). This calculation assumes that every parcel is the same size as the prototype with the same LU/LC for each type of subdivision. The amount of stormwater runoff generated for each type of development is based on the number of potential parcels that will fit inside the watershed boundary on Du/Ac basis. The following (Table 4.4) illustrate the development as typical scenario for the playa basin.

Table 4.4 Typical Development Amount of Parcels within the Watershed Boundary Based on Du/Ac

Development Precedents	Potential Lots in Playa Basin Watershed
Melonie Park	3,552
Monterey	5,074
Rushland Park	1,319
Vintage Township	5,074
Orchard Park	2,689
Average	3,542

The following (Figures 4.21- 4.27) illustrate the changes in flood boundary elevations for 1-year, 10-year, 100-year, 500-year, and 1000-year storm events in green, yellow, orange and red lines beyond the predevelopment levels shown in blue and blue outlines.

Melonie Park prototype for a 1-year storm generates 126,593.94 yd^3 increase of 96,956.86 yd^3 from a native condition (Figure 4.21). The 10-year runoff increase to 243,939.01 yd^3 increase of 186,830.12 yd^3 from the native condition (Figure 4.21). The 100-year runoff increase to 395,967.36 yd^3 increase of 303,266.91 yd^3 from the native condition (Figure 4.21). The 500-year runoff increase to 527,185.74 yd^3 increase of 403,765.85 yd^3 from the native condition (Figure 4.21). See appendix for key calculations (Appendix B).

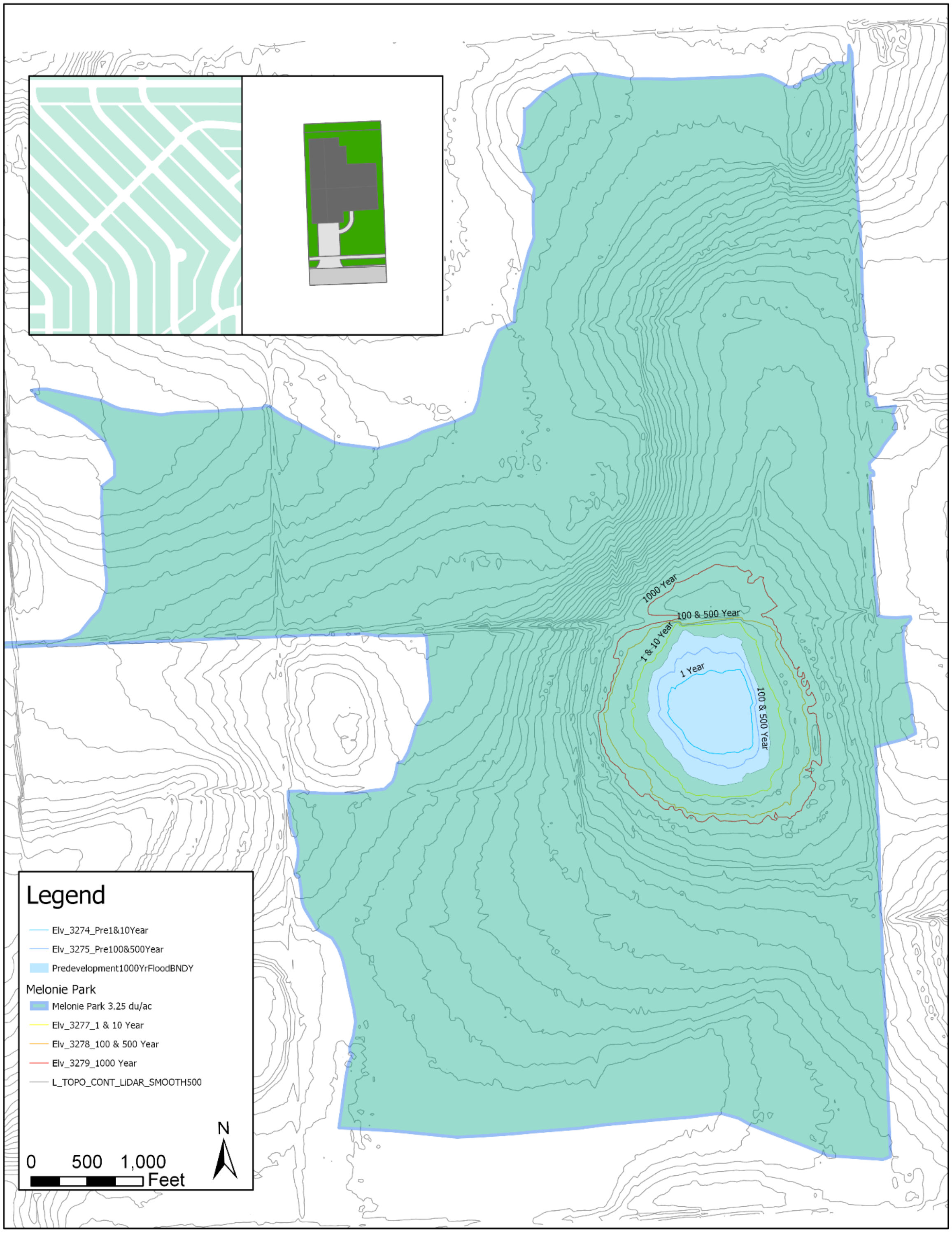


Figure 4.21 Typical Development Scenario: Melonie Park. Source: Tyson Watson

The amount of stormwater runoff generated from Monterey prototype for a 1-year storm is 147,926.88 yd^3 and increase of 118,289.80 yd^3 from a native condition (Figure 4.22). The 10-year runoff increases to 285,045.93 yd^3 and increase of 227,937.04 yd^3 from the native condition (Figure 4.22). The 100-year runoff increases to 462,693.05 yd^3 and increase 369,992.60 yd^3 from the native condition (Figure 4.22). The 500-year runoff increase to 616,023.44 yd^3 and increase of 492,603.28 yd^3 from the native condition (Figure 4.22). See appendix for key calculations (Appendix C).

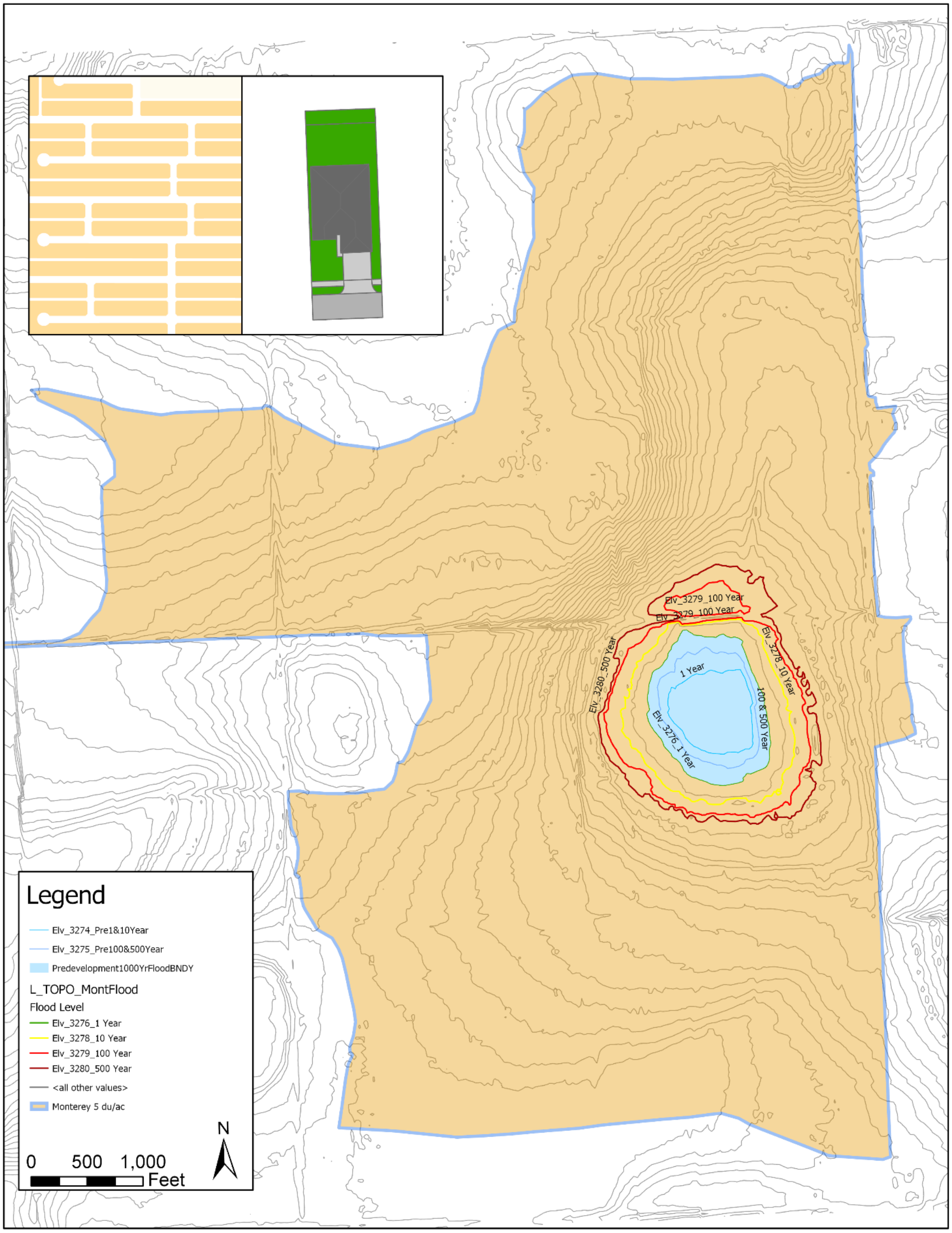


Figure 4.22 Typical Development Scenario: Monterey. Source: Tyson Watson

The amount of stormwater runoff generated from Rushland Park prototype for a 1-year storm is 103,780.51 yd^3 and increase of 74,143.43 yd^3 from a native condition (Figure 4.23). The 10-year runoff increase to 199,978.88 yd^3 and increase of 142,869.99 yd^3 from the native condition (Figure 4.23). The 100-year runoff increase to 324,610.26 yd^3 and increase of 2319,909.81 yd^3 from the native condition (Figure 4.23). The 500-year runoff increase to 432,181.84 yd^3 and increase of 308,761.68 yd^3 from the native condition. (Figure 4.23). See appendix for key calculations (Appendix D).

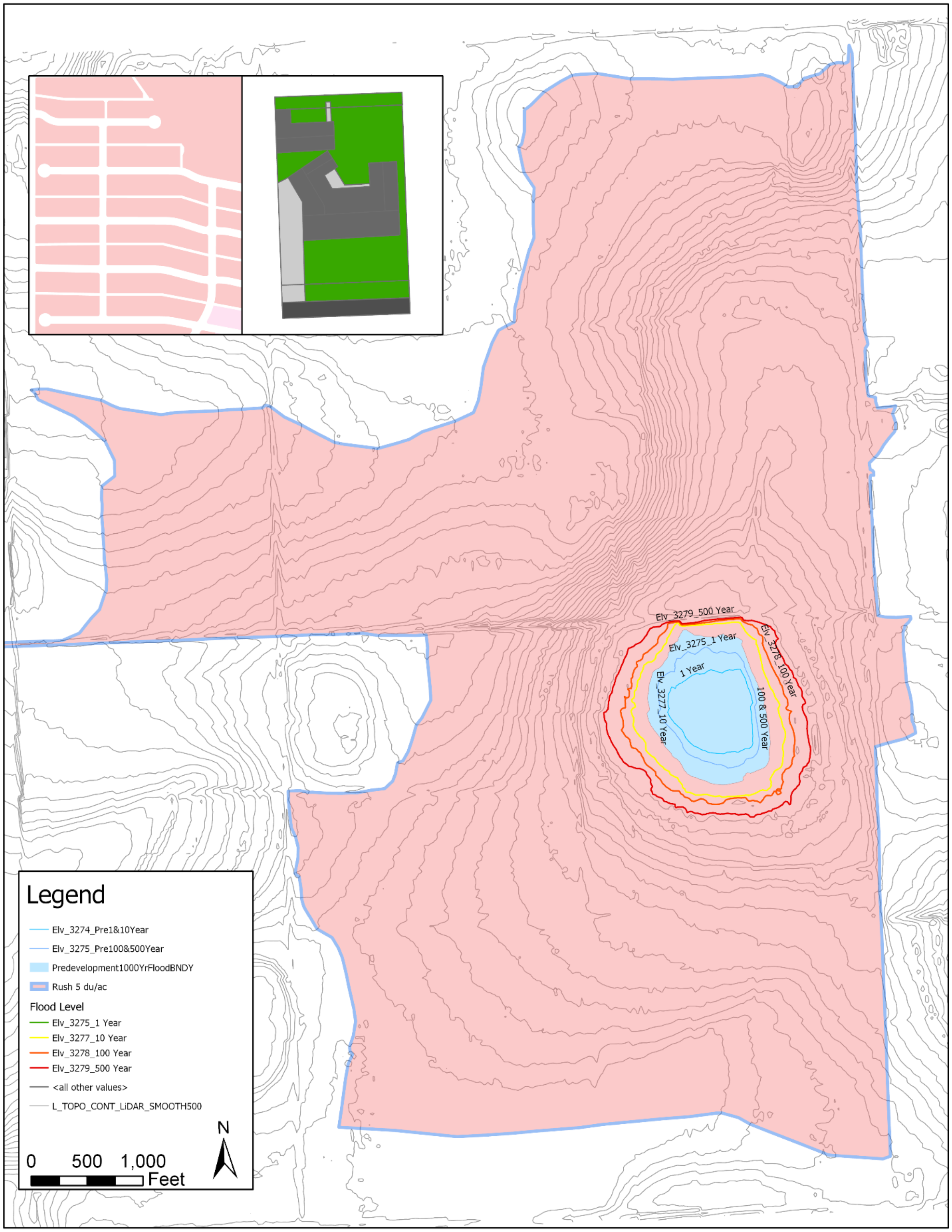


Figure 4.23 Typical Development Scenario: Rushland Park. Source: Tyson Watson

The amount of stormwater runoff generated from Vintage Township prototype for a 1-year storm is 141,788.39 yd^3 and increase of 112,151.31 yd^3 from a native condition (Figure 4.24). The 10-year runoff increase to 273,217.82 yd^3 and increase of 216,108.93 yd^3 from the native condition (Figure 4.24). The 100-year runoff increase to 443,493.38 yd^3 and increase of 350,792.93 yd^3 from the native condition (Figure 4.24). The 500-year runoff increase to 590,461.26 yd^3 and increase of 467,041.1 yd^3 from the native condition (Figure 4.24). See appendix for key calculations (Appendix E).

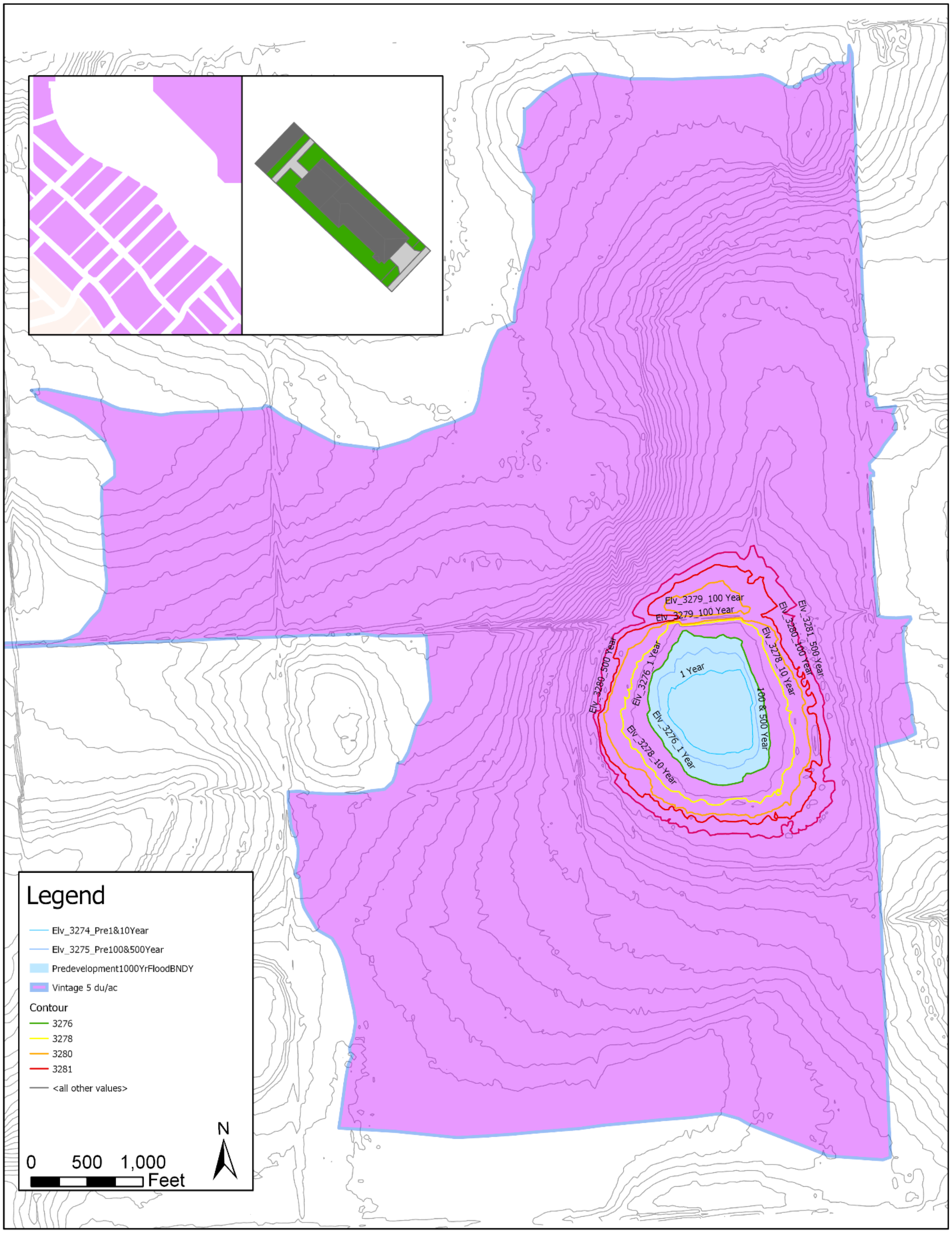


Figure 4.24 Typical Development Scenario: Vintage Township. Source: Tyson Watson

The amount of stormwater runoff generated from Orchard Park prototype for a 1-year storm is 160,714.25 yd^3 and increase of 131,077.17 yd^3 from a native condition (Figure 4.25). The 10-year runoff increase to 309,686.82 yd^3 and increase of 252,577.93 yd^3 from the native condition (Figure 4.25). The 100-year runoff increase to 502,690.96 yd^3 and increase of 409,690.69 yd^3 from the native condition (Figure 4.25). The 500-year runoff increase to 669,275.78 yd^3 and increase of 545,855.62 yd^3 from the native condition (Figure 4.25). See appendix for key calculations (Appendix F).

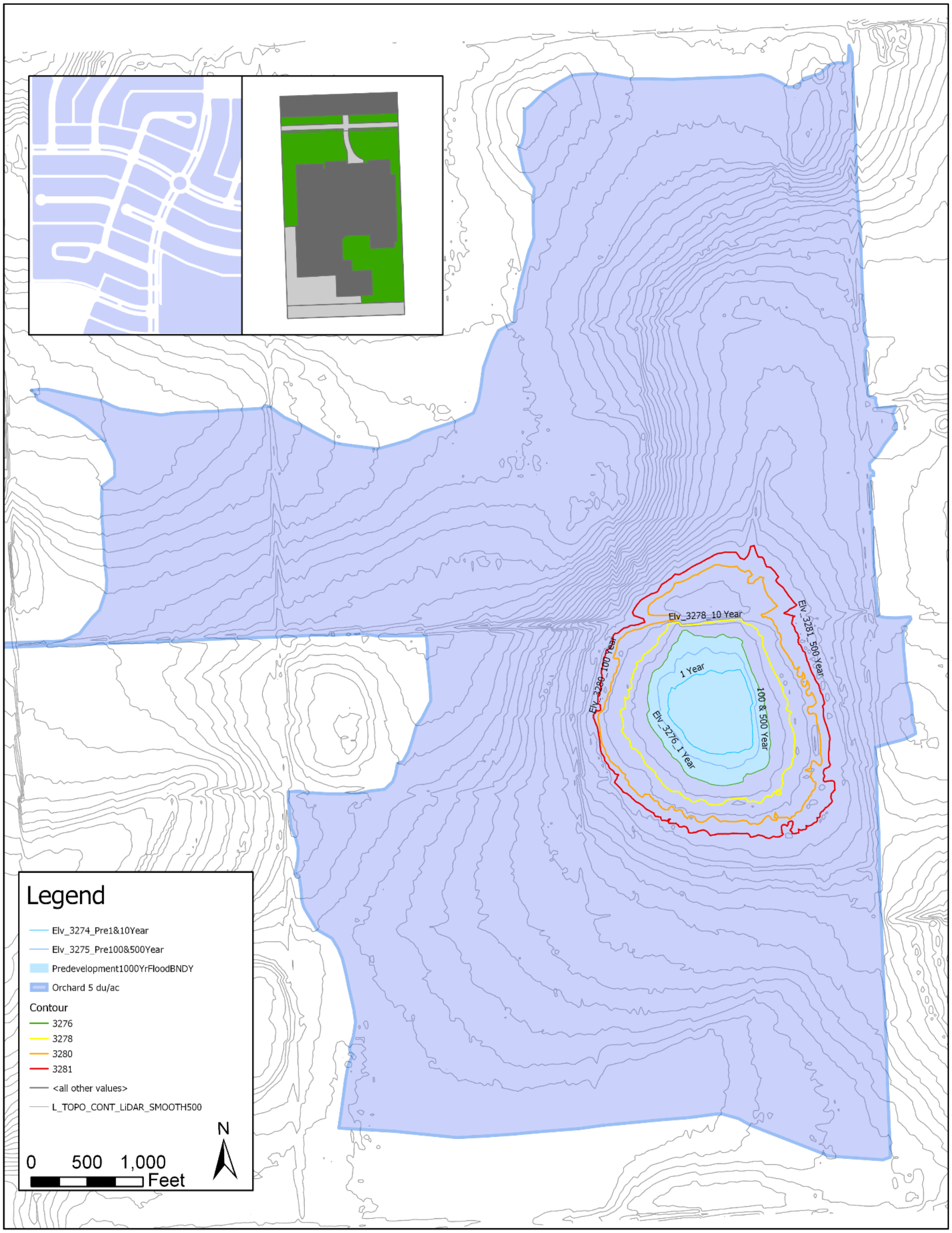


Figure 4.25 Typical Development Scenario: Orchard Park. Source: Tyson Watson

The different scenarios represent the worst possible outcome from typical development. These scenarios help justify the need for changing the way stormwater runoff is handled. Native playa conditions are not prepared to be inundated with this amount of increase in stormwater runoff and could dramatically affect the functioning ecosystem.

Alternative Designs to Increase Storage Capacity

Looking at alternative ways to handle excess amounts of storm water on each subdivision prototype proved to be challenging. What is the least demanding and most cost-effective way to retain water onsite while not exceeding the native runoff amount based on parcel size? The first alternative to collecting stormwater onsite is to create depressions in impervious areas on lots while maintaining the correct slope to drain water away from the structure for at least five feet. When creating landscape area depressions, (rain gardens, infiltration trenches, bioswales) how much is too much became an important aesthetic and use question. Most of the lot landscape areas used a six-inch depression to hold water to infiltrate, with larger lots affording up to a one-foot depressions to store water. Creating depressions throughout each parcel will help increase soil moisture and potentially decreases water usage for irrigation. These depths for depressed areas would be noticeable, however not so extreme as to change the existing aesthetic of most lawn areas.

Each of the prototypes was first calculated to determine its historic native shortgrass prairie, or predevelopment runoff amount. Next each prototype was calculated as typically developed. Once the amounts of runoff were determined for each prototype, predevelopment and typical development a realistic amount of storage capacity was evaluated. Each prototype differed on the amount of storage capacity due to the size of the lot and building and circulation coverage on the lot.

As illustrated in (Figure 4.26) for a 1-year storm on the Melonie Park prototype the native shortgrass prairie runoff volume is 15.91 yd^3 increasing to 29.00 yd^3 under typical development. The 10-year runoff volume predevelopment is 30.67 yd^3 increasing to 55.89 yd^3 under typical development. The100-year runoff volume predevelopment is 49.78 yd^3 increasing to 90.72 yd^3 under typical development. The 500-year runoff volume predevelopment is 66.28 yd^3 increasing to 120.78 yd^3 under typical development. The first goal was to determine how much runoff was being generated. However, once that was determined than evaluating max storage capacity by using grading techniques only, which resulted in 13.09 yd^3 of storage capacity.

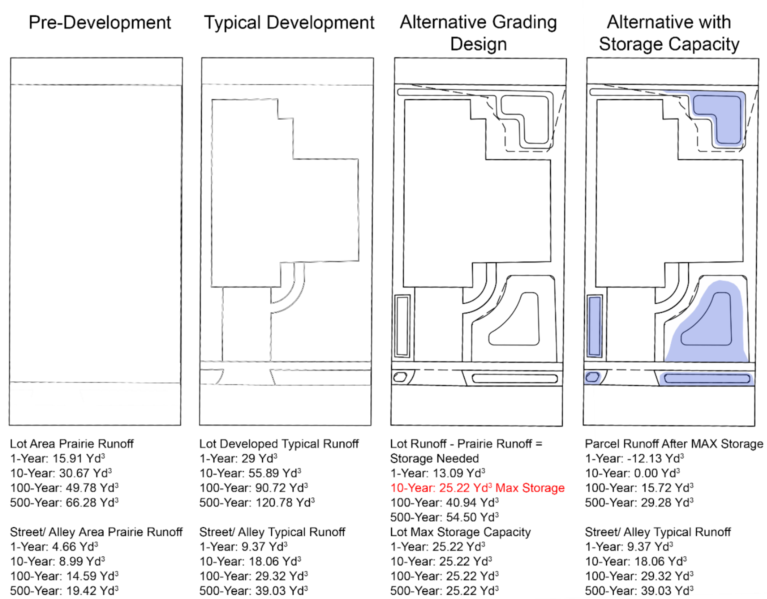


Figure 4.26 Pre-development/ Developed Runoff Amounts with Max Storage Capacity Melonie Park Type. Source: Tyson Watson

Figure 4.27 illustrates the Monterey prototype where the native shortgrass prairie runoff from a 1-year storm volume is 11.26 yd^3 increasing to 21.48 yd^3 under typical development. The 10-year runoff volume predevelopment is 21.70 yd^3 increasing to 41.38 yd^3 under typical development. The100-year runoff volume predevelopment is 35.22 yd^3 increasing to 67.18 yd^3 under typical development. The 500-year runoff volume predevelopment is 46.90 yd^3 increasing to 89.44 yd^3 under typical development. The first goal was to determine how much runoff was being generated. However, once that was determined than evaluating max storage capacity by using grading techniques only, which resulted in 12.60 yd^3 of storage capacity.

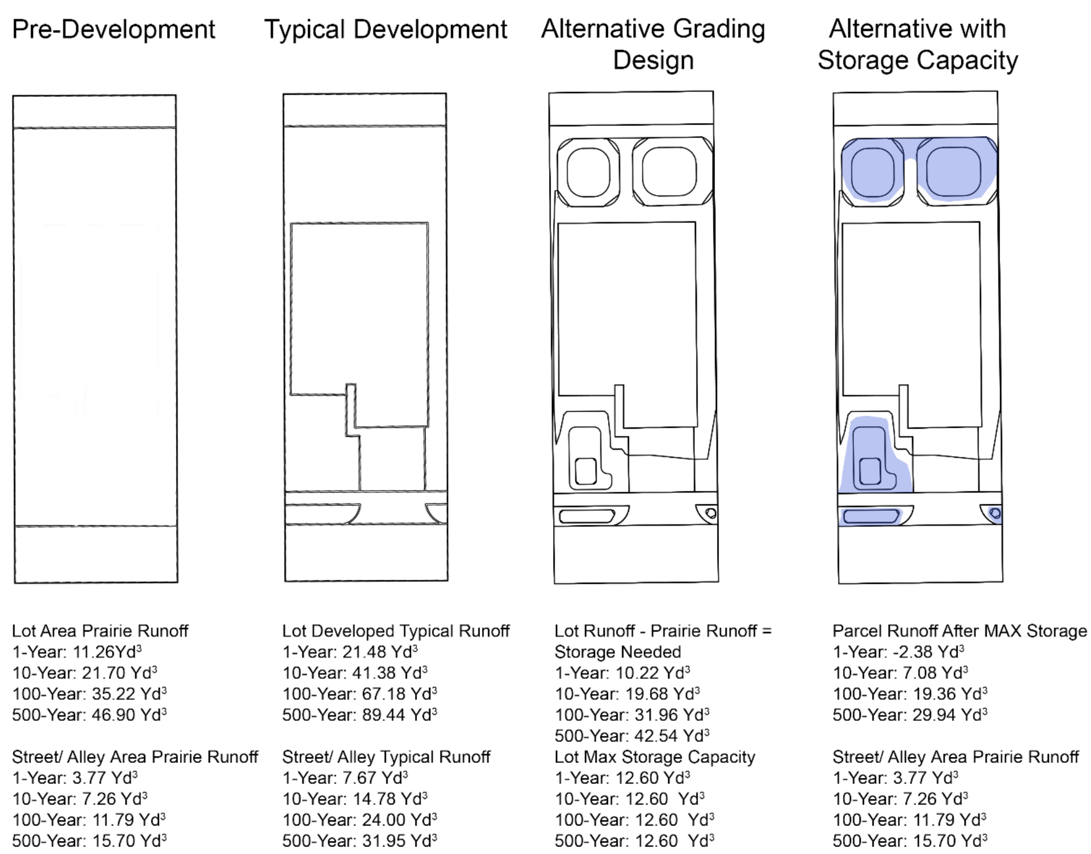


Figure 4.27 Pre-development/ Developed Runoff Amounts with Max Storage Capacity Monterey Type. Source: Tyson Watson

For a 1-year storm on the Rushland Park prototype (Figure 4.28) where the native shortgrass prairie runoff volume is 33.52 yd^3 increasing to 63.53 yd^3 under typical development. The 10-year runoff volume predevelopment is 64.60 yd^3 increasing to 122.42 yd^3 under typical development. The100-year runoff volume predevelopment is 104.85 yd^3 increasing to 198.71 yd^3 under typical development. The 500-year runoff volume predevelopment is 139.60 yd^3 increasing to 264.56 yd^3 under typical development. The first goal was to determine how much runoff was being generated. However, once that was determined than evaluating max storage capacity by using grading techniques only, which resulted in 57.82 yd^3 of storage capacity.

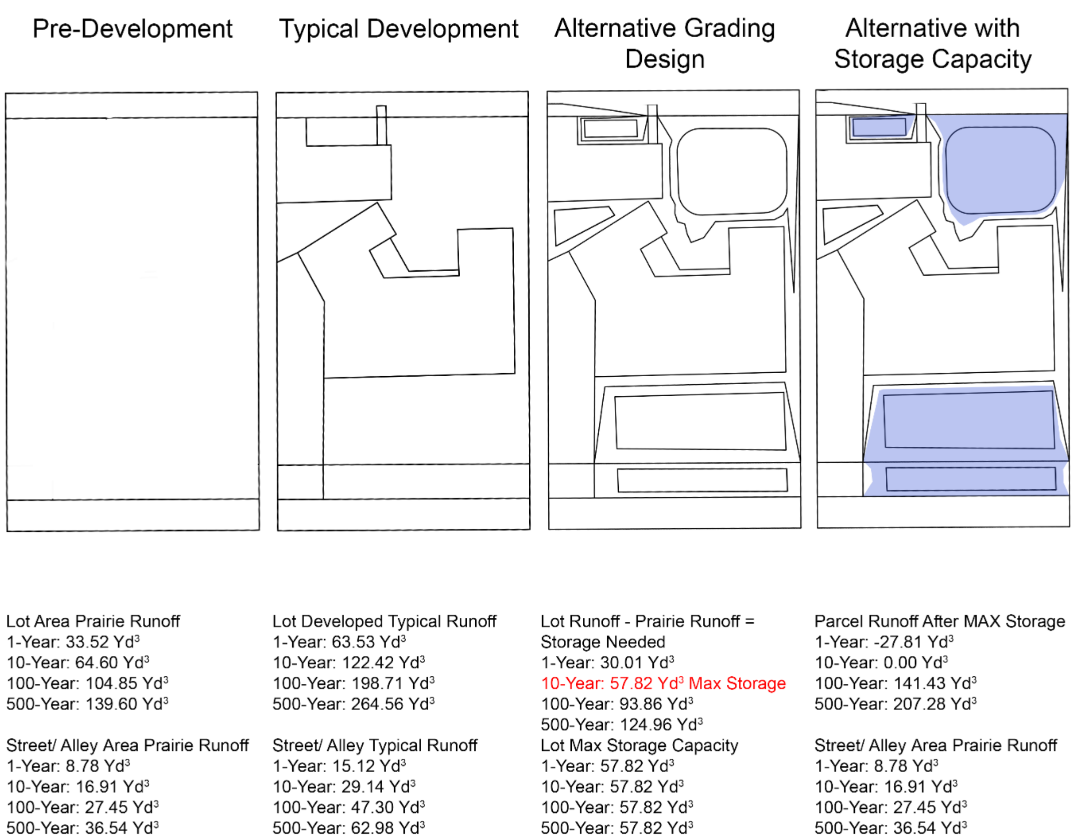


Figure 4.28 Pre-development/ Developed Runoff Amounts with Max Storage Capacity Rushland Park Type. Source: Tyson Watson

The Vintage Township prototype (Figure 4.29) 1-year storm on native shortgrass prairie runoff volume is 11.16 yd^3 increasing to 23.05 yd^3 under typical development. The 10-year runoff volume predevelopment is 21.50 yd^3 increasing to 44.42 yd^3 under typical development. The100-year runoff volume predevelopment is 34.89 yd^3 increasing to 72.10 yd^3 under typical development. The 500-year runoff volume predevelopment is 46.46 yd^3 increasing to 95.99 yd^3 under typical development. The first goal was to determine how much runoff was being generated. However, once that was determined than evaluating max storage capacity by using grading techniques only, which resulted in 11.89 yd^3 of storage capacity.

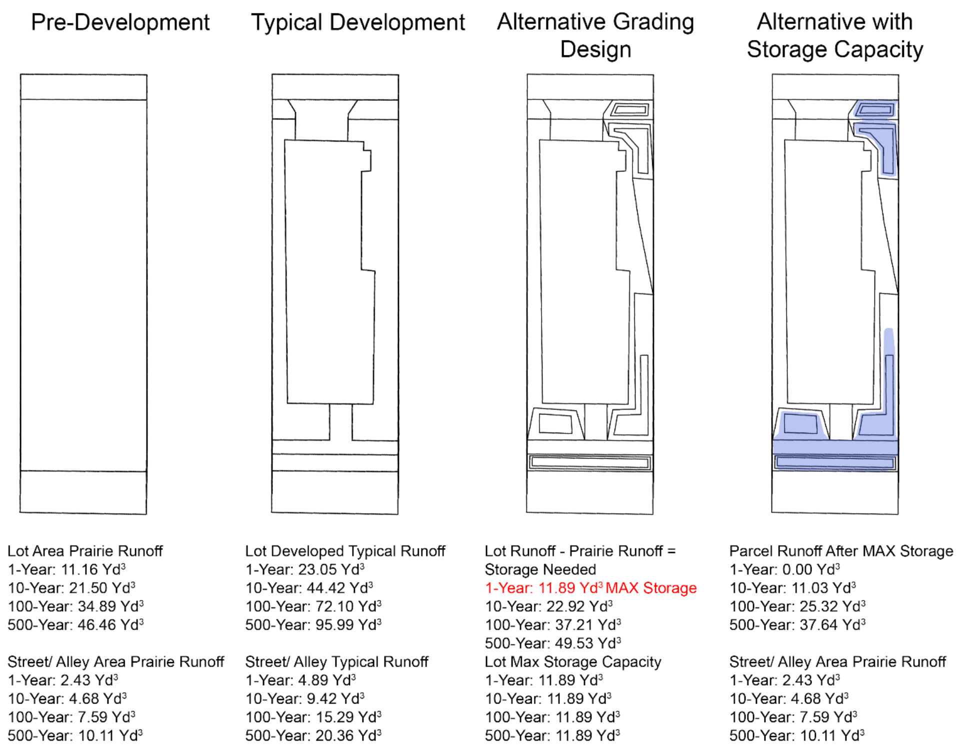


Figure 4.29 Pre-development/ Developed Runoff Amounts with Max Storage Capacity Vintage Township Type. Source: Tyson Watson

Finally, for a for a 1-year storm on the Orchard Park prototype (Figure 4.30) where the native shortgrass prairie runoff volume is 21.42 yd^3 increasing to 44.73 yd^3 under typical development. The 10-year runoff volume predevelopment is 41.28 yd^3 increasing to 86.19 yd^3 under typical development. The100-year runoff volume predevelopment is 67.01 yd^3 increasing to 139.91 yd^3 under typical development. The 500-year runoff volume predevelopment is 89.21 yd^3 increasing to 186.27 yd^3 under typical development. The first goal was to determine how much runoff was being generated. However, once that was determined than evaluating max storage capacity by using grading techniques only, which resulted in 28.74 yd^3 of storage capacity.

Figure 4.30 Pre-development/ Developed Runoff Amounts with Max Storage Capacity Orchard Park Type. Source: Tyson Watson

As presented above, alternative lot grading designs can reduce new runoff amounts caused by development and can hold up to a 10 year storm on the lot. The Rushland Park lot type was the most capable of reducing lot runoff while the Vintage Township and Monterey developments were the least due to lot size and structure coverage. The following sections illustrate how the alternative designs for lot types can be used to design the entire development in the playa basin. While respecting the predevelopment playa flood plain and reducing impacts on playa levels post development.

Alternative Subdivision Design and Likely Developed Watershed Boundary

Development is already occurring in the case study watershed. Presently a new outer loop highway system is being designed and property purchased for ROW along the southern edge of the case study site. Given existing suburban encroachment to the north, and the catalyst of a new highway corridor to the south, the pressure for development of this playa basin is intensifying. Recent developments just north of this site use straight streets and placing as many parcels as possible with small lots with high impervious cover percentage per lot and including no public green space or parks. Green space can be used to help control stormwater runoff increases from development decisions and limits impact on native functions of the playa. The goal is to maintain the playa system at its pre-development native prairie state and to not fill up past the predevelopment 500–year flood boundary while using the 1000-year flood boundary as a max amount of water allowed to the playa.

The development of the proposed subdivision increased the acreage of the watershed from the predevelopment size of 1014.97 acres to 1088.49 acres. This increase is due to the development of new roads that alter the original watershed boundary and the newly completed subdivision to the north. The modified playa basin boundary includes: 892.63 acres for development, the 125.28 acres in the fully developed subdivision to the north, and future development at 70.58 acres to the west, totaling 1088.49 acres (Figure 4.31).

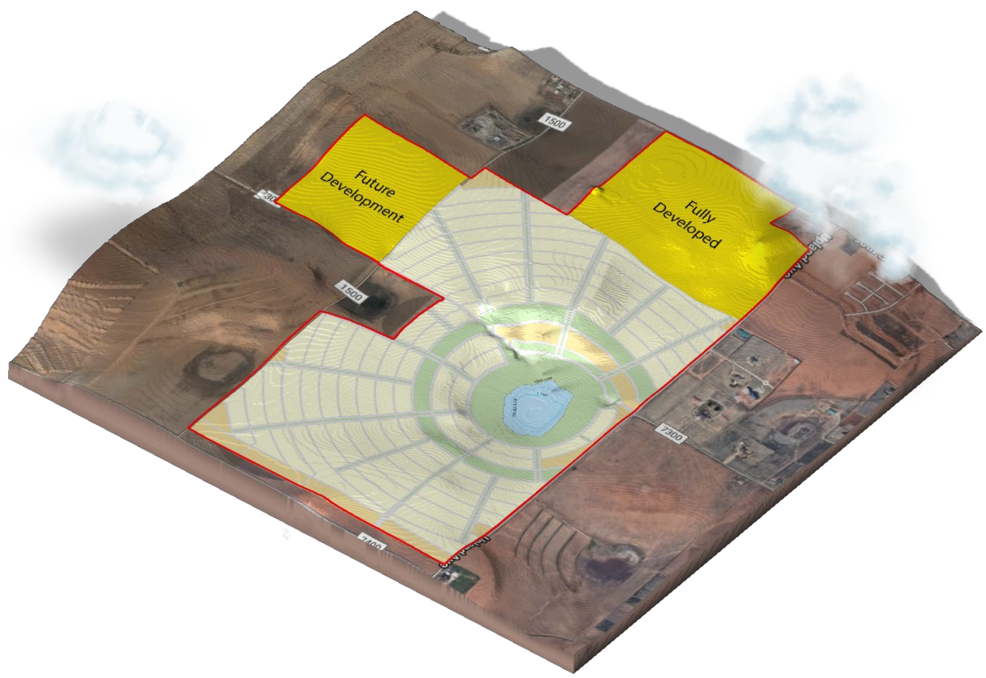


Figure 4.31 Proposed Subdivision Design. Source: Tyson Watson

The layout of the proposed development is designed to promote green space and use the green space to control the increase from runoff in a more natural approach. This subdivision design respects the playa basin bowl-like terrain by creating 300-foot road center line to road center line on contours which follows best practices identified previously (Figure 4.31). The proposed subdivision's radial design respects the lay of the land, and the playa's most important Randall clay pan and annulus, 500 and 1000-year pre-development flood plains. Green space connections are designed on rays to orient people to the playa, to create space for stormwater runoff filtration and storage to keep new development runoff from exceeding the 500-year flood plain (Figure 4.32). Green spaces provide access and connections to both the commercial-retail areas, and the larger park where the playa lake is located and radial park area designed to retain and filter stormwater that exceeds 500-year predevelopment flood plain capacity of the playa.

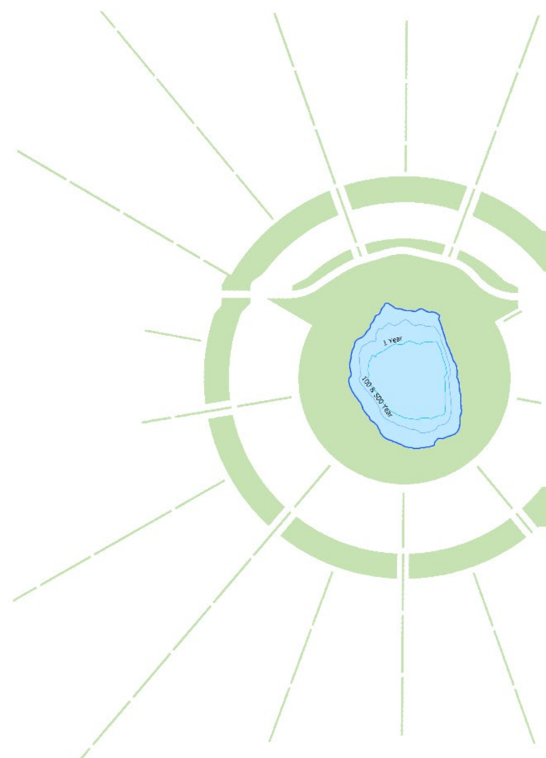
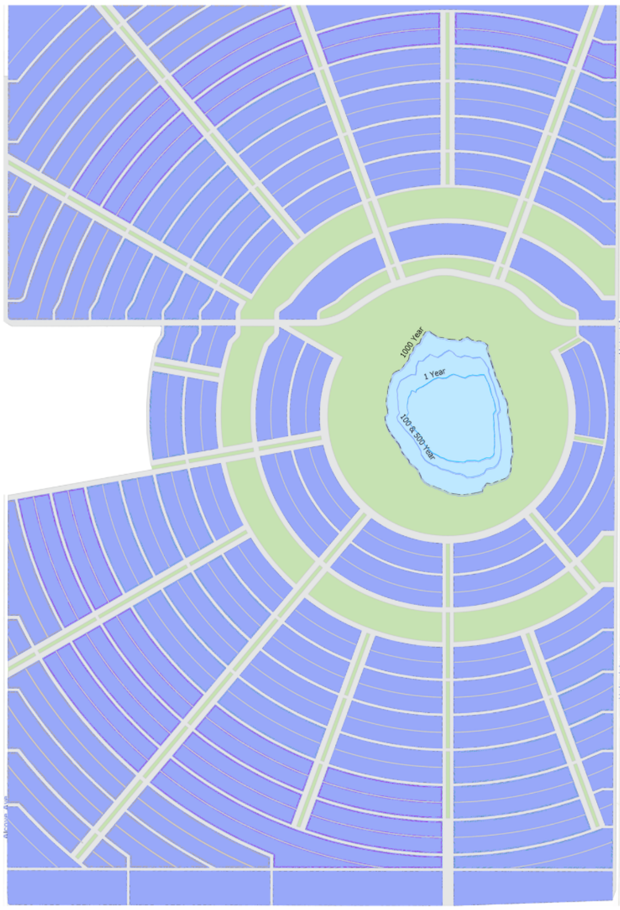


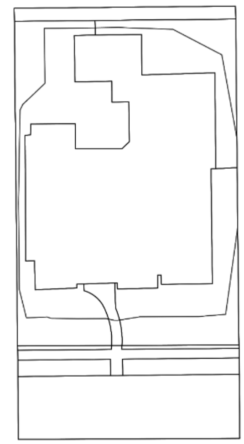
Figure 4.32 Proposed 81 Acres of Green Space to Manage and Control Stormwater Runoff. Source: Tyson Watson

The proposed subdivision includes 577 acres for residential and commercial development, while adding an additional 81 acers of green space, and preserving the space with-in the 1000-year predevelopment playa flood boundary. The 81 acres provide ample space to store increased amounts of stormwater runoff beyond the 500-year flood plain boundary to maintain the native playa functions. Looking first at the different scenarios as if each subdivision, Orchard Park Melonie Park ,Rushland Park, Monterey and Vintage Township were design as the single prototype for the proposed development. There are 577 acres which, if developed fully in each type of development would create the following lot counts by type within the developable area as shown in light yellow in Figure 4.31. Potential lots within the radial designed spaces by type are: 1,529 for Orchard Park, 1,875 for Melonie Park, 750 for Rushland Park, and 2885 for Monterey and Vintage Township each. The average lot count across all types in the radial design is 1985 lots. Figures 4.33-4.37 illustrate how much stormwater runoff is generated by typical and alternative lot designs within the proposed radial design subdivision by based on 1, 10, 100, and 500-year storm events for each development type.

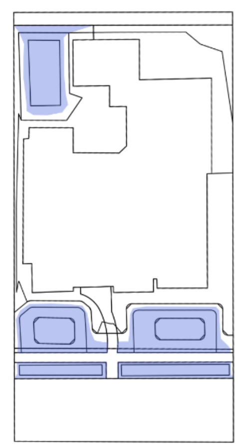
Orchard Park



Typical Development



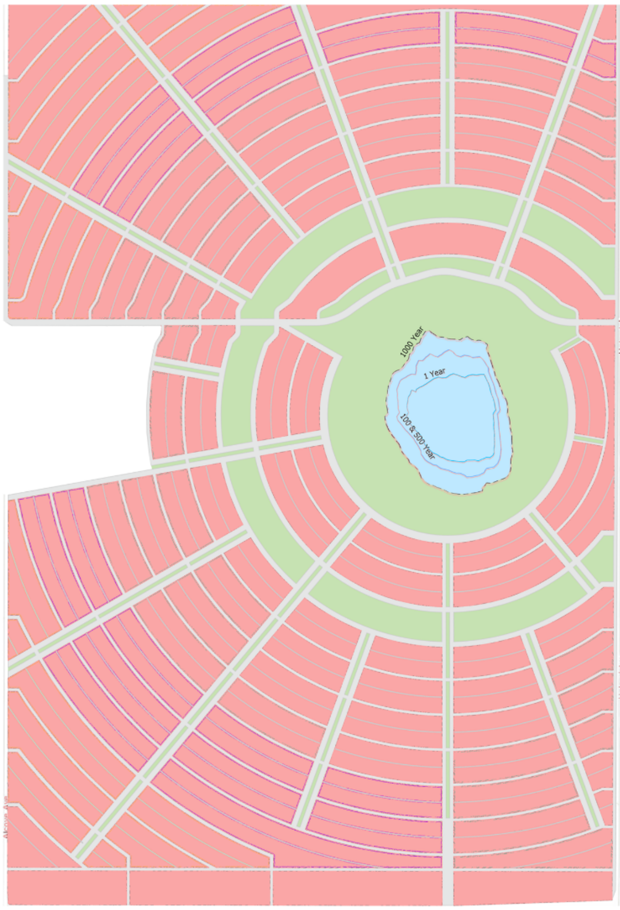
Alternative with Storage Capacity

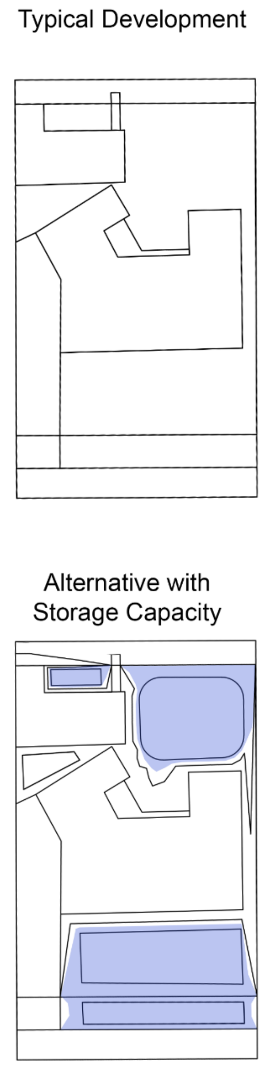


Typical Development 24hr Storm Event	(q = peak runoff rate, cubic feet per second)(CFS)	Peak runoff rate, cubic yards (yd3)
1-year storm	1,846,588.59 CFS	68,392.17 yd3
10-year storm	3,558,181.77 CFS	131,784.51 yd3
100-year storm	5,775,904.53 CFS	213,922.39 yd3
500-year storm	7,689,784.41 CFS	284,806.83 yd3
Storage Alternative Development		
1-year storm	-224,166.69 CFS	-8,302.47 yd3
10-year storm	667,546.10 CFS	24,723.93 yd3
100-year storm	1,823,057.28 CFS	67,520.64 yd3
500-year storm	2,820,454.56 CFS	104,461.28 yd3

Figure 4.33 Playa Basin Development and Calculations with Only One Type Orchard Park. Source: Tyson Watson

Rushland Park

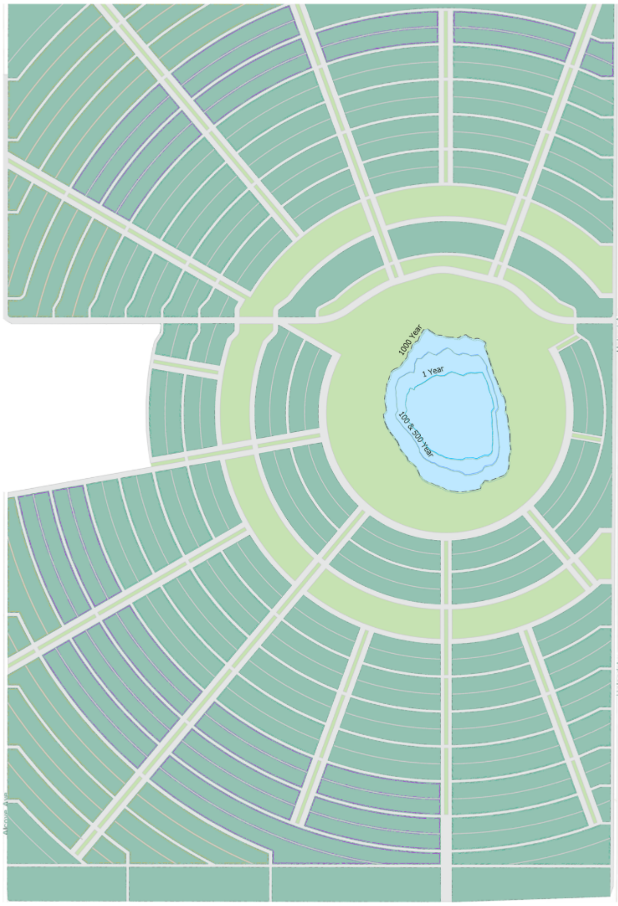




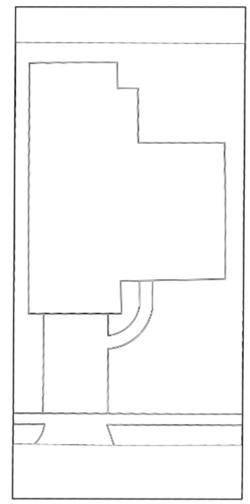
Typical Development 24hr Storm Event	(q = peak runoff rate, cubic feet per second)(CFS)	Peak runoff rate, cubic yards (yd3)
1-year storm	1,286,482.50 CFS	47,647.50 yd3
10-year storm	2,479,005.00 CFS	91,815.00 yd3
100-year storm	4,023,877.50 CFS	149,032.50 yd3
500-year storm	5,357,340.00 CFS	198,420.00 yd3
Storage Alternative Development		
1-year storm	-563,638.50 CFS	-20,857.50 yd3
10-year storm	0.00 CFS	0.00 yd3
100-year storm	2,863,957.50 CFS	106,072.50 yd3
500-year storm	4,197,420.00 CFS	155,460.00 yd3

Figure 4.34 Playa Basin Development and Calculations with Only One Type Rushland Park. Source: Tyson Watson

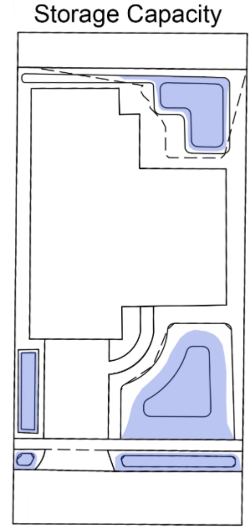
Melonie Park



Typical Development



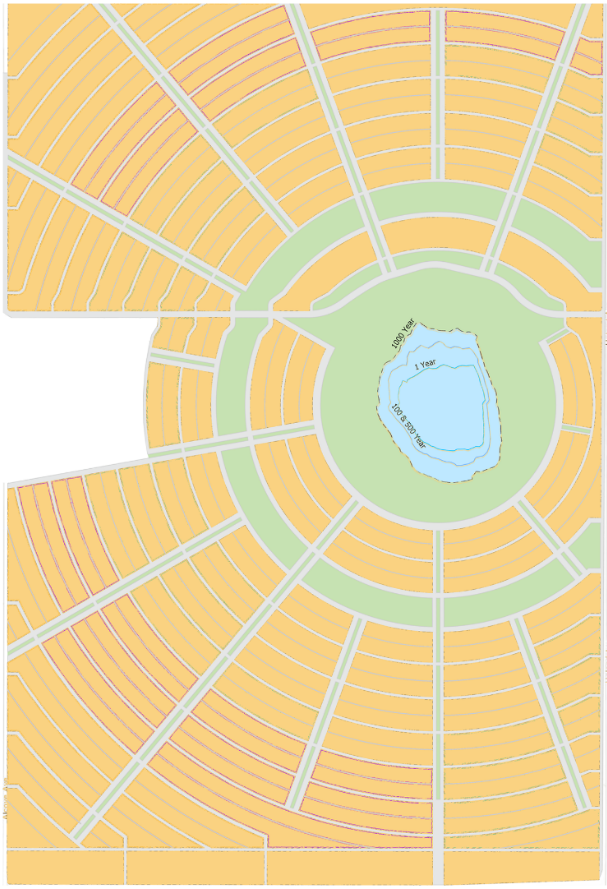
Alternative with
Storage Capacity



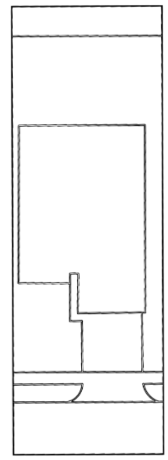
Typical Development 24hr Storm Event	(q = peak runoff rate, cubic feet per second)(CFS)	Peak runoff rate, cubic yards (yd3)
1-year storm	1,468,125.00 CFS	54,375.00 yd3
10-year storm	2,829,431.25 CFS	104,793.75 yd3
100-year storm	4,592,700.00 CFS	170,100.00 yd3
500-year storm	6,114,487.50 CFS	226,462.50 yd3
Storage Alternative Development		
1-year storm	-614,081.25 CFS	-22,743.75 yd3
10-year storm	0.00 CFS	0.00 yd3
100-year storm	795,825.00 CFS	29,475.00 yd3
500-year storm	1,482,300.00 CFS	54,900.00 yd3

Figure 4.35 Playa Basin Development and Calculations with Only One Type Melonie Park. Source: Tyson Watson

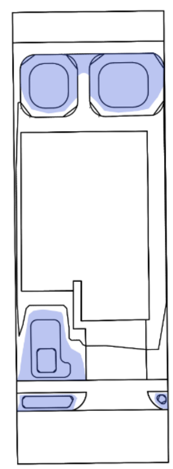
Monterey



Typical Development



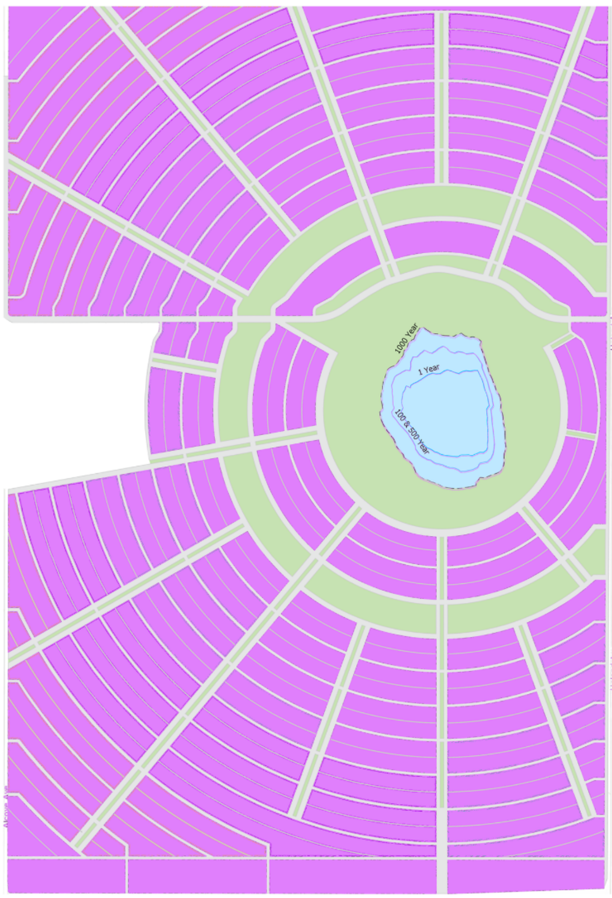
Alternative with
Storage Capacity



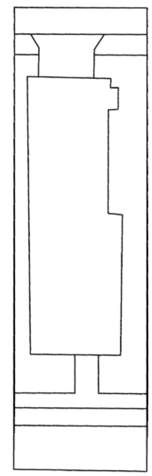
Typical Development 24hr Storm Event	(q = peak runoff rate, cubic feet per second)(CFS)	Peak runoff rate, cubic yards (yd3)
1-year storm	1,673,184.60 CFS	61,969.80 yd3
10-year storm	3,223,295.10 CFS	119,381.30 yd3
100-year storm	5,232,986.10 CFS	193,814.30 yd3
500-year storm	6,966,928.80 CFS	258,034.40 yd3
Storage Alternative Development		
1-year storm	-185,390.10 CFS	-6,866.30 yd3
10-year storm	551,496.60 CFS	20,425.80 yd3
100-year storm	1,508,047.20 CFS	55,853.60 yd3
500-year storm	2,332,176.30 CFS	86,376.90 yd3

Figure 4.36 Playa Basin Development and Calculations with Only One Type Monterey.
Source: Tyson Watson

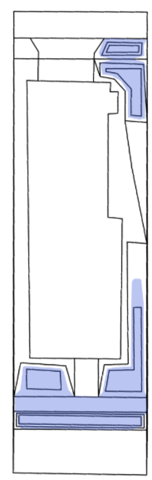
Vintage Township



Typical Development



Alternative with Storage Capacity



Typical Development 24hr Storm Event	(q = peak runoff rate, cubic feet per second)(CFS)	Peak runoff rate, cubic yards (yd3)
1-year storm	1,795,479.75 CFS	66,499.25 yd3
10-year storm	3,460,095.90 CFS	128,151.70 yd3
100-year storm	5,616,229.50 CFS	208,008.50 yd3
500-year storm	7,477,141.05 CFS	276,931.15 yd3
Storage Alternative Development		
1-year storm	0.00 CFS	0.00 yd3
10-year storm	859,181.85 CFS	31,821.55 yd3
100-year storm	1,970,301.40 CFS	73,048.20 yd3
500-year storm	2,931,967.00 CFS	108,591.40 yd3

Figure 4.37 Playa Basin Development and Calculations with Only One Type Vintage Township. Source: Tyson Watson

Figures 4.33-4.37 illustrate water volume impacts from each typical and alternative lot development type within the proposed radial subdivision layout. As illustrated in the figures, all alternative lot designs were able to hold a 1-year storm on-site, while Melonie Park and Rushland Park lots were able to hold up to a 10-year storm on-site. If the entire radial subdivision were to be developed with the same type of lot, the Melonie Park lot type would be best with 1875 lots and approximately 55,000 cubic yards of storage needed outside the playa 1000-year floodplain area. While some areas within Lubbock are developed fully under one type, a more plausible approach would be to incorporate this layout all five types offering a good mix of density and price points. The plan graphic shows a mixed lot type approach within the proposed radial subdivision design (Figure 4.38).

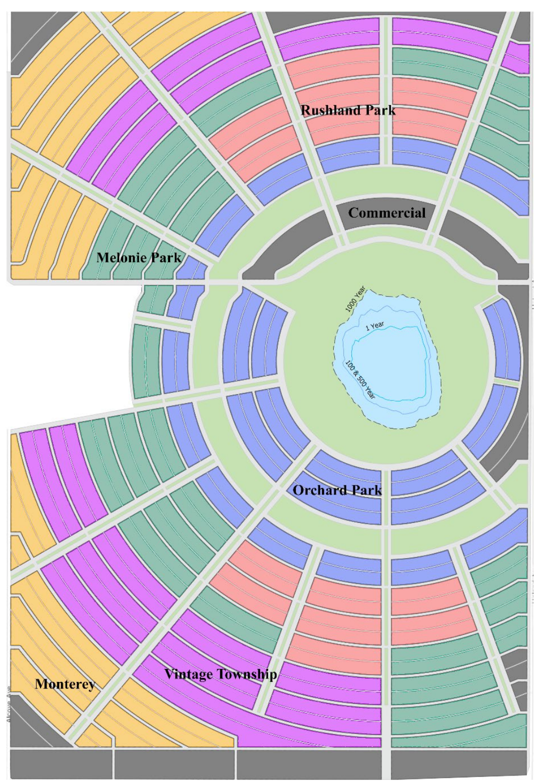


Figure 4.38 Proposed Subdivision Development Type Layout. Source: Tyson Watson

The following figures explain the mixed subdivision layout by lot type. The Orchard Park type, with a large on lot storage capacity surrounds the larger green spaces with a total acreage of 97.26 acres and 257 lots (Figure 4.39).

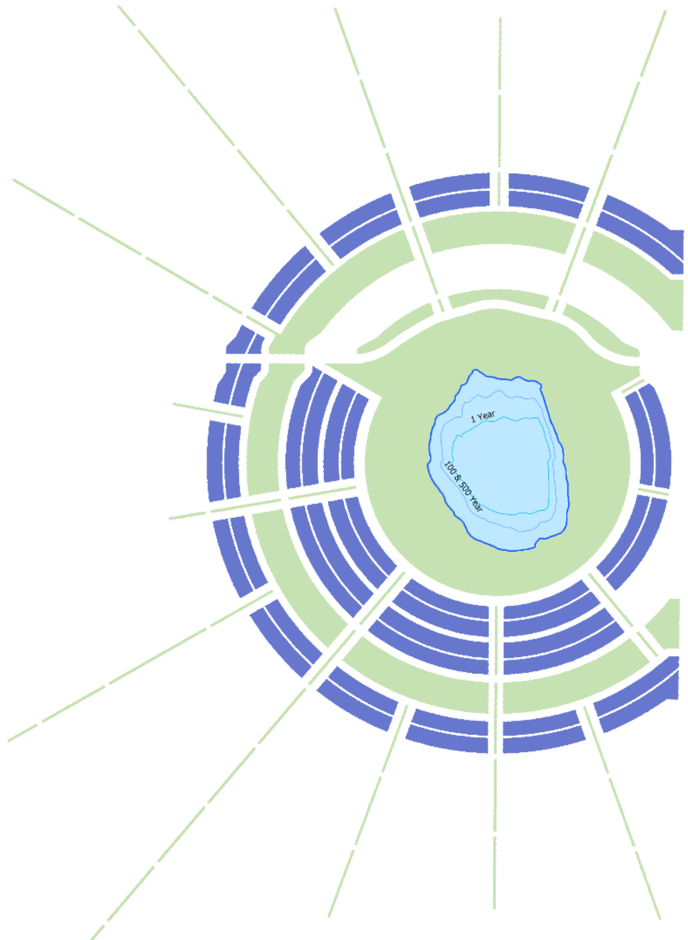


Figure 4.39 Orchard Park Development Proposed Location. Source: Tyson Watson

Placing the medium density Orchard Park lots close to the larger open spaces allows a 1-year storm be captured on lot with a moderate amount of needed storage in the green infrastructure outside the lot in close proximity. The moderate on lot storage can also capture first flush typical amounts reducing effects on the playa. Moving out from the playa, and beyond the Orchard Park lot types, are the Melonie Park and Rushland Park types. These two development types had the highest on-lot storage capacities holding up to a 10-year storm event (Figure 4.40). The Melonie Park type (green) totaled 121.79 acres and 395 lots, while the Rushland Park type totaled 68.64 acres and 89 lots.

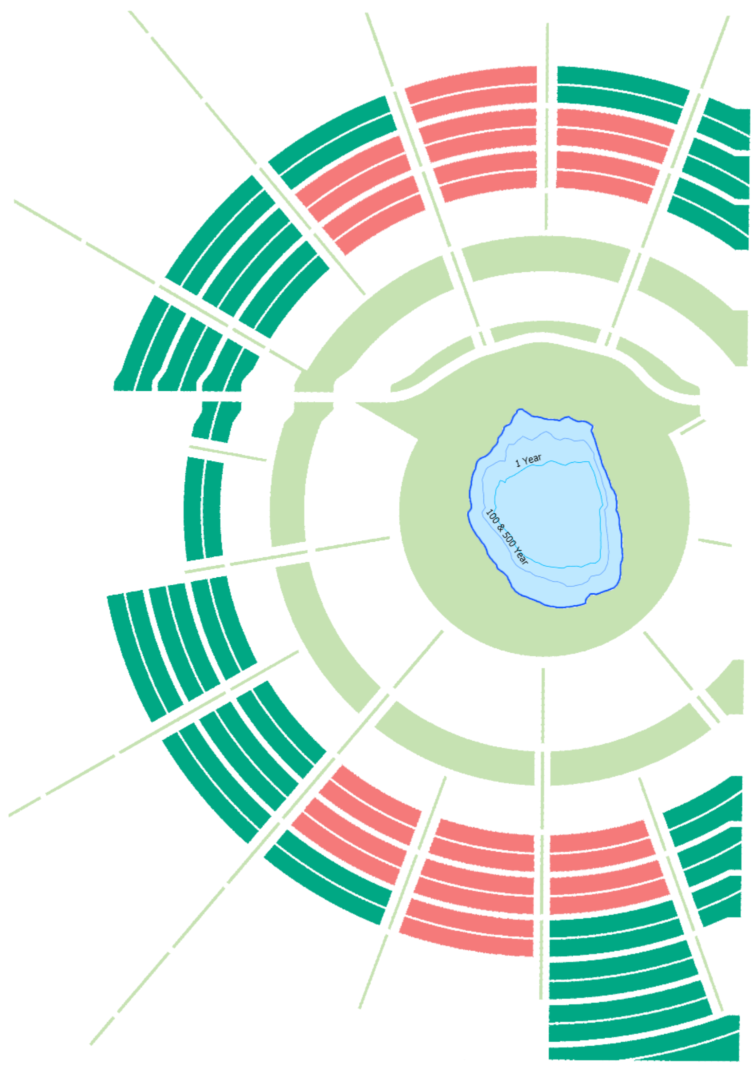


Figure 4.40 Melonie and Rushland Park Development Proposed Location. Source: Tyson Watson

With higher on-lot storage capacities, these development types can be closer to the playa because they are not contributing large amounts of runoff. Farthest from the playa are the two densest development types, Vintage Township and Monterey, which have the smallest on-lot storage capacity due to lot size and the size of the structure. The reason for placing these types of developments out farther from the playa was to allow maximum time and distance for runoff to be managed before reaching the playa. (Figure 4.41). Vintage Township type (purple areas) totaled 117.28 acres and 586 lots, and Monterey type totaled 90.62 acres and 453 lots.

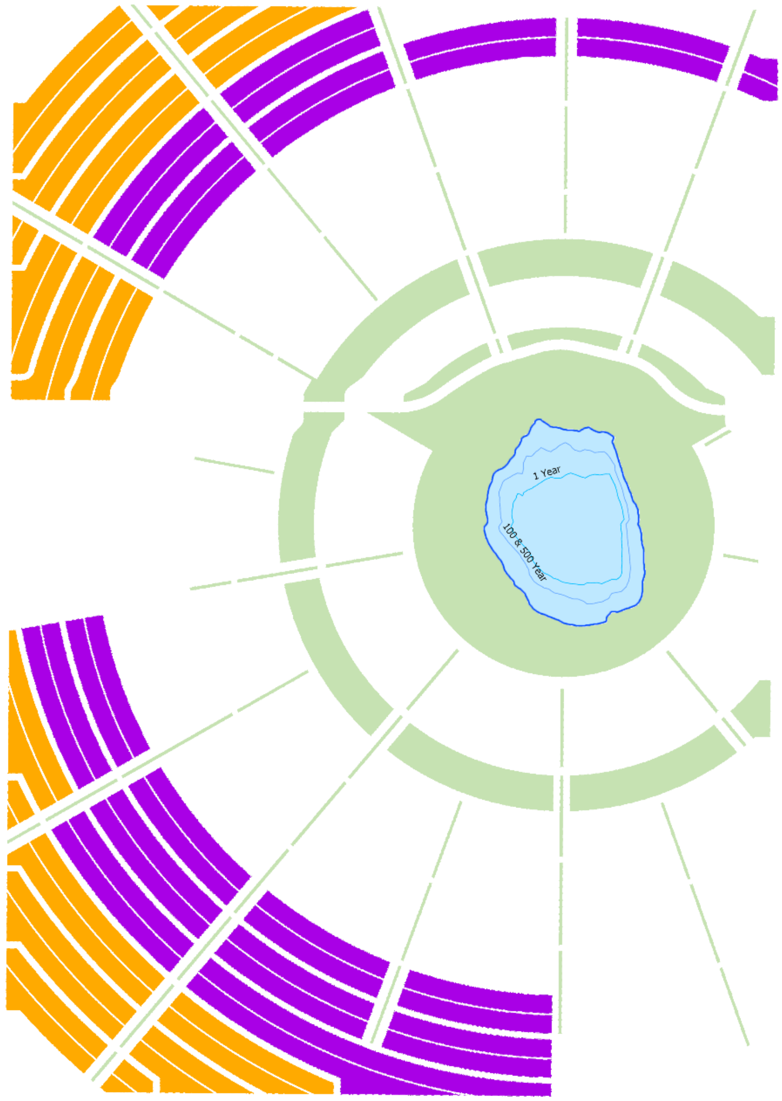


Figure 4.41 Vintage Township and Monterey Development Proposed Location. Source: Tyson Watson

A total of 186.48 acres of land is used for roads and alleys that contribute stormwater runoff volumes in the following amounts: 1-year storm 49,740.83 yd^3, 10-year 78,696.83 yd^3, 100-year 120,241.65 yd^3, and 500-year 160,087.97 yd^3. In contrast, the mixed residential including an estimated 1780 lots and commercial areas totaled 577 acres with runoff amounts beyond lot storage of: 1-year storm 46,754.60 yd^3, 10-year

83,215.42 yd^3, 100-year 159,081.53 yd^3, and 500-year 175,081.82 yd^3. The runoff calculations of the road/ alley network will generate nearly the same amount of stormwater runoff as the estimated 1780 residential lots (Figure 4.42).

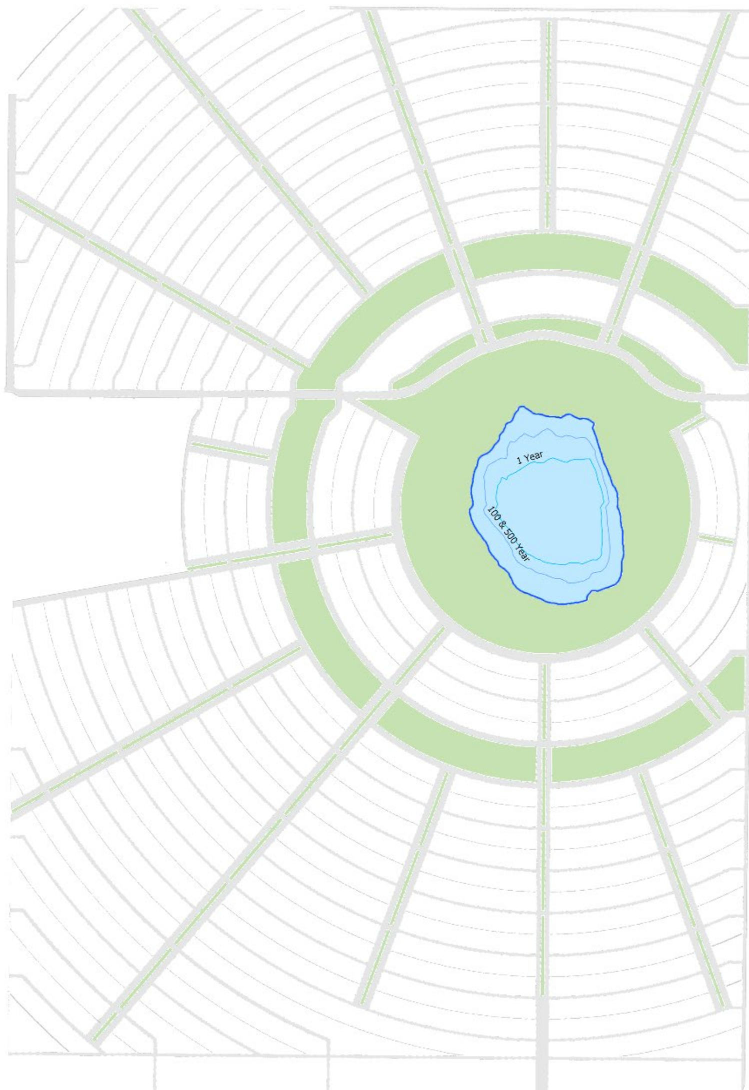


Figure 4.42 Major/ Minor Roads and Alleys. Source: Tyson Watson

The entire playa watershed includes existing fully developed areas to the north, future development to the west, the roads/alley, green space, and the proposed mixed type radial development. The fully developed playa watershed with proposed alternative lot designs and radial subdivision layout will generate the following stormwater runoff volumes: 1-year storm 129,172.48 yd^3, 10-year 224,878.14 yd^3, 100-year 381,532.24 yd^3, and 500-year at 471,364.65 yd^3 (Figure 4.43).

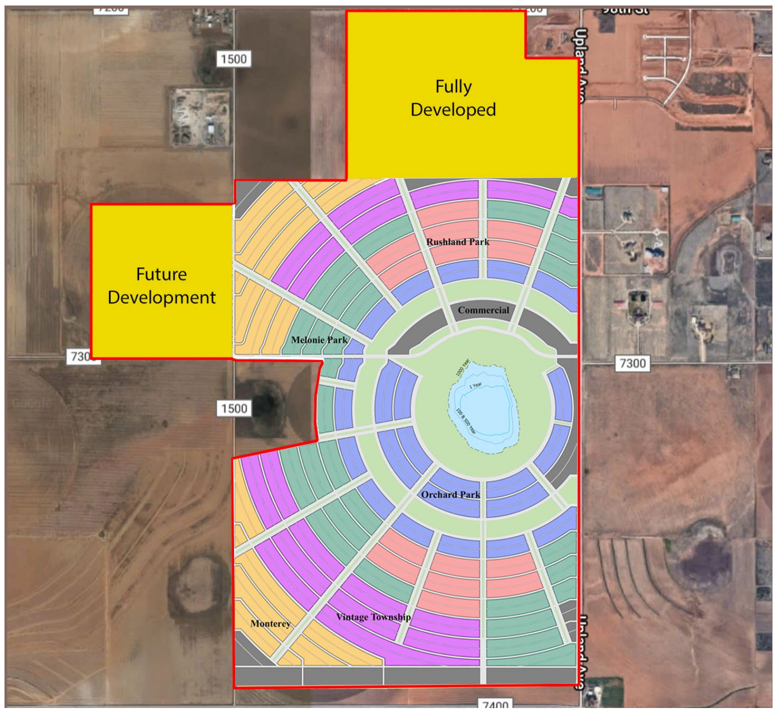


Figure 4.43 New Watershed Delineation after Development. Source: Tyson Watson

The 81 acres of green space, including the 1000-year playa floodplain area to be preserved, collectively provide stormwater storage. The boulevard green spaces store water and provide bike trials and walking paths to connect people to the larger ring and playa park areas and commercial-retail spaces (Figure 4.44). In the area surrounding the playa, maintenance will not occur inside the 500-year pre-development flood boundary to maintain biodiversity. Amenities for the park area outside the 500-year floodplain, or in the ring park areas can include a community center, neighborhood pool, soccer and baseball fields, playground, walking trails etc. Adding amenities like these will encourage individuals to get outdoors. The green spaces that branch into the subdivision along the center of the boulevard will provide stormwater collection as illustrated in (Figure 4.44).

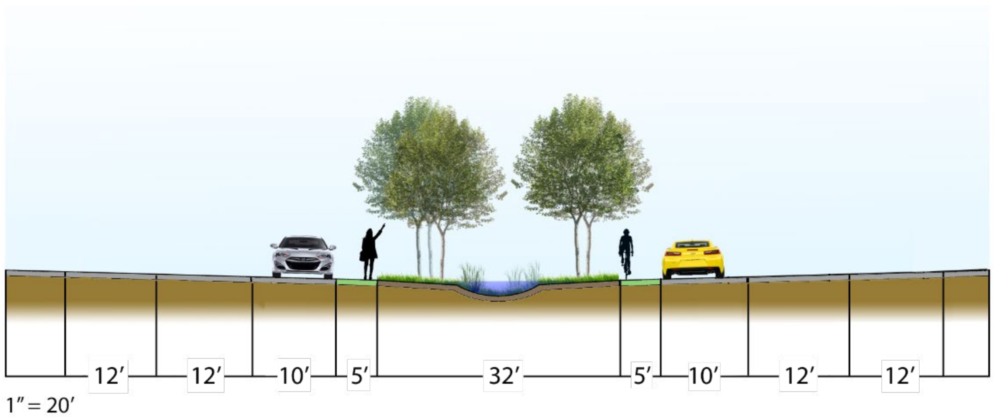


Figure 4.44 Section of Main Radial/ Ray Thoroughfare's. Source: Tyson Watson

The radial design of the proposed development respects the lay of the land and helps slow stormwater. The rays of greenspace create both visual and efficient connections for people. The ring of green infrastructure park (Figure 4.45) was designed for stormwater collection beyond the limits of the 500-year flood plain goal for storage in the playa. While the goal was to design the development to not surpass the 500-year pre-development floodplain level, the 1000-year pre-development floodplain was used as the development edge to allow additional storage space for larger than current design storms, or issues with storage systems up-basin. The intent was to prevent flooding hazards and risks. As designed, the development would produce 471,364.65 yd^3 of stromwater in the 500-year storm event. There are approximately 76 acres outside the 1000-year floodplain area. This means that the 300' wide ring park areas would be designed with shallow pans similar to playas and be up to 4 feet deep. A 4'depth in 150' (half the park width) is a

2.66 percent (2.66%) slope from edge to centerline of the park to accomdate all the stormwater from the development in a 500-year storm event.

The ring park can also be used for all kinds of sports and outdoor activities for residents. The layout and placement of the different protoypes was based on storge capacity of the playa and need to store additional runoff above the predevelopment playa 500-year storm-capacity. The placement of the lot prototypes with the least amount of storage space, or highest runoff volumes were on site placed farthest away from the playa basin, to allow the stormwater time to be collected and managed in boulevards and ring park areas. Areas outside the 500 year-floodplain which is approximately the edge of the playa annulus today would be used to store stormwater from the lots between the ring park and playa. Figure 4.45 illustrates a conceptual design for the boulevard and ring park system and illustrates designed traffic patterns in red arrows.

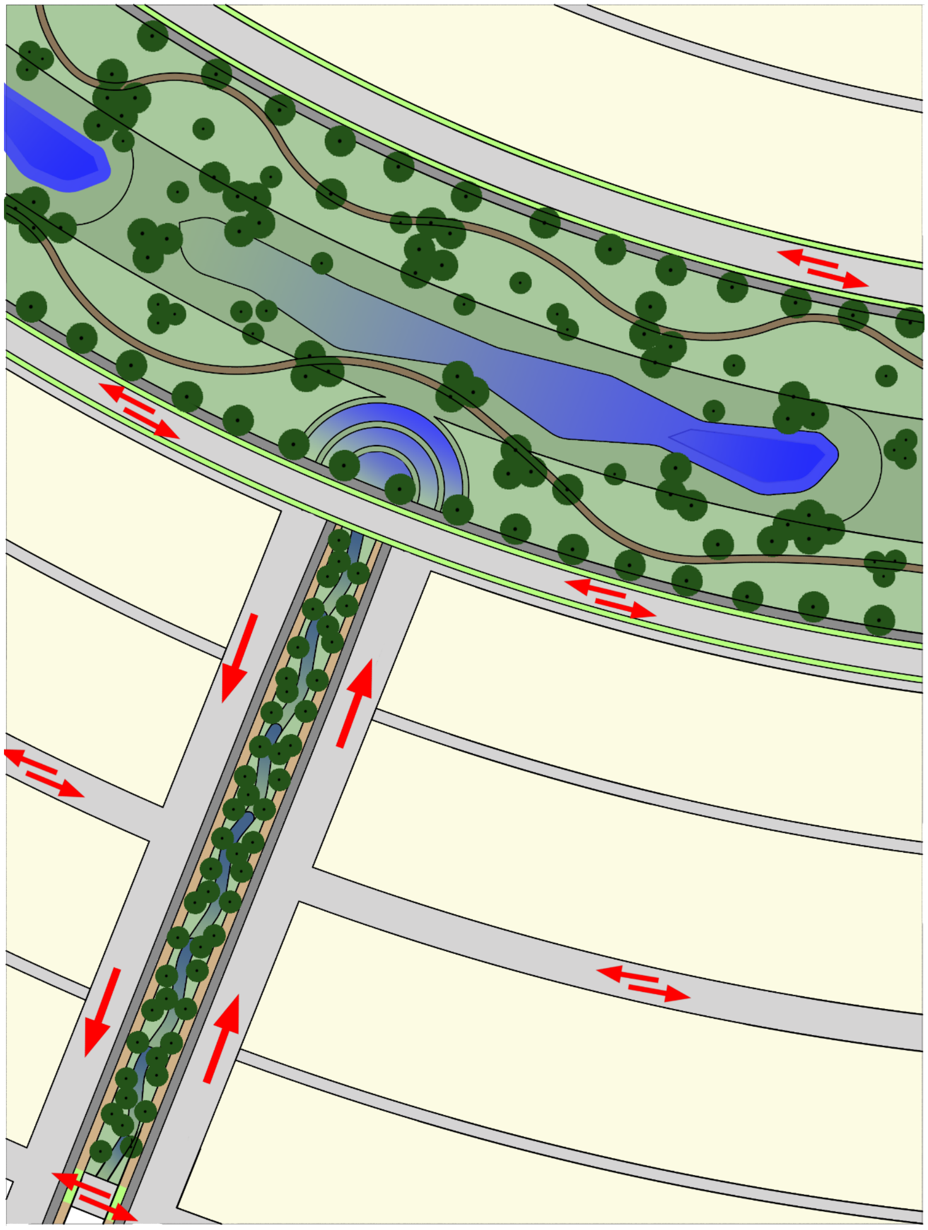


Figure 4.45 Example of Design alternatives to collect and Manage Stormwater Runoff in Boulevards and Ring Park Areas. Source: Tyson Watson

Implications and Discussion

This case study indicates that the management of stormwater runoff to maintain pre-development playa floodplain levels is possible if changes to traditional lot and subdivision design decisions are made. The design proposed provides grading alternatives for lots and open spaces to manage stormwater runoff beyond the playa's pre-development 500-year floodplain capacity. It is crucial to design and manage all types of developed areas to achieve the overall goal for the playa basin.

The pre-development 500-year floodplain goal was achieved by holding a reasonable amount of stormwater on each lot in the pervious areas 5' beyond the building envelope. The approach is designed to infiltrate stormwater into the soil on the lot for landscape water needs which can reduce irrigation water use. This approach would require final lot grading to first till construction compacted areas and then to depress the grades in areas typically covered in turf grass to allow water infiltration. These areas could also be designed as raingardens or infiltration basins to store additional water. These solutions were not presented here because they typically require gravel which is not readily available on the Llano Estacado.

The evaluation of each subdivision lot prototypes proved very helpful in understanding the lot size to building ratio and alternative locations and options for stormwater storage. Lots with high building to lot area ratios are very difficult to incorporate large capacity cisterns capable of storing roof runoff from the ranch style 1-story houses typical in the region. The calculations using the developed Excel spreadsheet to with all types of coefficients in the literature and provided with modeling tools like TR55, proved very helpful in quickly determining runoff amounts for each lot alternative design. The alternative design solutions presented used only grading solutions and no other storage alternatives, such as, cisterns and rain barrels. The grading solution is thought to be the most economical alternative because the lot has to be graded during and after construction, and other materials including gravel are imported to the region.

The proposed alternative designs for storage capacity show drastic improvements from the typical Lubbock development scenarios. Understanding the storage capacity helped in determining the placement of each type of development. The radial design of the proposed subdivision respected the lay of the land. The design also offered green boulevards that branched out from the outer ring of the playa to give the stormwater time to be managed before reaching the playa floodplain. The densest development types still create massive amounts of stormwater compared to the less dense and lower lot to building area ratio prototypes and placement farthest away can help mitigate the concentration times and increase in stormwater runoff generated.

An increase in stormwater runoff is going to happen as development occurs. Continuing with the current typical development and doing little to control or manage stormwater runoff, the typical development’s design has adverse effects on the natural functions of a playa lake. The importance of maintaining and preserving the native functions of the playa is to provide vitally important benefits of ecosystem services and aquifer recharge. In this approach, by designing the basin to never overflow and keep water infiltrating into soil, stormwater infrastructure typically installed by the City of Lubbock to provide an overflow mechanism are not necessary.

The implementation of the designed max capacity prototypes for each lot type make future development designs much easier to calculate in conceptual subdivision design phases. It is important to note that each development type has the potential to store more stormwater, but also at a higher cost than just grading of the site. If this development was to be considered for a zero runoff lot policy, how would that affect built costs and impact community diversity as some people might not be able to afford more expensive stormwater catchment systems. This approach tries to balance lot types and potential runoff to provide a diversity of housing options and price points at the lowest cost, while storing as much stormwater as makes sense aesthetically and functionally on the lot. As designed in the mixed layout, all residents live very near parks and greenspace. The radial subdivision layout respects existing topography and focuses views and circulation corridors on the amenity of the playa lake. While this is not as efficient as a grid layout, the diverse price point mixed development design provides 1780 lots.

Effective design alternatives can provide ecosystem services throughout the site rather than just in the playa floodplain area. Creating green spaces throughout the site can promote an increase in activity throughout the development, while increasing social and economic benefits. Many current practices for neighborhood development do not take into consideration the topography. This can cause an increase in the disturbance of the topsoil and increase erosion during construction, while radial development practices respect the lay of the land by following the contouring of the site. The radial design helps control and the velocity and direction that the stormwater runoff is flowing. As the radial design acts as a contouring effect, there are benefits of being able to hold water back and infiltrate before being released in the playa. Increasing development alternatives that respect the topography can help mitigate increased amounts of stormwater from future suburban developments in the Llano Estacado.

CHAPTER 5

CONCLUSION

Stormwater calculations become very complex when studied at larger scale than a site-specific level. The change in runoff coefficients based on the material and land cover becomes complex at larger scales when trying to achieve a high level of detail. This project attempted to demonstrate the effects on a playa lake hydrology based on the changing of the land-use, land-cover from a historic native short-grass prairie, to agriculture crop production to suburban development. Playa lake hydrology is extraordinarily complicated as some playas are closed basins which means that under a pre-development state the playa would never overflow and hold all stormwater of all storm events. Obviously the size of the playa basin, or watershed and basin depth are the key factors in understanding overflow. Therefore, each playa basin has to be modeled to understand its floodplain area and if it would overflow in a storm event. This playa basin would not ever overtop in a shortgrass prairie pre-development state.

Increasing development of urban/suburban areas further increases runoff over the productive agriculture land uses present around most playas in the region today. Any additional stormwater runoff generated will have damaging effects on the ecosystem functions of the playa if the hydrologic cycle is altered drastically. Understanding how playas function and the services they provide would be key in helping create and promote policies that respect playa hydrologic and ecologic functions and services. What would the region be like without these critical playa functions?

The research aimed to understand the effects of agricultural tillage practices and typical and alternative landscape designs incorporating green infrastructure practices. How do these different practices affect the playa as agricultural and urbanization continue to intrude on the playa basin? The case study explored two different scenarios prevailing in the Lubbock, Texas area – land developed in agricultural production and suburban development – and compared the resultant runoff effects on an existing playa. It addressed changes in land use and cover and their different runoff coefficients. While there are generalized runoff coefficients for urban development, they are limited. Also, current runoff coefficient tables do not provide coefficients for green infrastructure elements such as rain gardens. New coefficient research to test green infrastructure designs in playa basins would improve understanding of infiltration and runoff potential, and provide an accurate and detailed accounting of runoff amounts on a lot-by-lot basis. This would provide a more refined runoff amount if using existing development types throughout the city to predict the amount of stormwater that will be generated if fully developed in playa basin watershed.

Current practices

The city of Lubbock acknowledges that playas throughout the city play a role in stormwater management. The current practices of retrofitting the playa lakes to have a higher volume of capacity with conveyance infrastructure, and creating mown turf grass edges up to the water's edge are detrimental to both the hydrologic and ecological functions of playas. Playas are dependent on the Randall Clay pan, when the playa annulus zones and flood plains are tilled or dig-out to increase capacity or retrofitted with overflow pipe works, the clay pan is potentially removed, or profoundly disturbed and loses its capacity to crack when dry and therefore limit recharge of the aquifer. Restoration of a clay pan after they are damaged with sediment or altered would be extremely difficult. The manipulation of playa basin boundaries, or watershed boundaries by roadways trying to achieve positive drainage, and urban/suburban developments play a significant role in changing the runoff volume and should not be overlooked in design stages. As urban development continues, steps can be taking to address on-site stormwater runoff and reduce playa impacts as illustrated in this project. By doing this, the need to retrofit the playa to hold higher volumes of water and the expense it takes to do so will be reduced. Additional study of the costs to retrofit playas to overflow, and this lot and subdivision layout need to be compared.

In the City of Lubbock strategic water plan, the use of overflow water from the playa lakes retrofitted with overflow conveyance systems is planned for re-use after it is transported through pipe systems underground to just northwest of the Lubbock Lake Landmark. The State of Texas Water Development board granted the City of Lubbock $22 million dollars to install an underground drainage pipe from Maxey Park six miles north to the water treatment facility (KCBD 2018) to aid a historic playa flooding problem in the hospital district because the development was not designed to respect the playa pre-development hydrology or plan for surface overflow in green spaces. Once this playa's overflow water has been treated, it is then to be released into the Yellow House Canyon lakes system. The plan also suggests the building of a dam just west of I-27 to create lake number seven. This lake will hold the water released into the canyon lake system from the treatment facility. The plan is to use this lake is to be used for water (City of Lubbock 2018). While this plan helps a flood problem and provides additional potable water post-treatment, it does not reduce water use by increasing infiltration in the landscape areas. The approach presented here to infiltrate stormwater in landscape areas to increase soil moisture which reduces irrigation water use and demand should be a critical component of future planning and design.

Future Research

The playa basins hydrology is very different than stream flow systems that are modeled with linear flow hydrologic models. Playas are complex systems that needs to be treated differently from other streamflow based hydrologic systems. It is essential to understand how playa lakes function and the adverse effects that development causes. This research demonstrated the complexity of urban stormwater runoff and the increase in the amount by just changing the land-use and land-cover of lots. This case demonstrates that predevelopment hydrology can be met if that is a goal of the design process. The fusion of landscape architecture and geodesign processes aided the design process to illustrate options and determine their impacts.

Additional research could address the cost benefits for creating zero-runoff lots and policy alternatives. This could be extremely beneficial in currently developed playa basins that are prone to flooding. Understanding potential savings for taxpayers in typical City of Lubbock stormwater overflow infrastructures would be an important result to compare with development profits based on overall lot numbers which are lower due to green infrastructure storage. From this study alone, it was determined that the street and alley network would generate an ample amount of stormwater runoff to maintain the predevelopment hydrology. This typically approach to development in Lubbock should be reconsidered. Additionally, emerging materials for transportation corridors should be considered that provide stormwater storage should be considered as this would drastically reduce the total amount of storage required above pre-development playa flood plains. A cost comparison study using this design and alternative road types would be a great start for comparison purposes.

Using a coupled landscape architecture and geodesign approach with a goal to achieve pre-development playa floodplains can improve development of new subdivisions and limit the adverse effects on a playa hydrologic and ecosystems.

Residential and commercial developments have the potential to reduce landscape water used by creating depressions in open areas. This design approach mimics the playa system that defines this regions physiography. This is likely the cheapest alternative for managing stormwater in Lubbock and additional research to validate this statement would be very helpful. Alternative storage options such as rain barrels or Silva cells could increase the storage amounts to higher capacities; however, this comes with increased cost and maintenance over time. These systems could be used to store water for irrigation, which would reduce water consumption and aquifer use. The need for policies and tax incentives that promote zero-runoff could make the cost to the individual homeowner worth it. When it comes to promoting policies, especially those that involve water usage need to be studied further on how to promote an idea without making it a political factor. The integration of green space into a new development is vital to reaching the predevelopment goals for stormwater runoff. This goal cannot be achieved if the creation of more green space is not considered.

The proposed layout and placement of each type of development was focused on storage capacity and the amounts of runoff generated after storage capacity was meet. While the access to green space was intentional, for both stormwater runoff and social aspects, a study would need to be considered to study further the effects this proposed development has socially and economically. Does this development offer the same economic diversity as others around the city do, or does it prioritize some before others? The close access and large amounts of green space promote a healthy lifestyle compared to other developments.

Finally, the creation of a database of researched coefficients and techniques specific to the nonlinear streamflow hydrology of the playa lake dense Llano Estacado region would be a valuable resource for future resiliency seeking projects. Runoff coefficients that are representative of this area in specific cases of green infrastructure and infiltration would be extraordinarily helpful. As illustrated, agriculture contour, terraced, no-till with cover crop practices should also be studied further in this region. When using the different sources for determining runoff coefficients, the Landscape Architecture engineering numbers for agriculture were drastically different from TR-55 coefficients and TR55 coefficients for agriculture should be used.

This study illustrates how an understanding of playa hydrologic and ecologic functions and services is critical to planners and designers in the region for maintaining biodiversity, aquifer recharge and migratory species, and how coupling landscape architecture and geodesign processes can improve design outcomes by considering design alternative impacts.

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APPENDICES

Appendix A

Native Prairie Runoff and Cultivated Agriculture

1-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Pasture and Lawns	1	2.19	0.09	0.10	800,201.09	29,637.08	-
2.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Straight row (SR)	1	2.19	0.09	0.72	5,761,447.86	213,386.96	-
3.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Cultivated or No Plant Cover	1	2.19	0.09	0.30	2,400,603.27	88,911.23	-
5.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C) & Terraced (C&T)	1	2.19	0.09	0.61	4,881,226.65	180,786.17	-
6.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C)	1	2.19	0.09	0.70	5,601,407.64	207,459.54	-

10-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Pasture and Lawns	10	4.22	0.18	0.10	1,541,940.00	57,108.89	-
2.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Straight row (SR)	10	4.22	0.18	0.72	11,101,968.01	411,184.00	-
3.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Cultivated or No Plant Cover	10	4.22	0.18	0.30	4,625,820.01	171,326.67	-
5.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C) & Terraced (C&T)	10	4.22	0.18	0.61	9,405,834.01	348,364.22	-
6.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C)	10	4.22	0.18	0.70	10,793,580.01	399,762.22	-

100-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Pasture and Lawns	100	6.85	0.29	0.10	2,502,912.09	92,700.45	-
2.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Straight row (SR)	100	6.85	0.29	0.72	18,020,967.04	667,443.22	-
3.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Cultivated or No Plant Cover	100	6.85	0.29	0.30	7,508,736.26	278,101.34	-
5.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C) & Terraced (C&T)	100	6.85	0.29	0.61	15,267,763.74	565,472.73	-
6.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C)	100	6.85	0.29	0.70	17,520,384.62	648,903.13	-

500-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Pasture and Lawns	500	9.12	0.38	0.10	3,332,344.27	123,420.16	-
2.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Straight row (SR)	500	9.12	0.38	0.72	23,992,878.74	888,625.14	-
3.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Cultivated or No Plant Cover	500	9.12	0.38	0.30	9,997,032.81	370,260.47	-
5.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C) & Terraced (C&T)	500	9.12	0.38	0.61	20,327,300.04	752,862.96	-
6.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C)	500	9.12	0.38	0.70	23,326,409.89	863,941.11	-

1000-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Pasture and Lawns	1000	10.20	0.43	0.10	3,726,963.99	138,035.70	-
2.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Straight row (SR)	1000	10.20	0.43	0.72	26,834,140.69	993,857.06	-
3.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Cultivated or No Plant Cover	1000	10.20	0.43	0.30	11,180,891.96	414,107.11	-
5.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C) & Terraced (C&T)	1000	10.20	0.43	0.61	22,734,480.31	842,017.79	-
6.00	Multi	Multi	Multi	Multi	LiDAR	3ft	42258.01	44212023.75	1014.97	1014.97	Multi	Ag	0	Contoured (C)	1000	10.20	0.43	0.70	26,088,747.90	966,249.92	-

Appendix B

Typical Development Scenario: Melonie Park

1-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
3	Melonie Park	R136527	45878	13	LiDAR	3ft	170.06	1050.43	0.02	1014.97	City Right of Way	Public	3.25	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	142.59	5.28	17,420.40
9	Melonie Park	R136528	45878	13	LiDAR	3ft	99.39	263.14	0.01	1014.97	City Right of Way	Public	3.25	Lawns	1	2.19	0.09	0.35	16.67	0.62	2,036.49
11	Melonie Park	R136530	45878	13	LiDAR	3ft	27.03	47.45	0.00	1014.97	City Right of Way	Public	3.25	Lawns	1	2.19	0.09	0.35	3.01	0.11	367.24
13	Melonie Park	R136531	45878	13	LiDAR	3ft	263.85	416.30	0.01	1014.97	City Right of Way	Public	3.25	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	56.51	2.09	6,904.05
18	Melonie Park	R136532	45878	13	LiDAR	3ft	144.09	699.81	0.02	1014.97	Residential	Residential	3.25	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	94.99	3.52	11,605.67
19	Melonie Park	R136533	45878	13	LiDAR	3ft	37.65	81.45	0.00	1014.97	Residential	Residential	3.25	Lawns	1	2.19	0.09	0.35	5.16	0.19	630.33
24	Melonie Park	R136534	45878	13	LiDAR	3ft	192.40	1576.51	0.04	1014.97	Residential	Residential	3.25	Roofs	1	2.19	0.09	0.8	228.27	8.45	27,888.05
27	Melonie Park	R136535	45878	13	LiDAR	3ft	167.06	1261.36	0.03	1014.97	Residential	Residential	3.25	Roofs	1	2.19	0.09	0.8	182.64	6.76	22,313.17
33	Melonie Park	R136536	45878	13	LiDAR	3ft	612.77	4294.66	0.10	1014.97	Residential	Residential	3.25	Lawns	1	2.19	0.09	0.35	272.05	10.08	33,237.49
36	Melonie Park	R136537	45878	13	LiDAR	3ft	155.37	541.53	0.01	1014.97	City Right of Way	Public	3.25	Lawns	1	2.19	0.09	0.35	34.30	1.27	4,191.04
Total								**10232.63**	**0.23**										**1,036.19**	**38.38**	**126,593.94**

10-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
3	Melonie Park	R136527	45878	13	LiDAR	3ft	170.06	1050.43	0.02	1014.97	City Right of Way	Public	3.25	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	274.76	10.18	33,568.08
9	Melonie Park	R136528	45878	13	LiDAR	3ft	99.39	263.14	0.01	1014.97	City Right of Way	Public	3.25	Lawns	10	4.22	0.18	0.35	32.12	1.19	3,924.20
11	Melonie Park	R136530	45878	13	LiDAR	3ft	27.03	47.45	0.00	1014.97	City Right of Way	Public	3.25	Lawns	10	4.22	0.18	0.35	5.79	0.21	707.65
13	Melonie Park	R136531	45878	13	LiDAR	3ft	263.85	416.30	0.01	1014.97	City Right of Way	Public	3.25	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	108.89	4.03	13,303.69
18	Melonie Park	R136532	45878	13	LiDAR	3ft	144.09	699.81	0.02	1014.97	Residential	Residential	3.25	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	183.05	6.78	22,363.45
19	Melonie Park	R136533	45878	13	LiDAR	3ft	37.65	81.45	0.00	1014.97	Residential	Residential	3.25	Lawns	10	4.22	0.18	0.35	9.94	0.37	1,214.61
24	Melonie Park	R136534	45878	13	LiDAR	3ft	192.40	1576.51	0.04	1014.97	Residential	Residential	3.25	Roofs	10	4.22	0.18	0.8	439.86	16.29	53,738.62
27	Melonie Park	R136535	45878	13	LiDAR	3ft	167.06	1261.36	0.03	1014.97	Residential	Residential	3.25	Roofs	10	4.22	0.18	0.8	351.93	13.03	42,996.16
33	Melonie Park	R136536	45878	13	LiDAR	3ft	612.77	4294.66	0.10	1014.97	Residential	Residential	3.25	Lawns	10	4.22	0.18	0.35	524.23	19.42	64,046.66
36	Melonie Park	R136537	45878	13	LiDAR	3ft	155.37	541.53	0.01	1014.97	City Right of Way	Public	3.25	Lawns	10	4.22	0.18	0.35	66.10	2.45	8,075.89
Total								**10232.63**	**0.23**										**1,996.68**	**73.95**	**243,939.01**

Appendix B Continued

100-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
3	Melonie Park	R136527	45878	13	LiDAR	3ft	170.06	1050.43	0.02	1014.97	City Right of Way	Public	3.25	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	446.00	16.52	54,488.48
9	Melonie Park	R136528	45878	13	LiDAR	3ft	99.39	263.14	0.01	1014.97	City Right of Way	Public	3.25	Lawns	100	6.85	0.29	0.35	52.14	1.93	6,369.85
11	Melonie Park	R136530	45878	13	LiDAR	3ft	27.03	47.45	0.00	1014.97	City Right of Way	Public	3.25	Lawns	100	6.85	0.29	0.35	9.40	0.35	1,148.68
13	Melonie Park	R136531	45878	13	LiDAR	3ft	263.85	416.30	0.01	1014.97	City Right of Way	Public	3.25	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	176.76	6.55	21,594.86
18	Melonie Park	R136532	45878	13	LiDAR	3ft	144.09	699.81	0.02	1014.97	Residential	Residential	3.25	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	297.13	11.00	36,300.86
19	Melonie Park	R136533	45878	13	LiDAR	3ft	37.65	81.45	0.00	1014.97	Residential	Residential	3.25	Lawns	100	6.85	0.29	0.35	16.14	0.60	1,971.59
24	Melonie Park	R136534	45878	13	LiDAR	3ft	192.40	1576.51	0.04	1014.97	Residential	Residential	3.25	Roofs	100	6.85	0.29	0.8	713.99	26.44	87,229.74
27	Melonie Park	R136535	45878	13	LiDAR	3ft	167.06	1261.36	0.03	1014.97	Residential	Residential	3.25	Roofs	100	6.85	0.29	0.8	571.26	21.16	69,792.35
33	Melonie Park	R136536	45878	13	LiDAR	3ft	612.77	4294.66	0.10	1014.97	Residential	Residential	3.25	Lawns	100	6.85	0.29	0.35	850.95	31.52	103,962.00
36	Melonie Park	R136537	45878	13	LiDAR	3ft	155.37	541.53	0.01	1014.97	City Right of Way	Public	3.25	Lawns	100	6.85	0.29	0.35	107.30	3.97	13,108.97
Total								**10232.63**	**0.23**										**3,241.06**	**120.04**	**395,967.36**

500-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
3	Melonie Park	R136527	45878	13	LiDAR	3ft	170.06	1050.43	0.02	1014.97	City Right of Way	Public	3.25	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	593.79	21.99	72,545.24
9	Melonie Park	R136528	45878	13	LiDAR	3ft	99.39	263.14	0.01	1014.97	City Right of Way	Public	3.25	Lawns	500	9.12	0.38	0.35	69.42	2.57	8,480.73
11	Melonie Park	R136530	45878	13	LiDAR	3ft	27.03	47.45	0.00	1014.97	City Right of Way	Public	3.25	Lawns	500	9.12	0.38	0.35	12.52	0.46	1,529.33
13	Melonie Park	R136531	45878	13	LiDAR	3ft	263.85	416.30	0.01	1014.97	City Right of Way	Public	3.25	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	235.33	8.72	28,751.11
18	Melonie Park	R136532	45878	13	LiDAR	3ft	144.09	699.81	0.02	1014.97	Residential	Residential	3.25	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	395.59	14.65	48,330.48
19	Melonie Park	R136533	45878	13	LiDAR	3ft	37.65	81.45	0.00	1014.97	Residential	Residential	3.25	Lawns	500	9.12	0.38	0.35	21.49	0.80	2,624.94
24	Melonie Park	R136534	45878	13	LiDAR	3ft	192.40	1576.51	0.04	1014.97	Residential	Residential	3.25	Roofs	500	9.12	0.38	0.8	950.60	35.21	116,136.53
27	Melonie Park	R136535	45878	13	LiDAR	3ft	167.06	1261.36	0.03	1014.97	Residential	Residential	3.25	Roofs	500	9.12	0.38	0.8	760.57	28.17	92,920.61
33	Melonie Park	R136536	45878	13	LiDAR	3ft	612.77	4294.66	0.10	1014.97	Residential	Residential	3.25	Lawns	500	9.12	0.38	0.35	1,132.94	41.96	138,413.65
36	Melonie Park	R136537	45878	13	LiDAR	3ft	155.37	541.53	0.01	1014.97	City Right of Way	Public	3.25	Lawns	500	9.12	0.38	0.35	142.86	5.29	17,453.11
Total								**10232.63**	**0.23**										**4,315.10**	**159.82**	**527,185.74**

Appendix C

Typical Development Scenario: Monterey

1-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	Monterey	R303401	63356	1	LiDAR	3ft	135.76	894.06	0.02	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	121.36	4.49	22,810.97
2	Monterey	R303402	63356	1	LiDAR	3ft	22.20	30.17	0.00	1014.97	City Right of Way	Public	5	Lawns	1	2.19	0.09	0.35	1.91	0.07	359.19
3	Monterey	R303403	63356	1	LiDAR	3ft	55.09	123.53	0.00	1014.97	City Right of Way	Public	5	Lawns	1	2.19	0.09	0.35	7.83	0.29	1,470.83
5	Monterey	R303404	63356	1	LiDAR	3ft	21.76	27.51	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	3.73	0.14	701.81
6	Monterey	R303405	63356	1	LiDAR	3ft	70.38	207.30	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	28.14	1.04	5,289.14
8	Monterey	R303406	63356	1	LiDAR	3ft	54.06	92.12	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	12.50	0.46	2,350.24
11	Monterey	R303407	63356	1	LiDAR	3ft	79.43	394.32	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	53.53	1.98	10,060.78
13	Monterey	R303408	63356	1	LiDAR	3ft	54.17	125.94	0.00	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	18.24	0.68	3,427.56
14	Monterey	R303409	63356	1	LiDAR	3ft	39.75	45.70	0.00	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	6.20	0.23	1,166.11
16	Monterey	R303410	63356	1	LiDAR	3ft	95.61	405.61	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	55.06	2.04	10,348.78
19	Monterey	R303411	63356	1	LiDAR	3ft	142.74	777.87	0.02	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	112.63	4.17	21,169.71
20	Monterey	R303412	63356	1	LiDAR	3ft	127.25	683.78	0.02	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	99.01	3.67	18,609.06
21	Monterey	R303413	63356	1	LiDAR	3ft	100.11	424.94	0.01	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	61.53	2.28	11,564.69
24	Monterey	R303414	63356	1	LiDAR	3ft	532.38	2741.67	0.06	1014.97	Residential	Residential	5	Lawns	1	2.19	0.09	0.35	173.68	6.43	32,643.83
28	Monterey	R303415	63356	1	LiDAR	3ft	120.00	500.06	0.01	1014.97	City Right of Way	Public	5	Lawns	1	2.19	0.09	0.35	31.68	1.17	5,953.97
Total								**7474.58**	**0.17**										**787.02**	**29.15**	**147,926.68**

10-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	Monterey	R303401	63356	1	LiDAR	3ft	135.76	894.06	0.02	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	233.86	8.66	43,955.39
2	Monterey	R303402	63356	1	LiDAR	3ft	22.20	30.17	0.00	1014.97	City Right of Way	Public	5	Lawns	10	4.22	0.18	0.35	3.68	0.14	692.14
3	Monterey	R303403	63356	1	LiDAR	3ft	55.09	123.53	0.00	1014.97	City Right of Way	Public	5	Lawns	10	4.22	0.18	0.35	15.08	0.56	2,834.20
5	Monterey	R303404	63356	1	LiDAR	3ft	21.76	27.51	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	7.19	0.27	1,352.35
6	Monterey	R303405	63356	1	LiDAR	3ft	70.38	207.30	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	54.22	2.01	10,191.86
8	Monterey	R303406	63356	1	LiDAR	3ft	54.06	92.12	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	24.09	0.89	4,528.77
11	Monterey	R303407	63356	1	LiDAR	3ft	79.43	394.32	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	103.14	3.82	19,386.53
13	Monterey	R303408	63356	1	LiDAR	3ft	54.17	125.94	0.00	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	35.14	1.30	6,604.70
14	Monterey	R303409	63356	1	LiDAR	3ft	39.75	45.70	0.00	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	11.95	0.44	2,247.03
16	Monterey	R303410	63356	1	LiDAR	3ft	95.61	405.61	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	106.10	3.93	19,941.48
19	Monterey	R303411	63356	1	LiDAR	3ft	142.74	777.87	0.02	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	217.03	8.04	40,792.78
20	Monterey	R303412	63356	1	LiDAR	3ft	127.25	683.78	0.02	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	190.78	7.07	35,858.55
21	Monterey	R303413	63356	1	LiDAR	3ft	100.11	424.94	0.01	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	118.56	4.39	22,284.47
24	Monterey	R303414	63356	1	LiDAR	3ft	532.38	2741.67	0.06	1014.97	Residential	Residential	5	Lawns	10	4.22	0.18	0.35	334.66	12.39	62,902.73
28	Monterey	R303415	63356	1	LiDAR	3ft	120.00	500.06	0.01	1014.97	City Right of Way	Public	5	Lawns	10	4.22	0.18	0.35	61.04	2.26	11,472.95
Total								**7474.58**	**0.17**										**1,516.55**	**56.17**	**285,045.93**

Appendix C Continued

100-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	Monterey	R303401	63356	1	LiDAR	3ft	135.76	894.06	0.02	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	379.60	14.06	71,349.39
2	Monterey	R303402	63356	1	LiDAR	3ft	22.20	30.17	0.00	1014.97	City Right of Way	Public	5	Lawns	100	6.85	0.29	0.35	5.98	0.22	1,123.50
3	Monterey	R303403	63356	1	LiDAR	3ft	55.09	123.53	0.00	1014.97	City Right of Way	Public	5	Lawns	100	6.85	0.29	0.35	24.48	0.91	4,600.54
5	Monterey	R303404	63356	1	LiDAR	3ft	21.76	27.51	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	11.68	0.43	2,195.17
6	Monterey	R303405	63356	1	LiDAR	3ft	70.38	207.30	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	88.02	3.26	16,543.66
8	Monterey	R303406	63356	1	LiDAR	3ft	54.06	92.12	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	39.11	1.45	7,351.21
11	Monterey	R303407	63356	1	LiDAR	3ft	79.43	394.32	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	167.42	6.20	31,468.65
13	Monterey	R303408	63356	1	LiDAR	3ft	54.17	125.94	0.00	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	57.04	2.11	10,720.91
14	Monterey	R303409	63356	1	LiDAR	3ft	39.75	45.70	0.00	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	19.41	0.72	3,647.43
16	Monterey	R303410	63356	1	LiDAR	3ft	95.61	405.61	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	172.22	6.38	32,369.47
19	Monterey	R303411	63356	1	LiDAR	3ft	142.74	777.87	0.02	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	352.29	13.05	66,215.76
20	Monterey	R303412	63356	1	LiDAR	3ft	127.25	683.78	0.02	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	309.68	11.47	58,206.42
21	Monterey	R303413	63356	1	LiDAR	3ft	100.11	424.94	0.01	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	192.45	7.13	36,172.66
24	Monterey	R303414	63356	1	LiDAR	3ft	532.38	2741.67	0.06	1014.97	Residential	Residential	5	Lawns	100	6.85	0.29	0.35	543.24	20.12	102,105.14
28	Monterey	R303415	63356	1	LiDAR	3ft	120.00	500.06	0.01	1014.97	City Right of Way	Public	5	Lawns	100	6.85	0.29	0.35	99.08	3.67	18,623.15
Total								**7474.58**	**0.17**										**2,461.69**	**91.17**	**462,693.05**

500-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	Monterey	R303401	63356	1	LiDAR	3ft	135.76	894.06	0.02	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	505.40	18.72	94,993.64
2	Monterey	R303402	63356	1	LiDAR	3ft	22.20	30.17	0.00	1014.97	City Right of Way	Public	5	Lawns	500	9.12	0.38	0.35	7.96	0.29	1,495.81
3	Monterey	R303403	63356	1	LiDAR	3ft	55.09	123.53	0.00	1014.97	City Right of Way	Public	5	Lawns	500	9.12	0.38	0.35	32.59	1.21	6,125.09
5	Monterey	R303404	63356	1	LiDAR	3ft	21.76	27.51	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	15.55	0.58	2,922.62
6	Monterey	R303405	63356	1	LiDAR	3ft	70.38	207.30	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	117.19	4.34	22,026.01
8	Monterey	R303406	63356	1	LiDAR	3ft	54.06	92.12	0.00	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	52.07	1.93	9,787.30
11	Monterey	R303407	63356	1	LiDAR	3ft	79.43	394.32	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	222.91	8.26	41,896.95
13	Monterey	R303408	63356	1	LiDAR	3ft	54.17	125.94	0.00	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	75.94	2.81	14,273.67
14	Monterey	R303409	63356	1	LiDAR	3ft	39.75	45.70	0.00	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	25.84	0.96	4,856.14
16	Monterey	R303410	63356	1	LiDAR	3ft	95.61	405.61	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	229.29	8.49	43,096.29
19	Monterey	R303411	63356	1	LiDAR	3ft	142.74	777.87	0.02	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	469.04	17.37	88,158.80
20	Monterey	R303412	63356	1	LiDAR	3ft	127.25	683.78	0.02	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	412.30	15.27	77,495.26
21	Monterey	R303413	63356	1	LiDAR	3ft	100.11	424.94	0.01	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	256.23	9.49	48,159.81
24	Monterey	R303414	63356	1	LiDAR	3ft	532.38	2741.67	0.06	1014.97	Residential	Residential	5	Lawns	500	9.12	0.38	0.35	723.26	26.79	135,941.44
28	Monterey	R303415	63356	1	LiDAR	3ft	120.00	500.06	0.01	1014.97	City Right of Way	Public	5	Lawns	500	9.12	0.38	0.35	131.92	4.89	24,794.62
Total								**7474.58**	**0.17**										**3,277.46**	**121.39**	**616,023.44**

Appendix D

Typical Development Scenario: Rushland Park

1-Year

OBJECTID	Subdivision	PROP_ID_ LCAD	FID	Project _Parcel _ID	TOPO_ Source	Raster _Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED _ACRES	Property_Owner	Land_Use	Du/ Ac	Land_Cover	Year_Storm	Precip_ Inches	Inches _Per_ Hour	Runoff_ Coefficien t	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_ Volume_DU/AC_CY ((CF/27*(DU/AC_*10 14.97))
1	RuShland Park	R65103	16199	7	LiDAR	3ft	247.52	1502.01	0.03	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	203.89	7.55	9,963.82
2	RuShland Park	R65104	16199	7	LiDAR	3ft	210.24	1351.75	0.03	1014.97	City Right of Way	Public	1.3	Lawns	1	2.19	0.09	0.35	85.63	3.17	4,184.61
3	RuShland Park	R65105	16199	7	LiDAR	3ft	70.00	299.99	0.01	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	40.72	1.51	1,990.06
4	RuShland Park	R65106	16199	7	LiDAR	3ft	209.27	1780.26	0.04	1014.97	Residential	Residential	1.3	Roofs	1	2.19	0.09	0.8	257.77	9.55	12,596.90
5	RuShland Park	R65107	16199	7	LiDAR	3ft	214.12	1748.27	0.04	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	237.32	8.79	11,597.39
6	RuShland Park	R65108	16199	7	LiDAR	3ft	97.98	233.25	0.01	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	31.66	1.17	1,547.33
7	RuShland Park	R65109	16199	7	LiDAR	3ft	115.13	635.37	0.01	1014.97	Residential	Residential	1.3	Roofs	1	2.19	0.09	0.8	92.00	3.41	4,495.85
8	RuShland Park	R65110	16199	7	LiDAR	3ft	108.04	502.68	0.01	1014.97	Residential	Residential	1.3	Roofs	1	2.19	0.09	0.8	72.78	2.70	3,556.88
9	RuShland Park	R65111	16199	7	LiDAR	3ft	260.45	1797.55	0.04	1014.97	Residential	Residential	1.3	Roofs	1	2.19	0.09	0.8	260.27	9.64	12,719.27
10	RuShland Park	R65112	16199	7	LiDAR	3ft	68.16	194.41	0.00	1014.97	Residential	Residential	1.3	Roofs	1	2.19	0.09	0.8	28.15	1.04	1,375.65
11	RuShland Park	R65113	16199	7	LiDAR	3ft	124.53	607.85	0.01	1014.97	Residential	Residential	1.3	Roofs	1	2.19	0.09	0.8	88.01	3.26	4,301.08
12	RuShland Park	R65114	16199	7	LiDAR	3ft	753.19	7967.74	0.18	1014.97	Residential	Residential	1.3	Lawns	1	2.19	0.09	0.35	504.73	18.69	24,665.77
13	RuShland Park	R65115	16199	7	LiDAR	3ft	32.41	48.82	0.00	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	6.63	0.25	323.84
14	RuShland Park	R65116	16199	7	LiDAR	3ft	86.44	380.64	0.01	1014.97	Residential	Residential	1.3	Lawns	1	2.19	0.09	0.35	24.11	0.89	1,178.36
15	RuShland Park	R65117	16199	7	LiDAR	3ft	18.00	20.00	0.00	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	2.72	0.10	132.68
16	RuShland Park	R65118	16199	7	LiDAR	3ft	251.99	1189.95	0.03	1014.97	City Right of Way	Public	1.3	Lawns	1	2.19	0.09	0.35	75.38	2.79	3,683.72
17	RuShland Park	R65119	16199	7	LiDAR	3ft	149.19	772.66	0.02	1014.97	Residential	Residential	1.3	Roofs	1	2.19	0.09	0.8	111.88	4.14	5,467.29
Total								**21033.20**	**0.48**										**2,123.65**	**78.65**	**103,780.51**

10-Year

OBJECTID	Subdivision	PROP_ID_ LCAD	FID	Project _Parcel _ID	TOPO_ Source	Raster _Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED _ACRES	Property_Owner	Land_Use	Du/ Ac	Land_Cover	Year_Storm	Precip_ Inches	Inches _Per_ Hour	Runoff_ Coefficien t	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_ Volume_DU/AC_CY ((CF/27*(DU/AC_*10 14.97))
1	RuShland Park	R65103	16199	7	LiDAR	3ft	247.52	1502.01	0.03	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	392.88	14.55	19,199.69
2	RuShland Park	R65104	16199	7	LiDAR	3ft	210.24	1351.75	0.03	1014.97	City Right of Way	Public	1.3	Lawns	10	4.22	0.18	0.35	165.00	6.11	8,063.50
3	RuShland Park	R65105	16199	7	LiDAR	3ft	70.00	299.99	0.01	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	78.47	2.91	3,834.73
4	RuShland Park	R65106	16199	7	LiDAR	3ft	209.27	1780.26	0.04	1014.97	Residential	Residential	1.3	Roofs	10	4.22	0.18	0.8	496.71	18.40	24,273.49
5	RuShland Park	R65107	16199	7	LiDAR	3ft	214.12	1748.27	0.04	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	457.29	16.94	22,347.49
6	RuShland Park	R65108	16199	7	LiDAR	3ft	97.98	233.25	0.01	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	61.01	2.26	2,981.61
7	RuShland Park	R65109	16199	7	LiDAR	3ft	115.13	635.37	0.01	1014.97	Residential	Residential	1.3	Roofs	10	4.22	0.18	0.8	177.27	6.57	8,663.23
8	RuShland Park	R65110	16199	7	LiDAR	3ft	108.04	502.68	0.01	1014.97	Residential	Residential	1.3	Roofs	10	4.22	0.18	0.8	140.25	5.19	6,853.90
9	RuShland Park	R65111	16199	7	LiDAR	3ft	260.45	1797.55	0.04	1014.97	Residential	Residential	1.3	Roofs	10	4.22	0.18	0.8	501.53	18.58	24,509.28
10	RuShland Park	R65112	16199	7	LiDAR	3ft	68.16	194.41	0.00	1014.97	Residential	Residential	1.3	Roofs	10	4.22	0.18	0.8	54.24	2.01	2,650.79
11	RuShland Park	R65113	16199	7	LiDAR	3ft	124.53	607.85	0.01	1014.97	Residential	Residential	1.3	Roofs	10	4.22	0.18	0.8	169.59	6.28	8,287.92
12	RuShland Park	R65114	16199	7	LiDAR	3ft	753.19	7967.74	0.18	1014.97	Residential	Residential	1.3	Lawns	10	4.22	0.18	0.35	972.59	36.02	47,529.48
13	RuShland Park	R65115	16199	7	LiDAR	3ft	32.41	48.82	0.00	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	12.77	0.47	624.02
14	RuShland Park	R65116	16199	7	LiDAR	3ft	86.44	380.64	0.01	1014.97	Residential	Residential	1.3	Lawns	10	4.22	0.18	0.35	46.46	1.72	2,270.64
15	RuShland Park	R65117	16199	7	LiDAR	3ft	18.00	20.00	0.00	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	5.23	0.19	255.67
16	RuShland Park	R65118	16199	7	LiDAR	3ft	251.99	1189.95	0.03	1014.97	City Right of Way	Public	1.3	Lawns	10	4.22	0.18	0.35	145.25	5.38	7,098.31
17	RuShland Park	R65119	16199	7	LiDAR	3ft	149.19	772.66	0.02	1014.97	Residential	Residential	1.3	Roofs	10	4.22	0.18	0.8	215.58	7.98	10,535.15
Total								**21033.20**	**0.48**										**4,092.15**	**151.56**	**199,978.88**

Appendix D Continued

100-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	RuShland Park	R65103	16199	7	LiDAR	3ft	247.52	1502.01	0.03	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	637.73	23.62	31,165.37
2	RuShland Park	R65104	16199	7	LiDAR	3ft	210.24	1351.75	0.03	1014.97	City Right of Way	Public	1.3	Lawns	100	6.85	0.29	0.35	267.84	9.92	13,088.86
3	RuShland Park	R65105	16199	7	LiDAR	3ft	70.00	299.99	0.01	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	127.37	4.72	6,224.62
4	RuShland Park	R65106	16199	7	LiDAR	3ft	209.27	1780.26	0.04	1014.97	Residential	Residential	1.3	Roofs	100	6.85	0.29	0.8	806.26	29.86	39,401.28
5	RuShland Park	R65107	16199	7	LiDAR	3ft	214.12	1748.27	0.04	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	742.29	27.49	36,274.95
6	RuShland Park	R65108	16199	7	LiDAR	3ft	97.98	233.25	0.01	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	99.04	3.67	4,839.82
7	RuShland Park	R65109	16199	7	LiDAR	3ft	115.13	635.37	0.01	1014.97	Residential	Residential	1.3	Roofs	100	6.85	0.29	0.8	287.76	10.66	14,062.35
8	RuShland Park	R65110	16199	7	LiDAR	3ft	108.04	502.68	0.01	1014.97	Residential	Residential	1.3	Roofs	100	6.85	0.29	0.8	227.66	8.43	11,125.40
9	RuShland Park	R65111	16199	7	LiDAR	3ft	260.45	1797.55	0.04	1014.97	Residential	Residential	1.3	Roofs	100	6.85	0.29	0.8	814.10	30.15	39,784.02
10	RuShland Park	R65112	16199	7	LiDAR	3ft	68.16	194.41	0.00	1014.97	Residential	Residential	1.3	Roofs	100	6.85	0.29	0.8	88.05	3.26	4,302.83
11	RuShland Park	R65113	16199	7	LiDAR	3ft	124.53	607.85	0.01	1014.97	Residential	Residential	1.3	Roofs	100	6.85	0.29	0.8	275.29	10.20	13,453.14
12	RuShland Park	R65114	16199	7	LiDAR	3ft	753.19	7967.74	0.18	1014.97	Residential	Residential	1.3	Lawns	100	6.85	0.29	0.35	1,578.73	58.47	77,150.94
13	RuShland Park	R65115	16199	7	LiDAR	3ft	32.41	48.82	0.00	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	20.73	0.77	1,012.92
14	RuShland Park	R65116	16199	7	LiDAR	3ft	86.44	380.64	0.01	1014.97	Residential	Residential	1.3	Lawns	100	6.85	0.29	0.35	75.42	2.79	3,685.75
15	RuShland Park	R65117	16199	7	LiDAR	3ft	18.00	20.00	0.00	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	8.49	0.31	415.00
16	RuShland Park	R65118	16199	7	LiDAR	3ft	251.99	1189.95	0.03	1014.97	City Right of Way	Public	1.3	Lawns	100	6.85	0.29	0.35	235.78	8.73	11,522.14
17	RuShland Park	R65119	16199	7	LiDAR	3ft	149.19	772.66	0.02	1014.97	Residential	Residential	1.3	Roofs	100	6.85	0.29	0.8	349.93	12.96	17,100.89
Total								**21033.20**	**0.48**										**6,642.47**	**246.02**	**324,610.26**

500-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	RuShland Park	R65103	16199	7	LiDAR	3ft	247.52	1502.01	0.03	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	849.07	31.45	41,493.16
2	RuShland Park	R65104	16199	7	LiDAR	3ft	210.24	1351.75	0.03	1014.97	City Right of Way	Public	1.3	Lawns	500	9.12	0.38	0.35	356.59	13.21	17,426.33
3	RuShland Park	R65105	16199	7	LiDAR	3ft	70.00	299.99	0.01	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	169.58	6.28	8,287.38
4	RuShland Park	R65106	16199	7	LiDAR	3ft	209.27	1780.26	0.04	1014.97	Residential	Residential	1.3	Roofs	500	9.12	0.38	0.8	1,073.45	39.76	52,458.34
5	RuShland Park	R65107	16199	7	LiDAR	3ft	214.12	1748.27	0.04	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	988.28	36.60	48,295.99
6	RuShland Park	R65108	16199	7	LiDAR	3ft	97.98	233.25	0.01	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	131.86	4.88	6,443.67
7	RuShland Park	R65109	16199	7	LiDAR	3ft	115.13	635.37	0.01	1014.97	Residential	Residential	1.3	Roofs	500	9.12	0.38	0.8	383.12	14.19	18,722.43
8	RuShland Park	R65110	16199	7	LiDAR	3ft	108.04	502.68	0.01	1014.97	Residential	Residential	1.3	Roofs	500	9.12	0.38	0.8	303.10	11.23	14,812.21
9	RuShland Park	R65111	16199	7	LiDAR	3ft	260.45	1797.55	0.04	1014.97	Residential	Residential	1.3	Roofs	500	9.12	0.38	0.8	1,083.88	40.14	52,967.92
10	RuShland Park	R65112	16199	7	LiDAR	3ft	68.16	194.41	0.00	1014.97	Residential	Residential	1.3	Roofs	500	9.12	0.38	0.8	117.23	4.34	5,728.73
11	RuShland Park	R65113	16199	7	LiDAR	3ft	124.53	607.85	0.01	1014.97	Residential	Residential	1.3	Roofs	500	9.12	0.38	0.8	366.52	13.57	17,911.34
12	RuShland Park	R65114	16199	7	LiDAR	3ft	753.19	7967.74	0.18	1014.97	Residential	Residential	1.3	Lawns	500	9.12	0.38	0.35	2,101.90	77.85	102,717.74
13	RuShland Park	R65115	16199	7	LiDAR	3ft	32.41	48.82	0.00	1014.97	Residential	Residential	1.3	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	27.60	1.02	1,348.59
14	RuShland Park	R65116	16199	7	LiDAR	3ft	86.44	380.64	0.01	1014.97	Residential	Residential	1.3	Lawns	500	9.12	0.38	0.35	100.41	3.72	4,907.16
15	RuShland Park	R65117	16199	7	LiDAR	3ft	18.00	20.00	0.00	1014.97	City Right of Way	Public	1.3	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	11.31	0.42	552.53
16	RuShland Park	R65118	16199	7	LiDAR	3ft	251.99	1189.95	0.03	1014.97	City Right of Way	Public	1.3	Lawns	500	9.12	0.38	0.35	313.91	11.63	15,340.42
17	RuShland Park	R65119	16199	7	LiDAR	3ft	149.19	772.66	0.02	1014.97	Residential	Residential	1.3	Roofs	500	9.12	0.38	0.8	465.90	17.26	22,767.91
Total								**21033.20**	**0.48**										**8,843.69**	**327.54**	**432,181.84**

Appendix E

Typical Development Scenario: Vintage Township

1-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	Vintage	R310591	72825	8	LiDAR	3ft	47.53	117.01	0.00	1014.97	City Right of Way	Public	5	Lawns	1	2.19	0.09	0.35	7.41	0.27	1,393.20
2	Vintage	R310592	72825	8	LiDAR	3ft	17.72	13.52	0.00	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	1.96	0.07	367.85
3	Vintage	R310593	72825	8	LiDAR	3ft	100.09	225.22	0.01	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	30.57	1.13	5,746.20
4	Vintage	R310594	72825	8	LiDAR	3ft	74.99	290.80	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	39.47	1.46	7,419.56
5	Vintage	R310595	72825	8	LiDAR	3ft	28.58	51.60	0.00	1014.97	City Right of Way	Public	5	Lawns	1	2.19	0.09	0.35	3.27	0.12	614.37
6	Vintage	R310596	72825	8	LiDAR	3ft	67.18	188.16	0.00	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	27.24	1.01	5,120.65
7	Vintage	R310597	72825	8	LiDAR	3ft	144.70	693.00	0.02	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	100.34	3.72	18,859.87
8	Vintage	R310598	72825	8	LiDAR	3ft	64.40	224.83	0.01	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	32.55	1.21	6,118.86
9	Vintage	R310599	72825	8	LiDAR	3ft	159.07	833.40	0.02	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	120.67	4.47	22,680.84
10	Vintage	R310600	72825	8	LiDAR	3ft	287.42	1364.15	0.03	1014.97	Residential	Residential	5	Lawns	1	2.19	0.09	0.35	86.41	3.20	16,242.31
11	Vintage	R310601	72825	8	LiDAR	3ft	100.07	623.66	0.01	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	90.30	3.34	16,972.82
12	Vintage	R310602	72825	8	LiDAR	3ft	68.32	196.14	0.00	1014.97	Residential	Residential	5	Roofs	1	2.19	0.09	0.8	28.40	1.05	5,338.06
13	Vintage	R310603	72825	8	LiDAR	3ft	276.88	787.69	0.02	1014.97	Residential	Residential	5	Lawns	1	2.19	0.09	0.35	49.90	1.85	9,378.72
14	Vintage	R310604	72825	8	LiDAR	3ft	126.35	332.12	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	45.08	1.67	8,473.73
15	Vintage	R310605	72825	8	LiDAR	3ft	102.34	271.03	0.01	1014.97	City Right of Way	Public	5	Lawns	1	2.19	0.09	0.35	17.17	0.64	3,227.00
16	Vintage	R310606	72825	8	LiDAR	3ft	114.37	542.22	0.01	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	73.60	2.73	13,834.36
Total								**6754.54**	**0.16**										**754.36**	**27.94**	**141,788.39**

10-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	Vintage	R310591	72825	8	LiDAR	3ft	47.53	117.01	0.00	1014.97	City Right of Way	Public	5	Lawns	10	4.22	0.18	0.35	14.28	0.53	2,684.61
2	Vintage	R310592	72825	8	LiDAR	3ft	17.72	13.52	0.00	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	3.77	0.14	708.83
3	Vintage	R310593	72825	8	LiDAR	3ft	100.09	225.22	0.01	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	58.91	2.18	11,072.59
4	Vintage	R310594	72825	8	LiDAR	3ft	74.99	290.80	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	76.07	2.82	14,297.04
5	Vintage	R310595	72825	8	LiDAR	3ft	28.58	51.60	0.00	1014.97	City Right of Way	Public	5	Lawns	10	4.22	0.18	0.35	6.30	0.23	1,183.85
6	Vintage	R310596	72825	8	LiDAR	3ft	67.18	188.16	0.00	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	52.50	1.94	9,867.19
7	Vintage	R310597	72825	8	LiDAR	3ft	144.70	693.00	0.02	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	193.35	7.16	36,341.86
8	Vintage	R310598	72825	8	LiDAR	3ft	64.40	224.83	0.01	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	62.73	2.32	11,790.68
9	Vintage	R310599	72825	8	LiDAR	3ft	159.07	833.40	0.02	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	232.52	8.61	43,704.63
10	Vintage	R310600	72825	8	LiDAR	3ft	287.42	1364.15	0.03	1014.97	Residential	Residential	5	Lawns	10	4.22	0.18	0.35	166.52	6.17	31,297.96
11	Vintage	R310601	72825	8	LiDAR	3ft	100.07	623.66	0.01	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	174.01	6.44	32,705.62
12	Vintage	R310602	72825	8	LiDAR	3ft	68.32	196.14	0.00	1014.97	Residential	Residential	5	Roofs	10	4.22	0.18	0.8	54.73	2.03	10,286.13
13	Vintage	R310603	72825	8	LiDAR	3ft	276.88	787.69	0.02	1014.97	Residential	Residential	5	Lawns	10	4.22	0.18	0.35	96.15	3.56	18,072.25
14	Vintage	R310604	72825	8	LiDAR	3ft	126.35	332.12	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	86.87	3.22	16,328.38
15	Vintage	R310605	72825	8	LiDAR	3ft	102.34	271.03	0.01	1014.97	City Right of Way	Public	5	Lawns	10	4.22	0.18	0.35	33.08	1.23	6,218.24
16	Vintage	R310606	72825	8	LiDAR	3ft	114.37	542.22	0.01	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	141.83	5.25	26,657.98
Total								**6754.54**	**0.16**										**1,453.62**	**53.84**	**273,217.82**

Appendix E Continued

100-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	Vintage	R310591	72825	8	LiDAR	3ft	47.53	117.01	0.00	1014.97	City Right of Way	Public	5	Lawns	100	6.85	0.29	0.35	23.18	0.86	4,357.72
2	Vintage	R310592	72825	8	LiDAR	3ft	17.72	13.52	0.00	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	6.12	0.23	1,150.58
3	Vintage	R310593	72825	8	LiDAR	3ft	100.09	225.22	0.01	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	95.62	3.54	17,973.27
4	Vintage	R310594	72825	8	LiDAR	3ft	74.99	290.80	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	123.47	4.57	23,207.29
5	Vintage	R310595	72825	8	LiDAR	3ft	28.58	51.60	0.00	1014.97	City Right of Way	Public	5	Lawns	100	6.85	0.29	0.35	10.22	0.38	1,921.65
6	Vintage	R310596	72825	8	LiDAR	3ft	67.18	188.16	0.00	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	85.21	3.16	16,016.64
7	Vintage	R310597	72825	8	LiDAR	3ft	144.70	693.00	0.02	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	313.85	11.62	58,990.93
8	Vintage	R310598	72825	8	LiDAR	3ft	64.40	224.83	0.01	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	101.83	3.77	19,138.90
9	Vintage	R310599	72825	8	LiDAR	3ft	159.07	833.40	0.02	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	377.44	13.98	70,942.36
10	Vintage	R310600	72825	8	LiDAR	3ft	287.42	1364.15	0.03	1014.97	Residential	Residential	5	Lawns	100	6.85	0.29	0.35	270.29	10.01	50,803.56
11	Vintage	R310601	72825	8	LiDAR	3ft	100.07	623.66	0.01	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	282.45	10.46	53,088.50
12	Vintage	R310602	72825	8	LiDAR	3ft	68.32	196.14	0.00	1014.97	Residential	Residential	5	Roofs	100	6.85	0.29	0.8	88.83	3.29	16,696.69
13	Vintage	R310603	72825	8	LiDAR	3ft	276.88	787.69	0.02	1014.97	Residential	Residential	5	Lawns	100	6.85	0.29	0.35	156.07	5.78	29,335.28
14	Vintage	R310604	72825	8	LiDAR	3ft	126.35	332.12	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	141.01	5.22	26,504.60
15	Vintage	R310605	72825	8	LiDAR	3ft	102.34	271.03	0.01	1014.97	City Right of Way	Public	5	Lawns	100	6.85	0.29	0.35	53.70	1.99	10,093.58
16	Vintage	R310606	72825	8	LiDAR	3ft	114.37	542.22	0.01	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	230.22	8.53	43,271.84
Total								6754.54	0.16										2,359.54	87.39	443,493.38

500-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
1	Vintage	R310591	72825	8	LiDAR	3ft	47.53	117.01	0.00	1014.97	City Right of Way	Public	5	Lawns	500	9.12	0.38	0.35	30.87	1.14	5,801.80
2	Vintage	R310592	72825	8	LiDAR	3ft	17.72	13.52	0.00	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	8.15	0.30	1,531.87
3	Vintage	R310593	72825	8	LiDAR	3ft	100.09	225.22	0.01	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	127.31	4.72	23,929.38
4	Vintage	R310594	72825	8	LiDAR	3ft	74.99	290.80	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	164.39	6.09	30,897.88
5	Vintage	R310595	72825	8	LiDAR	3ft	28.58	51.60	0.00	1014.97	City Right of Way	Public	5	Lawns	500	9.12	0.38	0.35	13.61	0.50	2,558.46
6	Vintage	R310596	72825	8	LiDAR	3ft	67.18	188.16	0.00	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	113.45	4.20	21,324.35
7	Vintage	R310597	72825	8	LiDAR	3ft	144.70	693.00	0.02	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	417.86	15.48	78,539.75
8	Vintage	R310598	72825	8	LiDAR	3ft	64.40	224.83	0.01	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	135.57	5.02	25,481.27
9	Vintage	R310599	72825	8	LiDAR	3ft	159.07	833.40	0.02	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	502.52	18.61	94,451.72
10	Vintage	R310600	72825	8	LiDAR	3ft	287.42	1364.15	0.03	1014.97	Residential	Residential	5	Lawns	500	9.12	0.38	0.35	359.86	13.33	67,639.19
11	Vintage	R310601	72825	8	LiDAR	3ft	100.07	623.66	0.01	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	376.05	13.93	70,681.33
12	Vintage	R310602	72825	8	LiDAR	3ft	68.32	196.14	0.00	1014.97	Residential	Residential	5	Roofs	500	9.12	0.38	0.8	118.27	4.38	22,229.75
13	Vintage	R310603	72825	8	LiDAR	3ft	276.88	787.69	0.02	1014.97	Residential	Residential	5	Lawns	500	9.12	0.38	0.35	207.79	7.70	39,056.61
14	Vintage	R310604	72825	8	LiDAR	3ft	126.35	332.12	0.01	1014.97	Residential	Residential	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	187.74	6.95	35,287.88
15	Vintage	R310605	72825	8	LiDAR	3ft	102.34	271.03	0.01	1014.97	City Right of Way	Public	5	Lawns	500	9.12	0.38	0.35	71.50	2.65	13,438.46
16	Vintage	R310606	72825	8	LiDAR	3ft	114.37	542.22	0.01	1014.97	City Right of Way	Public	5	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	306.51	11.35	57,611.56
Total								6754.54	0.16										3,141.46	116.35	590,461.26

Appendix F

Typical Development Scenario: Orchard Park

1-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
5	Orchard Park	R312902	71349	6	LiDAR	3ft	223.52	1155.64	0.03	1014.97	Residential	Residential	2.65	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	156.87	5.81	15,627.03
12	Orchard Park	R312902	71349	6	LiDAR	3ft	412.64	5392.15	0.12	1014.97	Residential	Residential	2.65	Roofs	1	2.19	0.09	0.8	780.75	28.92	77,776.00
30	Orchard Park	R312902	71349	6	LiDAR	3ft	433.95	2452.18	0.06	1014.97	Residential	Residential	2.65	Lawns	1	2.19	0.09	0.35	155.34	5.75	15,474.44
31	Orchard Park	R312902	71349	6	LiDAR	3ft	68.24	138.71	0.00	1014.97	Residential	Residential	2.65	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	18.83	0.70	1,875.75
33	Orchard Park	R312902	71349	6	LiDAR	3ft	75.25	57.32	0.00	1014.97	City Right of Way	Public	2.65	Lawns	1	2.19	0.09	0.35	3.63	0.13	361.71
35	Orchard Park	R312902	71349	6	LiDAR	3ft	240.11	1514.17	0.03	1014.97	Residential	Residential	2.65	Lawns	1	2.19	0.09	0.35	95.92	3.55	9,555.14
37	Orchard Park	R312902	71349	6	LiDAR	3ft	92.70	62.36	0.00	1014.97	City Right of Way	Public	2.65	Lawns	1	2.19	0.09	0.35	3.95	0.15	393.52
48	Orchard Park	R312902	71349	6	LiDAR	3ft	83.85	224.62	0.01	1014.97	City Right of Way	Public	2.65	Lawns	1	2.19	0.09	0.35	14.23	0.53	1,417.46
49	Orchard Park	R312902	71349	6	LiDAR	3ft	193.14	355.90	0.01	1014.97	City Right of Way	Public	2.65	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	48.31	1.79	4,812.60
50	Orchard Park	R312902	71349	6	LiDAR	3ft	102.02	281.16	0.01	1014.97	City Right of Way	Public	2.65	Asphalt and Concrete Pavments	1	2.19	0.09	0.75	38.17	1.41	3,801.92
55	Orchard Park	R312902	71349	6	LiDAR	3ft	200.03	1275.20	0.03	1014.97	City Right of Way	Public	2.65	Roofs	1	2.19	0.09	0.8	184.64	6.84	18,393.42
60	Orchard Park	R312902	71349	6	LiDAR	3ft	188.20	778.24	0.02	1014.97	City Right of Way	Public	2.65	Roofs	1	2.19	0.09	0.8	112.68	4.17	11,225.26
Total								**13687.64**	**0.31**										**1,613.31**	**59.75**	**160,714.25**

10-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
5	Orchard Park	R312902	71349	6	LiDAR	3ft	223.52	1155.64	0.03	1014.97	Residential	Residential	2.65	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	302.28	11.20	30,112.36
12	Orchard Park	R312902	71349	6	LiDAR	3ft	412.64	5392.15	0.12	1014.97	Residential	Residential	2.65	Roofs	10	4.22	0.18	0.8	1,504.45	55.72	149,869.74
30	Orchard Park	R312902	71349	6	LiDAR	3ft	433.95	2452.18	0.06	1014.97	Residential	Residential	2.65	Lawns	10	4.22	0.18	0.35	299.33	11.09	29,818.33
31	Orchard Park	R312902	71349	6	LiDAR	3ft	68.24	138.71	0.00	1014.97	Residential	Residential	2.65	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	36.28	1.34	3,614.45
33	Orchard Park	R312902	71349	6	LiDAR	3ft	75.25	57.32	0.00	1014.97	City Right of Way	Public	2.65	Lawns	10	4.22	0.18	0.35	7.00	0.26	697.00
35	Orchard Park	R312902	71349	6	LiDAR	3ft	240.11	1514.17	0.03	1014.97	Residential	Residential	2.65	Lawns	10	4.22	0.18	0.35	184.83	6.85	18,412.18
37	Orchard Park	R312902	71349	6	LiDAR	3ft	92.70	62.36	0.00	1014.97	City Right of Way	Public	2.65	Lawns	10	4.22	0.18	0.35	7.61	0.28	758.28
48	Orchard Park	R312902	71349	6	LiDAR	3ft	83.85	224.62	0.01	1014.97	City Right of Way	Public	2.65	Lawns	10	4.22	0.18	0.35	27.42	1.02	2,731.35
49	Orchard Park	R312902	71349	6	LiDAR	3ft	193.14	355.90	0.01	1014.97	City Right of Way	Public	2.65	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	93.09	3.45	9,273.60
50	Orchard Park	R312902	71349	6	LiDAR	3ft	102.02	281.16	0.01	1014.97	City Right of Way	Public	2.65	Asphalt and Concrete Pavments	10	4.22	0.18	0.75	73.54	2.72	7,326.08
55	Orchard Park	R312902	71349	6	LiDAR	3ft	200.03	1275.20	0.03	1014.97	City Right of Way	Public	2.65	Roofs	10	4.22	0.18	0.8	355.79	13.18	35,443.03
60	Orchard Park	R312902	71349	6	LiDAR	3ft	188.20	778.24	0.02	1014.97	City Right of Way	Public	2.65	Roofs	10	4.22	0.18	0.8	217.13	8.04	21,630.40
Total								**13687.64**	**0.31**										**3,108.76**	**115.14**	**309,686.82**

Appendix F Continued

100-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
5	Orchard Park	R312902	71349	6	LiDAR	3ft	223.52	1155.64	0.03	1014.97	Residential	Residential	2.65	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	490.67	18.17	48,879.07
12	Orchard Park	R312902	71349	6	LiDAR	3ft	412.64	5392.15	0.12	1014.97	Residential	Residential	2.65	Roofs	100	6.85	0.29	0.8	2,442.06	90.45	243,271.97
30	Orchard Park	R312902	71349	6	LiDAR	3ft	433.95	2452.18	0.06	1014.97	Residential	Residential	2.65	Lawns	100	6.85	0.29	0.35	485.88	18.00	48,401.80
31	Orchard Park	R312902	71349	6	LiDAR	3ft	68.24	138.71	0.00	1014.97	Residential	Residential	2.65	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	58.90	2.18	5,867.06
33	Orchard Park	R312902	71349	6	LiDAR	3ft	75.25	57.32	0.00	1014.97	City Right of Way	Public	2.65	Lawns	100	6.85	0.29	0.35	11.36	0.42	1,131.38
35	Orchard Park	R312902	71349	6	LiDAR	3ft	240.11	1514.17	0.03	1014.97	Residential	Residential	2.65	Lawns	100	6.85	0.29	0.35	300.02	11.11	29,887.08
37	Orchard Park	R312902	71349	6	LiDAR	3ft	92.70	62.36	0.00	1014.97	City Right of Way	Public	2.65	Lawns	100	6.85	0.29	0.35	12.36	0.46	1,230.86
48	Orchard Park	R312902	71349	6	LiDAR	3ft	83.85	224.62	0.01	1014.97	City Right of Way	Public	2.65	Lawns	100	6.85	0.29	0.35	44.51	1.65	4,433.60
49	Orchard Park	R312902	71349	6	LiDAR	3ft	193.14	355.90	0.01	1014.97	City Right of Way	Public	2.65	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	151.11	5.60	15,053.12
50	Orchard Park	R312902	71349	6	LiDAR	3ft	102.02	281.16	0.01	1014.97	City Right of Way	Public	2.65	Asphalt and Concrete Pavments	100	6.85	0.29	0.75	119.38	4.42	11,891.86
55	Orchard Park	R312902	71349	6	LiDAR	3ft	200.03	1275.20	0.03	1014.97	City Right of Way	Public	2.65	Roofs	100	6.85	0.29	0.8	577.53	21.39	57,531.94
60	Orchard Park	R312902	71349	6	LiDAR	3ft	188.20	778.24	0.02	1014.97	City Right of Way	Public	2.65	Roofs	100	6.85	0.29	0.8	352.46	13.05	35,110.96
Total								**13687.64**	**0.31**										**5,046.21**	**186.90**	**502,690.69**

500-Year

OBJECTID	Subdivision	PROP_ID_LCAD	FID	Project_Parcel_ID	TOPO_Source	Raster_Size	SHAPE_LENGTH	SHAPE_AREA	AREA_ACRES	WATERSHED_ACRES	Property_Owner	Land_Use	Du/Ac	Land_Cover	Year_Storm	Precip_Inches	Inches_Per_Hour	Runoff_Coefficient	Volume CF (Q*86400)	Volume CY (CF/27)	Developed_Volume_DU/AC_CY ((CF/27*(DU/AC_*1014.97))
5	Orchard Park	R312902	71349	6	LiDAR	3ft	223.52	1155.64	0.03	1014.97	Residential	Residential	2.65	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	653.27	24.20	65,076.95
12	Orchard Park	R312902	71349	6	LiDAR	3ft	412.64	5392.15	0.12	1014.97	Residential	Residential	2.65	Roofs	500	9.12	0.38	0.8	3,251.33	120.42	323,889.11
30	Orchard Park	R312902	71349	6	LiDAR	3ft	433.95	2452.18	0.06	1014.97	Residential	Residential	2.65	Lawns	500	9.12	0.38	0.35	646.89	23.96	64,441.52
31	Orchard Park	R312902	71349	6	LiDAR	3ft	68.24	138.71	0.00	1014.97	Residential	Residential	2.65	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	78.41	2.90	7,811.33
33	Orchard Park	R312902	71349	6	LiDAR	3ft	75.25	57.32	0.00	1014.97	City Right of Way	Public	2.65	Lawns	500	9.12	0.38	0.35	15.12	0.56	1,506.30
35	Orchard Park	R312902	71349	6	LiDAR	3ft	240.11	1514.17	0.03	1014.97	Residential	Residential	2.65	Lawns	500	9.12	0.38	0.35	399.44	14.79	39,791.26
37	Orchard Park	R312902	71349	6	LiDAR	3ft	92.70	62.36	0.00	1014.97	City Right of Way	Public	2.65	Lawns	500	9.12	0.38	0.35	16.45	0.61	1,638.75
48	Orchard Park	R312902	71349	6	LiDAR	3ft	83.85	224.62	0.01	1014.97	City Right of Way	Public	2.65	Lawns	500	9.12	0.38	0.35	59.26	2.19	5,902.83
49	Orchard Park	R312902	71349	6	LiDAR	3ft	193.14	355.90	0.01	1014.97	City Right of Way	Public	2.65	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	201.18	7.45	20,041.52
50	Orchard Park	R312902	71349	6	LiDAR	3ft	102.02	281.16	0.01	1014.97	City Right of Way	Public	2.65	Asphalt and Concrete Pavments	500	9.12	0.38	0.75	158.93	5.89	15,832.66
55	Orchard Park	R312902	71349	6	LiDAR	3ft	200.03	1275.20	0.03	1014.97	City Right of Way	Public	2.65	Roofs	500	9.12	0.38	0.8	768.91	28.48	76,597.26
60	Orchard Park	R312902	71349	6	LiDAR	3ft	188.20	778.24	0.02	1014.97	City Right of Way	Public	2.65	Roofs	500	9.12	0.38	0.8	469.26	17.38	46,746.27
Total								**13687.64**	**0.31**										**6,718.46**	**248.83**	**669,275.78**