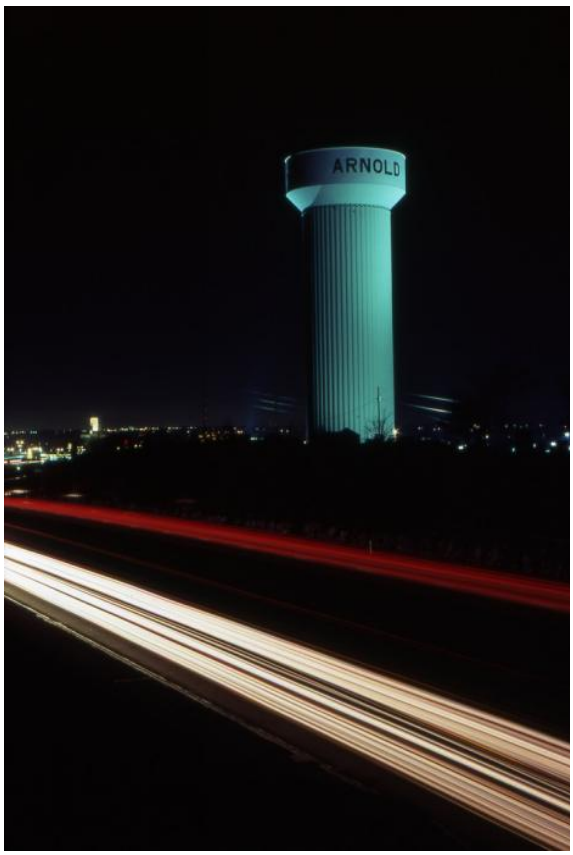
Infrastructure Framework

INTRODUCTION

The infrastructure available to Arnold residents contained in this framework include public potable water, public sanitary sewer, and stormwater management. Some of these services are provided by governmental jurisdictions and agencies other than Arnold. Public infrastructure is an important foundation of quality of life in Arnold, though largely taken for granted. Efficient facilities are vital to most daily activities and require regular maintenance and upgrading both to meet the demands of a growing population and to be sensitive to environmental resources.

The quality and availability of these services influence the type, timing, and density of development in the future. Conversely, development patterns can have a significant impact on the ability of a City to pay and maintain these services in the future. The primary purpose of the Infrastructure Framework chapter is to define and plan for new public infrastructure systems to serve the community through 2030.



Arnold Water Tower .

Framework Structure

For the Comprehensive Plan Update, three types of infrastructure services have been assessed in this Framework chapter, they include:

- **Public Potable Water encompasses water supply, treatment, storage and water delivery to residents.**
- **Public Sanitary Sewer Service systems collect wastewater from all sources and convey it to the treatment facility for residents.**
- **Stormwater Management encompasses managing runoff from rain events to control or mitigate conveyance, treatment, recharge, mitigation, reuse and management of events for residents.**

PUBLIC POTABLE WATER SERVICE

Water Supply Study Area Boundary

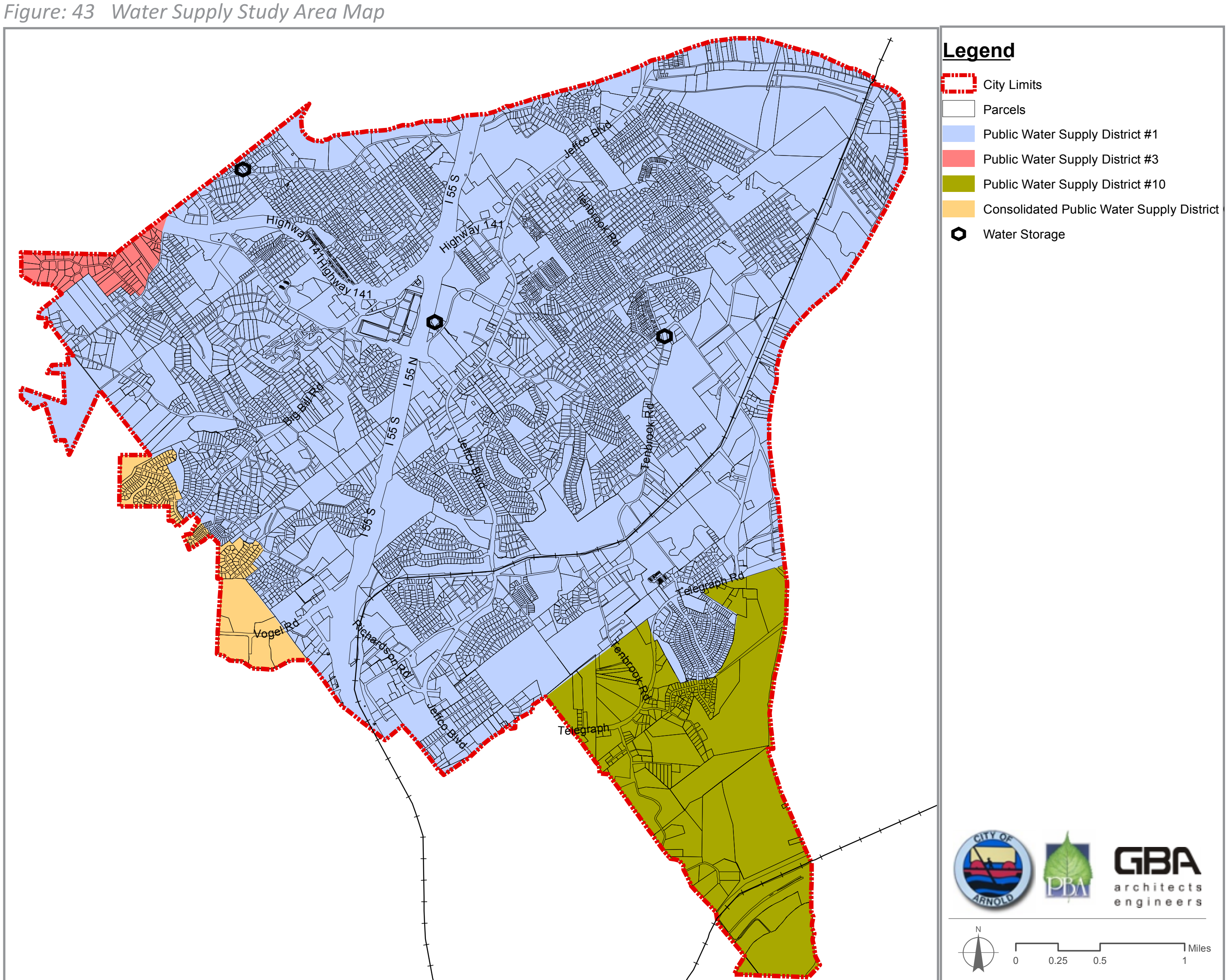
Within the study area boundary, there are four public potable water service providers: 1) Public Water Supply District No. 1, 2) Public Water Supply District No. 3, 3) Public Water Supply District No. 10, and 4) Consolidated Public Water Supply District C-1. The service area boundaries within City limits are shown in the illustration below.

Water Supply

All of the water service providers obtain their water from Missouri American Water via the Meramec River Plant. Therefore, current added capacity is limited only by the ability of the Districts to modify contracts with Missouri American for additional supply.

Water Supply Study Area Map

Figure: 43 Water Supply Study Area Map



Public Water Supply District No. 1

Public Water Supply District No. 1 serves over ninety percent of the City of Arnold and purchases and obtains water from Missouri American Water Company via three connections: one sixteen-inch connection along US 61-67, two parallel eight-inch lines on Lonedell Road west of Interstate 55, and two parallel sixteen-inch mains just east of Interstate 55. These three connections have a total contracted supply capacity of 7.5 million gallons per day (MGD) with average daily usage of 2.5 MGD and a peak day usage of 4.5 MGD. Currently there is an adequate water supply available for the areas of undeveloped land within the study area.

Public Water Supply District No. 3

Public Water Supply District No. 3 serves a small portion of the City of Arnold where subdivisions have been annexed into City limits. Public Water Supply District No. 3 purchases water from Missouri American Water Company. This district has no plans for expansion in the City of Arnold.

Public Water Supply District No. 10

Public Water Supply District No. 10 purchases and obtains water from Missouri American Water Company via two parallel ten-inch lines crossing the Meramec River at Missouri State Highway 231. The district has eight percent of its customers living within the corporate limits of Arnold. Currently there is an adequate capacity of water supply available for the areas of undeveloped land within the study area.

Consolidated Public Water Supply District C-1

Consolidated Public Water Supply District C-1 serves a small portion of the City of Arnold and purchases water from Missouri American Water Company. The district also holds four deep wells that had originally served the district for emergency purposes.

Water Storage and Distribution

Public Water Supply District No. 1

All of this district's water mains are constructed of cast iron, ductile iron, asbestos cement, or polyvinyl chloride (PVC) pipe. Some water mains are over 50 years old. The district currently has annual water main replacements budgeted to replace and upsize existing two-inch ductile iron water pipes. The district water mains in the study area boundary vary from two-inches to sixteen-inches in diameter.

The district currently has 2 million gallons of water storage in the distribution system. The storage facilities are adequate to meet normal and peak demands. The district currently has one 1,000,000 gallon elevated tank (located on the east side of Interstate 55) and two ground level tanks with capacities of 600,000 gallons (located on Lonedell Road) and 400,000 gallons (located on Tenbrook Road).

Public Water Supply District No. 3

All of this district's water mains are constructed of polyvinyl chloride (PVC) pipe. Most of the water mains in the study area are about 20 years old. The district currently does not have an annual budget line item for water main replacements or capital improvements.

All repairs in this district are handled as problems arise as an emergency repair. The district water mains in the study boundary area are eight-inches in diameter. The volume of water storage and amount dedicated for the City are not available from the District.

Public Water Supply District No. 10

All of this district's water mains are constructed of cast iron and ductile iron pipe. Some water mains are over 40 years old. The district currently does not have an annual budget line item for water main replacements or capital improvements. All repairs in this district are handled as problems arise as an emergency repair. The district water mains in the study boundary area vary from six-inches to twelve-inches in diameter.

The district currently has 1.1 million gallons of water storage in the distribution system. The storage facilities are adequate to meet normal and peak demands. The district currently has one 100,000 gallon elevated tank and a 1,000,000 gallon ground level storage tank, both of which are more than 1.5 miles from the corporate limits.

Consolidated Public Water Supply District C-1

All of this district's water mains are constructed of polyvinyl chloride (PVC) and ductile iron pipe. Some of the water mains are over 40 years old. The district currently does not have an annual budget for water main replacements. The district water mains in the study boundary area vary from six-inches to 20-inches in diameter.

District C-1's system consists of over 175 miles of pipelines, 4 ground storage tanks with re-pump facilities with a combined capacity of 4.2 million gallons, along with 4 elevated storage tanks with a combined capacity of 1.3 million gallons. All of the listed storage tanks and most of the water system for district C-1 are located outside of the study area.

Development Issues

The current policy of all the water service providers is that as land develops, the land developers or the adjacent property owners will bear the cost for the extension of the public water mains required to serve the developing area to meet both fire protection and domestic needs and the district then charge a tap on fee for each connection made to the system. Consequently, developers would need to consider the cost associated with the extension of public water mains in their development plans.

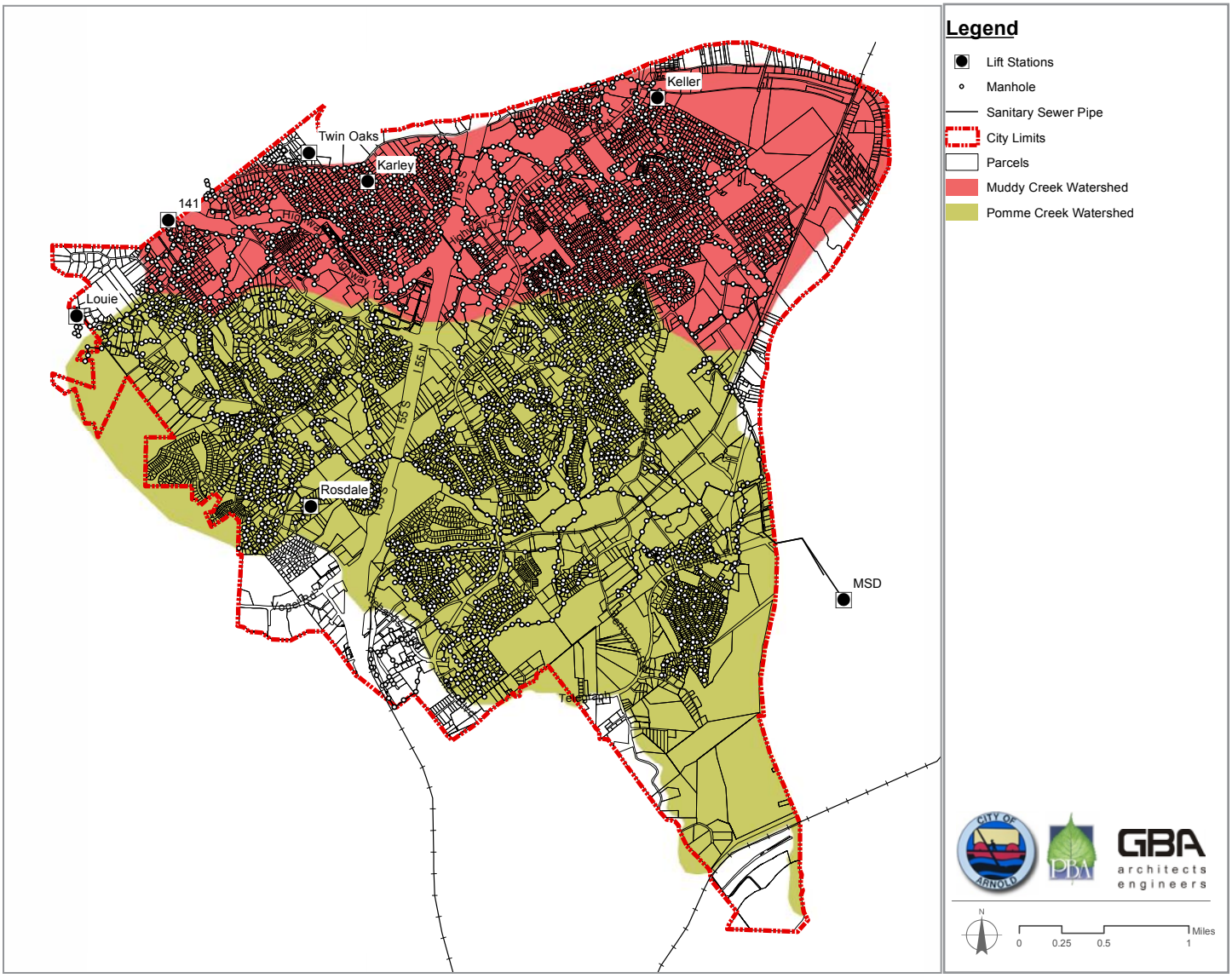
PUBLIC SANITARY SEWER SERVICE

Sanitary Sewer Study Area

Prior to the incorporation of the City of Arnold, the area lacked a central sewer authority. This and rapid growth led to the construction of numerous small treatment facilities, primarily lagoons and individual residential septic tanks. Due to the resulting pollution and to the lack of a central sewer authority, the Clean Water Commission (CWC) placed a moratorium on the issuance of sewage facility construction permits in northeast Jefferson County (inclusive of the City of Arnold) from May, 1971 to September, 1971, pending a study of the area by the CWC. In September of 1971, the CWC lifted the moratorium to permit construction of treatment facilities that serve the entire watershed or replace existing inadequate facilities. A study completed by Zurheide-Hermann, Inc. and the East West Gateway Coordinating Council in September of 1972 identified 71 known treatment

Sanitary Sewer Area Map

Figure: 44 Sanitary Sewer Area Map



facilities located within the City Limits. The result of the moratorium and subsequent treatment restrictions was a tremendous reduction in the rate of growth in the City of Arnold.

In November, 1973 the City retained the services of Horner and Shifrin, Inc. to develop alternative concepts to alleviate the multiple individual treatment facilities for the City and surrounding tributary areas. Horner and Shifrin, Inc. prepared a report that was adopted by City Council in May, 1974. In November, 1975 the voters passed a bond issue to construct a sanitary sewer collection system and an interim municipal wastewater treatment facility (the Meramec Lagoon Facility) located in St. Louis County and operated and maintained by the Metropolitan St. Louis Sewer District (MSD). In 2007, MSD completed construction of the Lower Meramec Treatment Facility (LMTF), and the City's wastewater was diverted and conveyed to this facility. The City pays MSD for treatment based on the volume of wastewater conveyed to the LMTF. Once wastewater was conveyed to MSD's LMTF, the Meramec Lagoon Facility was decommissioned.

The City of Arnold has agreed to a flow allocation of 4.5 MGD for average flow and a peak flow (based on peak day) of 18 MGD. In the first quarter of 2008 the City was billed for an average daily flow of 4.32 MGD. Therefore the City has little additional capacity prior to exceeding the existing flow allocation based on the existing MSD agreement; however MSD has significant excess capacity to treat additional flows with an amended agreement. Based on the age of the existing collection system and a peaking factor of 4.0 (peak flow (18 MGD) / average daily flow (4.5 MGD)), there is concern that the peak flow may occasionally be exceeded during wet weather events. Similar systems throughout the Midwest have peaking factors well above 4.0.

Wastewater Rate Study

In 2008 the City retained the services of Municipal & Financial Services Group (MFSG) to prepare a *Wastewater Rate Study.* The study indicated the following findings:

1. Current sewer rates do not produce sufficient cash revenue to cover cash revenue requirements within the Sewer Fund for Fiscal Year 2009 or the years following. Based on projected water sales, the current rates will produce cash revenues roughly 20% less than the required cash revenue in Fiscal Year 2009 with subsequent significant shortfalls annually over the planning period.

Sanitary Sewer.

2. The capital expenses, in the form of annual debt service, related to the new Lower Meramec Treatment Plant is the primary reason for the current and projected shortfall in the Sewer Fund.

3. The City does not have any dedicated reserves within the Sewer Fund.

4. The City incurs costs while operating and maintaining the sewer system that do not benefit customers in the Rock Creek District.

5. A significant portion of the City's sewer collection system was installed in the 1950's and will reach its estimated useful

life over the next 10 years.

6. The current residential sewer rate structure which charges all customers the same fixed amount does not allocate costs proportionately among residential customers (i.e. large residential users pay the same amount as small users).

7. The current connection fee of $2,500 for connecting to the wastewater system is set at the appropriate level to recover the cost of providing capacity to new wastewater connections.

Based on these finding, Municipal & Financial Services Group made the following recommendations:

1. City should formally establish an O&M Reserve and a Repair, Renewal and Rehabilitation Reserve for the sewer system. That the City begins contributing to the "3R" Reserve by Fiscal Year 2012 at the latest to allow the City to begin planning for the significant repairs and replacements that will be required within the collection system as it begins to reach its useful life.

2. The City charge Rock Creek customers approximately 17% less than City of Arnold customers due to the fact that the City does not provide local maintenance to lines serving these customers and because the City incurs expenses not related to serving these customers.

3. The City adopt a new rate structure that will more appropriately charge residential customers based on their contribution to the City's system and the costs they cause the City to incur. The rate structure consists of a fixed charge which includes 15,000 gallons of usage per quarter and a usage charge based on winter quarter usage for residential customers and actual usage for non-residential customers. The following table presents the current sewer rates and the recommended rates for Fiscal Year 2009.

4. We recommend that the City maintain its sewer connection fee set at $2,500 per connection.

Based on these recommendations the City has begun increasing the sewer rates in subsequent years; however, the amounts of increases have not been to the level recommended by MSFG primarily due the current economy. The City's primary funding lapse is in the area of system rehabilitation and reconstruction as the original system ages.

Sanitary Sewer Collection System

Currently, the City of Arnold provides sanitary sewer service to approximately 8,820 customer accounts. Of these 8,820 accounts there are approximately 340 non-residential sewer accounts in the City. The 8,820 accounts also consist of providing sanitary sewer service to approximately 500 customer accounts to properties in other sanitary sewer districts. Approximately 480 of the 500 accounts are located within the boundaries of the Rock Creek Sanitary Sewer District (RCSSD). Within the account located in the RCSSD, the City is not responsible for the maintenance of the collection system.

The majority of the sewer collection system was constructed in the 1950's through the 1970's and the system is constructed of vitrified clay pipe (VCP), concrete and poly vinyl chloride (PVC) pipe. The Sanitary Sewer Map shown in this section, identifies the primary

sewer lines and lift station locations. Within the study boundary area, the sanitary sewer collection system consists of approximately 242 lineal miles of sewers that range in size from 6" to 27". The majority, approximately 51%. of the pipe network is VCP. The collection system also has six (6) lift stations. These lift stations are identified below and have the associated pumping capacities:

Lift Station Name	Pumping Capacity
• Keller	300 GPM (gallons per minute)
• Twin Oaks	100 GPM
• 141	130 GPM
• Louie	50 GPM
• Rosedale	55.5 GPM
• Karley	1 GPM

Gaps In Service

There are some obvious gaps in public sanitary sewer service within the study boundary area. Some of these gaps have individual residences or small subdivisions with large acre tracts that are on septic systems. Septic systems generally work fine for a period of time, but due to the presence of high water tables and restrictive soils in the area, this type of system can and often does result in significant maintenance and health issues. When the public sanitary sewers are extended, an effort is made to connect those residents on septic systems to the public sewer system. In addition, due to the steep terrain in undeveloped areas of the City several of these undeveloped areas will be costly to provide sanitary sewer service.

The City is currently under contract with the project team of Fribis Engineering, HDR and Trekk to perform a Sanitary Sewer Evaluation Study (SSES) for the City's sanitary sewer collection system. Work on the study began in June 2010 and is scheduled to be completed in 2012. The work consists of flow and rainfall monitoring, inflow and infiltration (I/I) investigations, GIS mapping of the system and improvement recommendations. The project team, through flow monitoring has identified approximately eight (8) sub-watersheds that have significant I/I issues. System improvement recommendations will be presented in 2012 when the SSES is completed. It is important to keep in mind that another benefit to having proper management of stormwater facilities is the removal and prevention of inflow and infiltration (I&I) into the sanitary sewer system.

Development Issues

The study area has two (2) principal watersheds consisting of the Pomme Creek Watershed and the Muddy Creek Watershed. The Pomme Creek Watershed encompasses the southern half of the City and the Muddy Creek consists of the northern half of the City. The Pomme and Muddy Creek Watersheds have been fully developed with the exception of relatively small pockets and unsewered existing developments that haven't been sewered due to terrain issues. The most significant issue with the development of land tracts is being able to provide public sanitary sewer service.

This is due to the following:

- **Large cost to install gravity sewer mains and wastewater treatment facilities**

- **Environmental issues associated with obtaining government approval for new wastewater treatment plants and/or lift stations**
- **Public sentiment against constructing treatment facilities and/or lift stations near residential or commercial developments**

Public Funds

Public funds (local) available for the design and construction of wastewater collection and treatment facilities to serve the study area are limited. State and Federal funds through the State Revolving Fund Loan program are readily available at attractive interest rates. Providing public sanitary sewer service to the study area will require a considerable amount of gravity sewers, lift stations and force mains, which will be a significant capital expenditure.

The key to development within the study area will be to obtain sufficient funding for the City to be able to install key infrastructure components such as lift stations or trunk sewers within each watershed. Another key issue to the development of the study area is the capacity of the existing sewers and treatment facility to receive more flows. Solving the infiltration and inflow problems in the existing sewer collection system is a key to maintaining sewer service for all without negative health issues, interceptor capacity issues and treatment capacity issues. If this problem remains unsolved, additional sewer flows from the developing areas will need to be directed elsewhere that may include a new treatment facility.

Sporadic Development Patterns

Another issue that has and will complicate matters in the study area is when development occurs sporadically throughout the watershed. When development occurs in this manner, it becomes increasingly more difficult to bring sewer service to each individual area cost effectively. If a systematic development approach from the lower to the upper parts of the watershed can be developed, the funding of wastewater collection improvements becomes easier to achieve.

Installation of gravity sewers and treatment facilities are the most preferred, desirable and cost effective means for collecting and treating wastewater flows primarily due to health issues and system maintenance. However, due to permitting constraints with federal and state agencies as well as public opinion it is very difficult to construct new wastewater treatment facilities today. The only other alternative is to install a system of gravity sewers draining to lift stations that then pump sewage through force mains to the existing treatment facility, which is expanded as necessary. This second approach to providing sanitary sewer service limits development.

Currently MSD provides sufficient treatment capacity to allow for substantial development within and surrounding the City of Arnold.

Infrastructure construction.

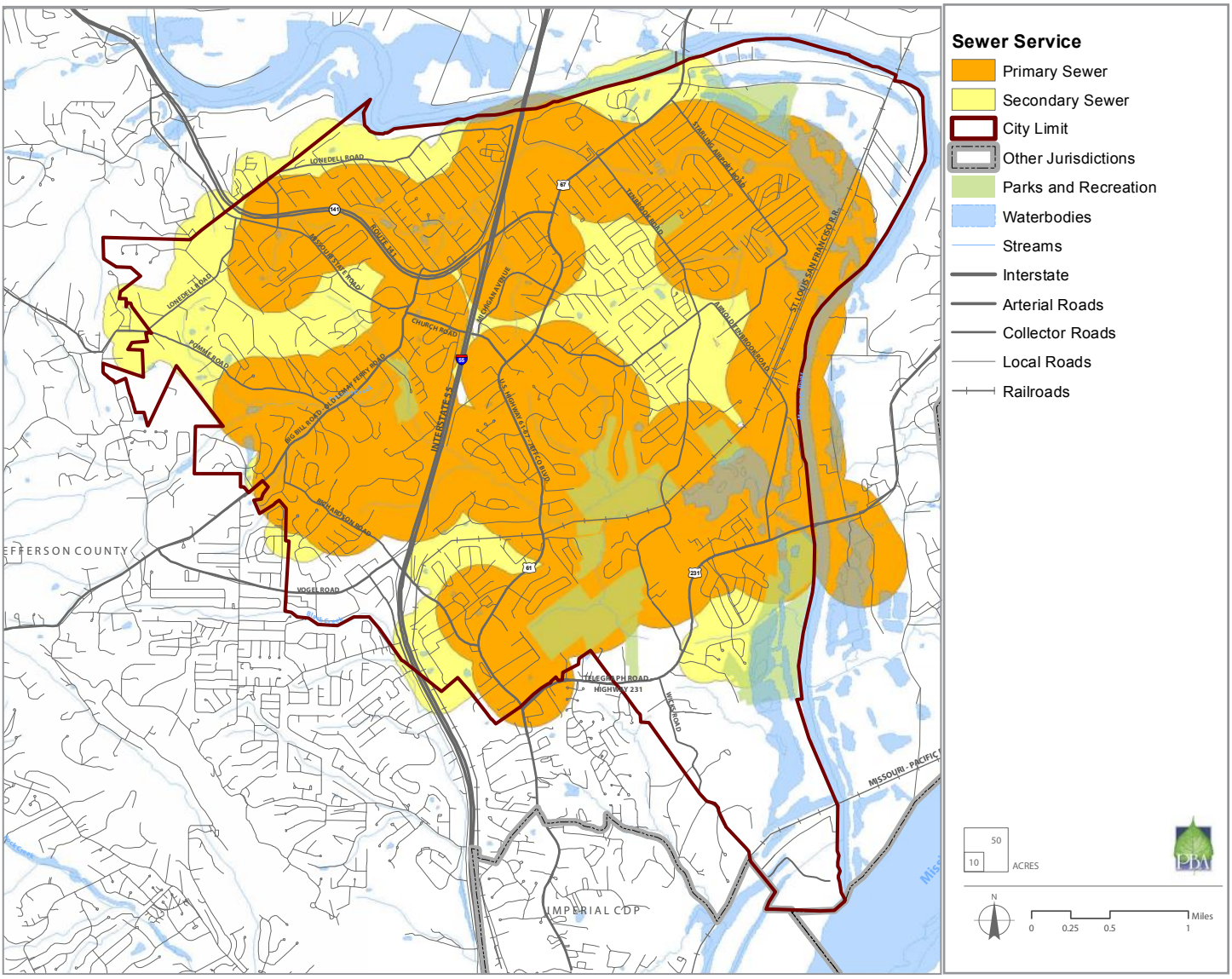
Sanitary Sewer Service Analysis

The Consultant Team utilized the Susceptibility to Change analysis to assess the urban growth potential of the City. Five factors of road access, projected growth areas, water and sewer infrastructure, location of parks and trails, and land cover were ranked based on attributes; all composite factor scores were then combined. The higher values represent ideal conditions for change and lower values represent conditions less likely to change.

Analysis values for sanitary sewer access were calibrated at three levels from “areas within one-quarter mile (1/4)” to “areas within one-eighth mile (1/8)” to “no sewer access”. Areas identified as highly susceptible to change, colored orange on the map, have excellent sewer access. The light yellow areas illustrate those areas generally not served by sewers.

Sanitary Sewer Service Analysis Map

Figure: 45 Sanitary Sewer Service Analysis Map



PUBLIC STORMWATER MANAGEMENT

Stormwater Area Boundary

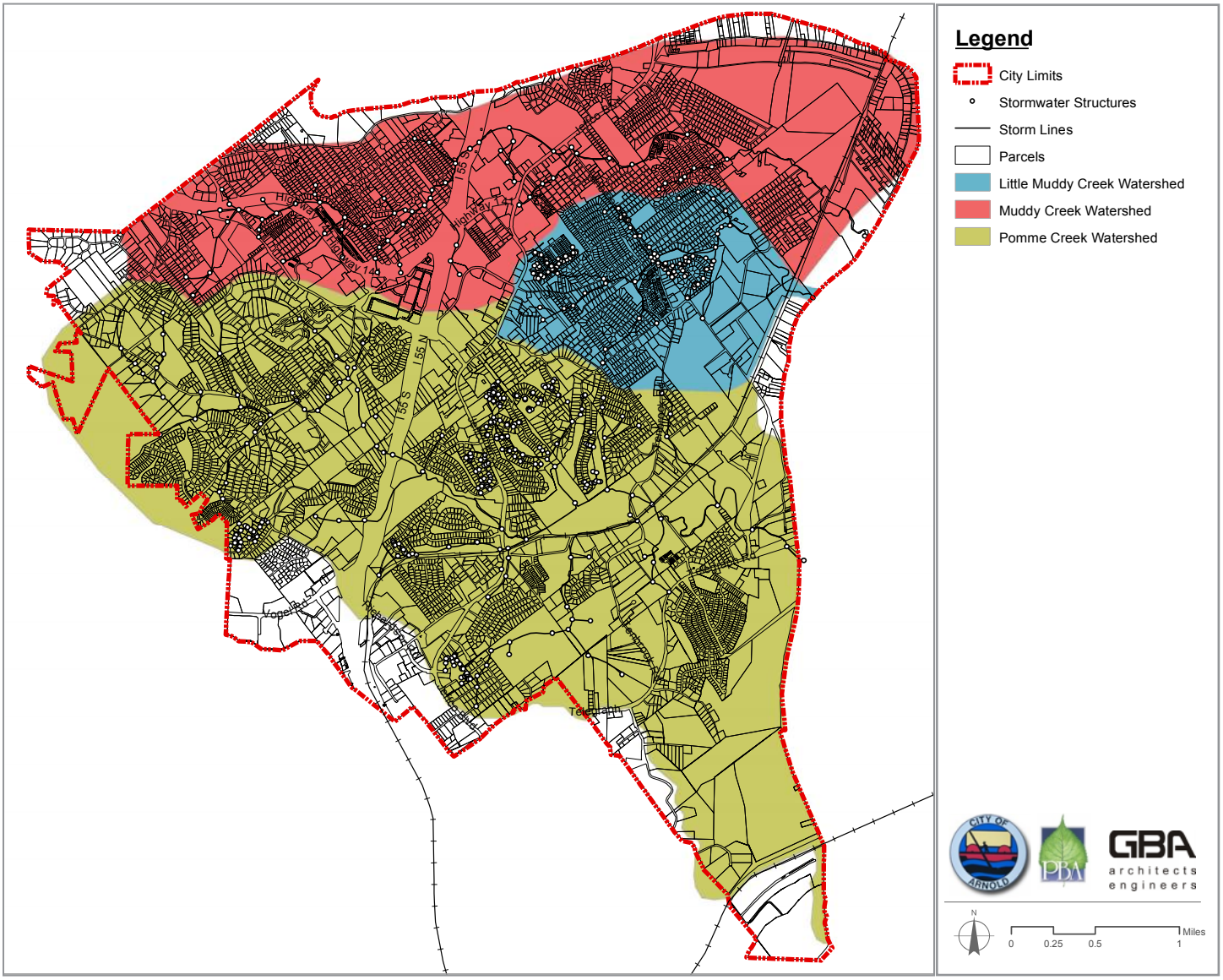
Located at the confluence of the Meramec and Mississippi Rivers the study area has three (3) principal drainage basins that ultimately flow to the Meramec River, which are shown on the illustration below:

Pomme Creek Watershed

The Pomme Creek watershed drains eastward to the Meramec River and has a drainage area of approximately 6.7 square miles. Pomme Creek is classified as a Class P Stream as listed in 10 CSR 20-7.031. A Class P stream is defined as a stream which maintains permanent flow during drought conditions. Pomme Creek has use designations for Livestock and Wildlife Watering and for the Protection of Aquatic Life and Human Health.

Stormwater Area Map

Figure: 46 Stormwater Area Map



Muddy Creek Watershed

The Muddy Creek watershed drains east to the Meramec River and has a drainage area of approximately 2.3 square miles. Muddy Creek is an unclassified stream.

Little Muddy Creek Watershed

Little Muddy Creek watershed drains east to the Meramec River and has a drainage area of less than one square mile. Little Muddy Creek is an unclassified stream.

Arnold 2004 Stormwater Master Plan

The City of Arnold recently completed a stormwater master plan which included directives and milestones to comply with the NPDES Phase II stormwater requirements. These requirements are to track and improve stormwater discharges by reducing stormwater runoff quantity and improving stormwater runoff quality. Best Management Practices (BMPs) can improve stormwater quality by mitigating extreme pH values and assisting in the removal of sediment, petroleum base materials, biochemical oxygen demand (BOD), metals, bacteria, nutrients, toxic organic compounds and other substances that may be present in harmful concentrations. Key stormwater management issues currently facing the City include the following:

Arnold park flood.

1. Provide and organize technical information (maps, studies, reports, etc.) in electronic format for quick distribution to City staff and outside professionals who will be able to use it for design and planning of stormwater improvements.
2. Provide information to the public about the NPDES Phase II stormwater requirements and educating the public on what they can do to help implement BMPs.
3. Develop data on existing stormwater facilities that can be tracked and speed up reporting requirements for regulatory agencies and provide valuable information for planning and design.
4. Continue implementing the Stormwater Management Utility Implementation Plan from the *2004 Stormwater Master Plan*.
5. Continue implementing the GIS Mapping as detailed in the 2004 Stormwater Master Plan.
6. Continue implementing stormwater improvements as detailed in the 2004 Stormwater Master Plan:
7. Six Roads South – Culvert replacement and embankment lining is recommended along with regular maintenance to clear debris.
8. Web Terrace – Culvert replacement and embankment lining is recommended along with regular maintenance to clear debris.
9. Rosewood Subdivision – Replace undersized inlets along with regular maintenance to clear debris.
10. Christ Drive and Maple Meadows – New inlets and piped stormwater system conveyance be installed.

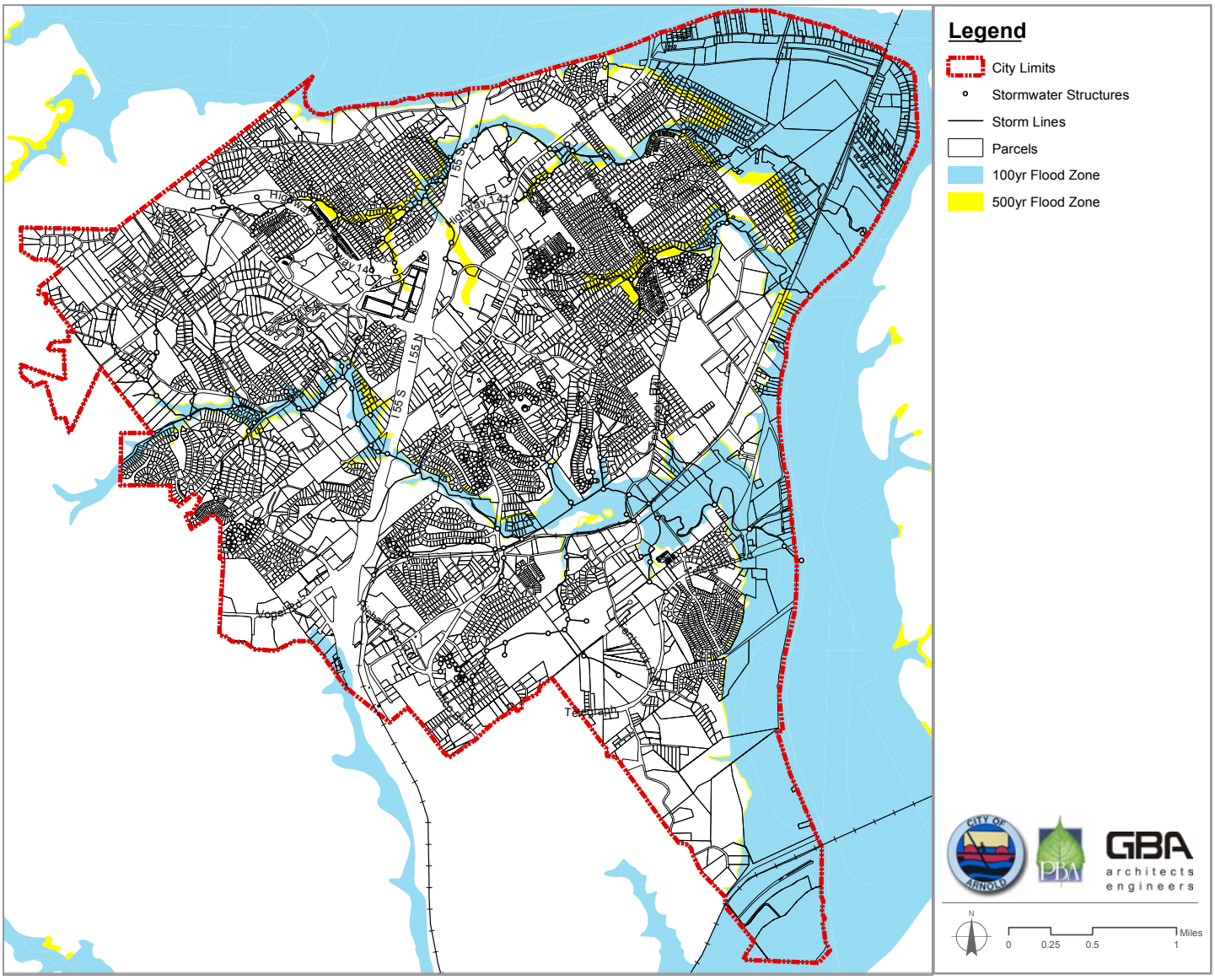
Arnold flooding

Past Flooding Events

The City of Arnold is affected by flooding from both the Mississippi and Meramec rivers. The floodplain from these two rivers encompasses approximately 1,688 acres, which is shown on the illustration below. Major flooding occurs as a result of high water elevations on the Meramec and Mississippi Rivers which cause inundation that can cover a considerable area within the City, blocking major thoroughfares, and causing significant property damage. Flooding along the Meramec River is caused not only from Mississippi River flood events but from heavy rainfall in the Meramec River basin as well. Flood events originating on the Meramec River usually rise over a period of a few days and last for several weeks.

Flood Zone Map

Figure: 47 Flood Zone Map



Flooding along Pome Creek, Muddy Creek, and Little Muddy Creek is usually a flash flood type event resulting from intense localized thunderstorms. These events usually rise quickly and only last for a few hours. The lower reaches of these creeks also experience flooding caused by high water elevations on the Meramec and Mississippi Rivers.

Significant flooding has occurred on several occasions within City limits. Recent floods of significant magnitude include the following:

- **1973 - 30-year frequency, Meramec River.**
- **1982 - 100-year frequency, Mississippi River.**
- **1993 - 166-year frequency, Mississippi River.**
- **1995 - 50-year frequency, Meramec River and Mississippi River.**

Example stormwater issue.

Development Issues

The current policy of the City is that as land develops, the land developers incorporate stormwater collection and detention into the site. As the City of Arnold grows and NPDES regulations change stormwater quality treatments are likely to be required in the future. The City should take a proactive approach to stormwater management by evaluating the water quality requirements of surrounding municipalities.

The floodplain management ordinance in the City severely limits new developments and buildings in the floodplain. This ordinance also limits the types of construction that can be permitted in the floodplain. Alternative land uses should be considered in these areas such as parks, trails, and athletic fields.

Example stormwater issue.

Another benefit to having proper management of stormwater facilities is the removal and prevention of inflow and infiltration (I&I) into the sanitary sewer system.

There are no easy solutions to stormwater management as there are many different groups involved with differing priorities. The key issue is working to together to achieve common goals. City and County officials working together for the good of residents in the area is a priority.

Stormwater Recommendations

Future development in Arnold should be designed to respect the natural environment and coexist in harmony with existing natural features. Development planning should attempt to avoid engineering techniques, such as significant cut and fill to force-fit development into the environment. Instead, natural physical features should be incorporated into the overall development design, with drainage areas and other natural features left in their natural state.

Example stormwater issue.

A comprehensive approach for environmental and stormwater management should be implemented in Arnold to increase water “quality” and to reduce storm runoff “quantity”. This approach is consistent with the goals and objectives of the City’s Stormwater Master Plan and will:

- **Provide a system-wide series of regional stormwater facilities to reduce downstream flood damage.**
- **Provide localized stormwater infiltration and detention in new development areas to protect regional facilities and the streamways.**

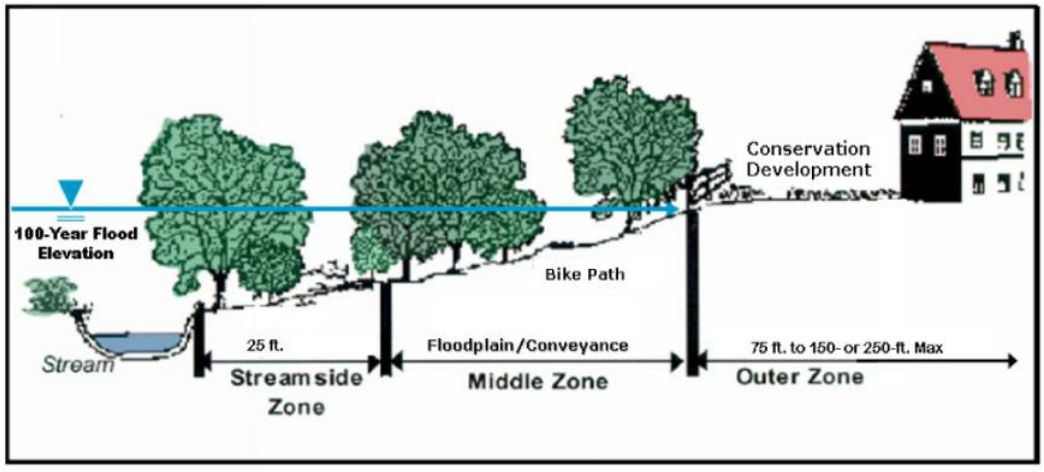
- **Provide stream buffer setbacks.**
- **Provide areas of slope protection adjacent to streamway buffers.**
- **Protect environmentally and culturally sensitive areas.**

Environmental Approach

Future development in Arnold should be encouraged to retain its natural infrastructure and visual character derived from topography, woodlands, streams and riparian corridors. If found, these environmentally sensitive areas are recommended to be protected by a Stream Buffer Ordinance as permanent public or private parks, conservation easements, or common open space. In many instances, these areas to be protected could also be located under the provisions of Section 5600 APWA – Storm Drainage Systems and Facilities.

Stream Buffer Zones

- **Streamside buffers:** Are located along identified streams. The definition on the Streamside Zone is 25-feet wide from the edge of the active channel on each side of the stream. Only utility, road, and trail crossings are allowed, as well as properly designed stormwater outfalls, access for fishing and wildlife viewing, and trail overlook areas.
- **Middle Zone:** Much of the Middle Zone is located in the 100-year floodplain or 100-year conveyance determined by an engineer, and wetlands. This Middle Zone varies based on actual stream characteristics. Activities in this zone include all uses in the Streamside Zone, plus utility corridors and recreational trails. Vegetation management and stream bank stabilization is key in this Zone.
- **Outer Zones:** Could have variable width, but it extends 75-feet from the edge of the Middle Zone, to a maximum of 150-feet (or 250 if using the open space development or conservation development). It includes slopes greater that 15% or mature riparian vegetation. If steep slopes or mature riparian vegetation extends beyond 150 feet from the edge of the Middle Zone, there are two options:
  - If the maximum is 150 feet, the Outer Zone must be protected as permanent open space. If extended to a maximum of 250-feet, open space and conservation development can exist and additional flexibility for no-residential development is allowed. See the approved Stream Buffer Ordinance for exact details and regulations.



Low Impact Development:

Portions of Arnold are located outside of the identified conservation areas are heavily wooded. A sensible balance must be employed with future development in these areas when providing for preservation of existing noteworthy environmental features. Areas with woodlands protection should use enhanced measures in development design to preserve significant trees or tree masses where possible. These measures may include:

- Cluster development design with flexible development standards such as reduced lot sizes and setbacks and alternative street designs to concentrate buildings on a part of the site (the cluster area) and allow the remaining land to be preserved as open space.

Cluster Development:

A form of planned residential development that concentrates buildings on a part of the site (the cluster area) to allow the remaining land (the open space) to be used for recreation, common open space, or preservation of environmentally sensitive areas. The open space may be owned by either a private or public entity.

Stormwater Management Approach

An overall system design approach can address the key adverse impacts of stormwater runoff by: reducing pollutant loading from new developments; reducing stream bank and channel erosion; reducing overbank flooding; and safely passing or reducing the runoff from extreme storm events.

Overall System Design

An overall system design approach relies on the use of regional stormwater facilities combined with localized detention and Best Management Practices (BMPs) to route storm events into the floodplain. The use of multiple smaller localized stormwater storage areas constructed in conjunction with private development, instead of larger regional detention facilities, will improve the overall water quality and reduce the area and volume required for regional detention facilities. A system of smaller retention ponds will also aid in the preservation of local streams by decreasing water velocities during storm events.

Conservation development proposed.

Regional Stormwater Facilities:

The construction of multiple, smaller "off-line" regional stormwater facilities is recommended as the preferred stormwater management approach. These facilities should be maintained by the public-at-large and will vary in size, capacity, and design. The facilities are designated for areas generally not considered developable, such as floodplains and stream buffers, or they may be located within the roadway or parkway right-of-way.

The specific location and capacity of the various facilities should remain flexible until preliminary engineering studies are completed to determine the most cost effective options with the least environmental impact.

Each regional facility should be:

- **Designed in a manner to serve as an amenity and/or gateway feature for the development area, while accommodating the storage necessary for regional detention and improving water quality.**
- **Designed to include "retention" of stormwater thus providing a visual water feature, which may include a series of smaller detention facilities with pumps to recirculate water between them.**
- **Constructed prior to future development in the upstream watershed of the given facility.**

Should land acquisition or construction cost considerations limit the locations for multiple facilities, another option may include combining multiple stormwater facilities into a single large facility. However, this option results in lower water quality due to less infiltration and the tendency for larger facilities to retain more pollutants.

Proposed stormwater solution with architectural feature.

Detention basins are another type of stormwater regional BMP.

Typical Best Management Practices (BMPs)

OPEN SPACE	SOURCE CONTROL	SOURCE FILTRATION	REGIONAL RETENTION
			
Native Vegetation	Infiltration Trenches	Bioretention	Wet Ponds
Vegetated Open Space	Filter Strips	Regional Storm Filters	Constructed Wetlands
Disconnect Impervious Surfaces	Pervious Paving	Dry Swales and Channels	Extended Retention Ponds
Phasing Development Grading	Rain Gardens	Sediment Basins	
	Construction Management	Localized Retention	
	Storm Drain Maintenance		

Localized Stormwater Management:

New developments in Arnold should be responsible for providing and maintaining localized stormwater infiltration and detention to achieve flood protection (for the impacts generated by specific development) in channel protection, overbank flood protection, and extreme flood protection events. This may be provided by a combination of detention, retention, and/or BMPs.

Example of a detention basin.

Options to street standards allow flexibility for treating runoff.

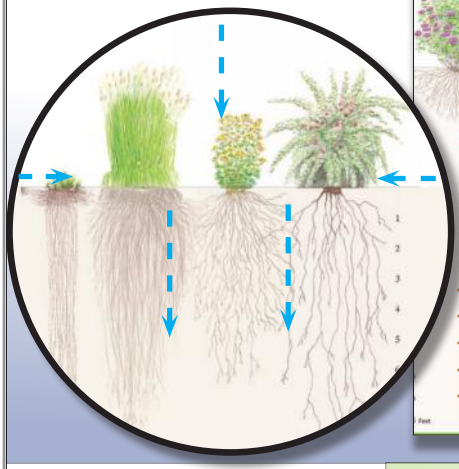
Stormwater management should be enhanced in by implementing a series of BMPs that achieve the following goals:

- **Increase infiltration (water absorbed by the soil) of stormwater runoff while in the basin;**
- **Increase the amount of time for stormwater runoff to reach its receiving stream;**
- **Reduce the potential amount of sediment/pollutants that can be carried off by stormwater runoff from rainfall; and**
- **Treat stormwater runoff before it reaches the receiving stream.**

To improve water quality, BMPs should be designed and located so runoff is routed though a chain of successive treatments that remove pollutants and increase water quality as much

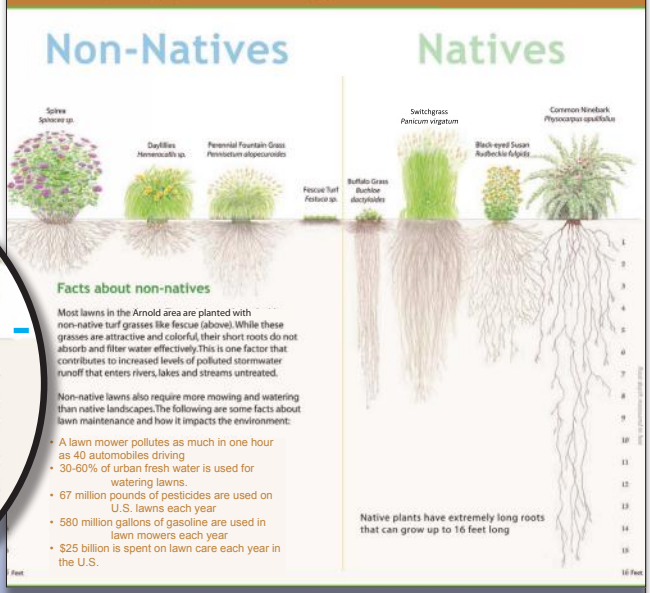
What is a Stormwater BMP?

Stormwater Best Management Practices (BMPs) are techniques used to control stormwater runoff, sediment control, and soil stabilization, as well as management decisions to prevent or reduce non-point source pollution. They can be used in the form of rain gardens to utilize stormwater as an amenity as well as provide aesthetic value to the surrounding landscape.



Native and non-native root comparison chart

Root depths of species commonly found in the Arnold area



Why use Stormwater BMPs?

Erosion Control
- Reduces flow rates into stream channels
- Allows plant root systems to develop

Flood Control

Recharges Groundwater
- Water is allowed to infiltrate soil

Cleans Water
- Filters out sediment and pollutants

Using Native Switchgrass in Rain Gardens

Switchgrass seed

Switchgrass is a warm-season perennial grass that is native to North America and can be found in many environments. Due to its native origin, switchgrass is highly tolerant of poor soils, flooding, drought, plant pests, and diseases making it an ideal specimen for planting areas which receive high impacts and little maintenance. The extensive root system of the plant can extend to soil depths of 10 feet. Switchgrass takes on a glossy green color during its growing season and does not require mowing. Typically, the grass is cut only annually, preferably in late February or March, to allow birds to feed on the seeds dropped during the dormant months and to reduce maintenance cost/ impacts.

'Northwind' Switchgrass
Panicum virgatum 'Northwind'

Best Management Practices
in Roadway Settings

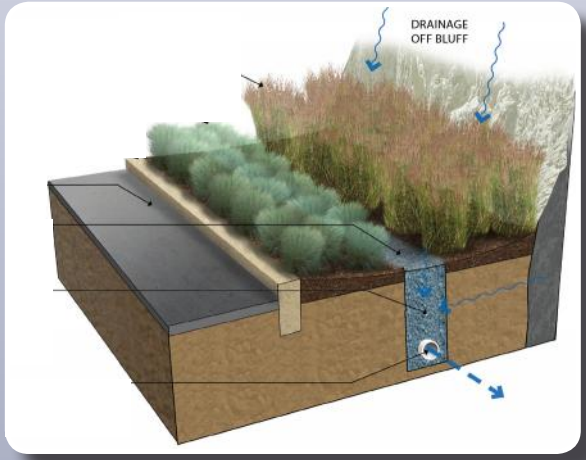
BMP design can be incorporated throughout the city along major arterials or collectors. Rain gardens, bio-swales, and permeable paving are common types of BMP's that can also be found in commercial and residential developments.

RIGHT OF WAY

Bioswales can be used along the edge of roadways to treat stormwater by filtering it through vegetation and soils prior to it entering the storm sewer.

MEDIAN PLANTINGS

Bioswales can also be used within the roadway when there is ample space for a median. The advantage to this treatment is that it gets both sides of the roadway with one system. The plantings also function to calm traffic and beautify the streetscape.



Best Management Practices
in Residential Settings

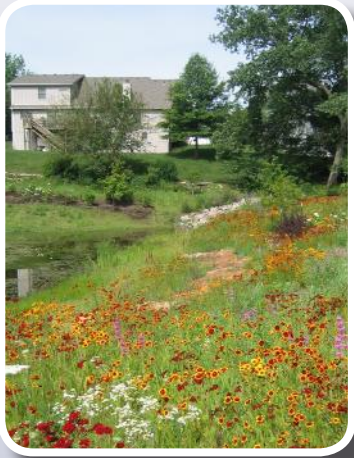
BMP design can be incorporated throughout the Planning Area, especially in residential neighborhoods and along local streets. Rain gardens, permeable paving, and detention basins are common types of BMP's that can be found in residential settings.

RAIN GARDEN

Planted depression designed to absorb rainwater runoff from impervious urban areas like roofs, driveways, and walkways.

DETENTION BASIN

Designed to protect against flooding and, in some cases, downstream erosion by storing water for a limited period of time. Basins can be "dry" or "wet", depending on whether they are designed to permanently retain a volume of water.



PERMEABLE PAVING

Paving method for roads, parking lots, driveways, and walkways that allows the movement of water around the paving material and into the soil.

Best Management Practices
in Commercial Settings

BMP design can be incorporated throughout the Planning Area in commercial developments and along major arterials or collectors. Rain gardens, bio-swales, and permeable paving are common types of BMP's that can be found in commercial developments.

PERMEABLE PAVING

Paving method for roads, parking lots, driveways, and walkwaysthatallows the movement of water around the paving material and into the soil.

RAIN GARDEN

Planted depression designed to absorb rainwater runoff from impervious urban areas like roofs, driveways, and walkways.

DETENTION BASIN

Basins can be "dry" or "wet", depending on whether they are designed to permanently retain a volume of water.

BIO-SWALE

Landscape elements designed to remove silt and pollution from surface runoff water. A common application is around parking lots, where substantial automotive pollution is collected by the paving and then flushed by rain.

as possible before entering the streams of the watershed. BMPs should meet the minimum requirements set forth in American Public Works Association Section 5600. Developers should submit stormwater studies that demonstrate the effectiveness of proposed BMPs in lieu of localized detention facilities.

Careful consideration of the placement of BMPs throughout any watershed must be given to ensure water quality. Most BMPs implemented to improve stormwater "quality" may also reduce the stormwater "quantity". This reduction in water "quantity" may also reduce the amount of detention storage required for the development, which in turn will reduce development costs. Potential reductions in development cost are true for many of the BMPs that could be implemented in the watershed. The use of natural buffers and native vegetation may reduce the need for grading and the need for larger enclosed pipe systems which reduces long-term maintenance needs of the City.

Localized stormwater management may also be incorporated into the design of local and collector residential streets and parking lot designs. Swales may be used in place of curbs and gutters along streets and within parking lots. Alternative street designs may also include reduced pavement widths with a concrete apron rather than raised curbs, as well as vegetated swales with plantings similar to rain gardens in lieu of enclosed stormwater pipe systems. Such alternative designs may result in reduced construction costs and achieve the objective of reducing the quantity of runoff while increasing infiltration and the quality of runoff.

This parking lot incorporates stormwater drainage into its design.

Bioretention facilities are vegetated areas where soil acts as a filter for stormwater contaminants.

Rain gardens reduce runoff by allowing stormwater to soak into the ground.