November 2024

Public Improvement Specifications Chapter 14: Stormwater Quality Management

Introduction:

This Chapter shall be applicable to all subdivision or site plan applications that disturb one acre or more per KYR10 and are located within the City limits or within the Phase II boundary of Daviess County unless eligible for an exemption or granted a waiver by the City of Owensboro or Daviess County under the specifications of the Stormwater Ordinance and the OMPC Public Improvement Specifications.

This Chapter also applies to land development activities that are located within the City limits or within the Phase II boundary of Daviess County that are smaller than one (1) acre, if such activities are part of a larger common plan of development. A map of the City/County Phase II boundary can be found at http://www.Owensboro.org/engineering/stormwater

Site development plans submitted as a redevelopment project as defined in the applicable Stormwater Ordinance, are subject to permitting and on-site stormwater requirements as determined by the City of Owensboro or Daviess County. Each redevelopment project shall have no net increase in imperviousness without an approved development plan or site plan.

No excavation, cut or fill of earth or debris shall be undertaken unless an Excavation, Cut or Fill permit is issued by the City or County Engineer.

(a) Post construction stormwater quality management in new development, redevelopment, and existing systems

Post-Construction Stormwater Management is a key element of the MS4 permit and the Nation's and Commonwealth's strategy for achieving the goals of the Clean Water Act. An effective Post-Construction Stormwater Management program has the ability to positively impact the chemical, biological, and overall health of the Commonwealth's streams, rivers, and lakes by reducing the rate and volume of, and improving the quality of, stormwater runoff from the MS4.

Post-Construction Stormwater Management refers to the activities that take place after construction is completed, and includes structural and non-structural stormwater controls that protect the environment from the harmful impacts of urban stormwater runoff. Stormwater BMPs incorporate planning practices and site improvements in a manner that promotes groundwater recharge, reduces the volume of, reduces peak discharge rates of, and removes pollutants from runoff.

All *Storm Water Management Plans* shall provide details related to all aspects of the construction. Developments are to be designed to ensure that controls are in place that would prevent or minimize water quality impacts. Designers are to develop and implement strategies, which include a combination of structural and/or non-structural Best Management Practices (BMPs) appropriate for the community. The plans must also ensure adequate long-term operation and maintenance of BMPs through notes or labels on construction drawings, Final Subdivision Plats, and Final Site Plans.

Supporting documentation is required to provide calculations justifying the use of the BMPs specified in the plans. These documents are to be submitted in conjunction with the Construction Plans for proposed developments. All proposed stormwater management plans are to be certified by the designer that the plans comply with the local city or county regulations (as applicable). Upon completion of the project, the designer shall certify that the infrastructure was built according to the design drawings and standards.

(b) Post-Construction Stormwater Management Site Performance Criteria

Unless judged by the City of Owensboro or Daviess County to be exempt or granted a waiver, the following performance criteria shall be addressed for stormwater quality management at all sites:

1. All site designs shall establish post-construction stormwater management practices to control the peak flow rates of stormwater discharge and reduce the generation of stormwater runoff. Where applicable, these practices should seek to utilize pervious areas for stormwater treatment and to infiltrate stormwater runoff from driveways, sidewalks, rooftops, parking lots, and landscaped areas to the maximum extent practical.

2. Post-construction stormwater management measures shall be required, in combination or alone, that are designed, built, and maintained to treat, filter, flocculate, infiltrate, screen, evapo-transpire, harvest and reuse the first **0.64** inches of a rain event (measured over the impervious area) in order to manage stormwater runoff quality.

    Example: A commercial site 25,000 square feet of impervious surface is proposed. Measures (BMPs) must be designed to effectively treat the runoff volume generated from a 0.64 inch rainfall event falling on the impervious surface which equates to 0.03 ac-ft or 1333 cubic feet (see section (c) Stormwater Runoff Water Quality Treatment). If topography indicates that runoff will leave the site in more than one location the BMPs must be sized according to that portion of the runoff reaching them (i.e. if runoff is split so 30% goes to one exit point and 70% to another they must treat 400 cf and 933 cf of runoff, respectively).

3. Structural and non-structural controls may be used to obtain permanent stormwater management over the life of the property's use. Structural stormwater controls include, but are not limited to, grass swales, filter strips, infiltration basins, detention ponds, stormwater wetlands, natural filtration areas, sand filters, and rain gardens. Non-structural BMPs incorporate site planning and design techniques including, but not limited to, open spaces, vegetated conveyances and buffers, natural infiltration, and low impact development. Engineer shall check for tailwater conditions that may result from the water quality standard rainfall event and tailwater conditions shall be accounted for in outlet designs.

4. Areas of development and re-development that result in new or expanded discharge to high quality waters (HQWs) shall follow the "Standards for Protection of HQWs" in that follow in section (d) in order to protect existing in-stream water uses and the level of water quality necessary to protect existing uses.

High Quality Waters are defined as follows in 401 KAR 10:030 Section 1(3) (http://www.lrc.ky.gov/kar/401/010/030.htm):

1. A surface water shall be categorized as high quality water if the surface water is not listed as an outstanding national resource water or an exceptional water in Table 1 or 2 of this section and if the surface water does not meet the criteria for impaired water as provided for in subsection 4(a) of this section. (below)
2. A surface water shall be categorized as a high quality water if the surface water is listed as an outstanding state resource water in 401 KAR 10:026 and is not listed as an outstanding national resource water in Table 1 or an exceptional water in Table 2 of this section.

(4) Impaired water.

(a) Categorization criteria. A surface water categorized as impaired for applicable

1 or 2 of this section and if the surface water does not meet the criteria for impaired water as provided for in subsection 4(a) of this section. (below)

2. A surface water shall be categorized as a high quality water if the surface water is listed as an outstanding state resource water in 401 KAR 10:026 and is not listed as an outstanding national resource water in Table 1 or an exceptional water in Table 2 of this section.

(4) Impaired water.

(a) Categorization criteria. A surface water categorized as impaired for applicable designated uses shall be a water identified pursuant to 33 U.S.C. 1315(b).

1. Surface water categorized as impaired shall be assessed by the cabinet as not fully supporting any applicable designated uses.
2. A surface water shall not be categorized as impaired water if the surface water is listed as an outstanding state resource water in 401 KAR 10:026.
3. A surface water shall not be categorized as impaired for the purposes of this administrative regulation if the surface water is listed only as mercury impaired for fish consumption.

Note: As of November 2013, there are no identified outstanding natural resource waters, exceptional waters, or outstanding state resource water in Daviess County.

5. A Stormwater Pollution Prevention Plan (SWPPP) shall be prepared and implemented and a Notice of Intent (NOI) filed under the provisions of the National Pollutant Discharge Elimination System (NPDES) general or individual permit. The SWPPP requirement applies to both existing and new development sites.

6. Stormwater discharges from land uses or activities with higher potential pollutant loadings, known as "hotspots", may require the use of specific structural Stormwater Treatment Practices (STPs) and pollution prevention practices. Examples include business and industry producing or storing hazardous materials (petro-chemicals, toxic and persistent chemicals, metals, or biological substances). Wellhead Protection Zones shall also be considered hotspots due to the sensitivity of the area with regard to potential contamination of local aquifers.

7. Stormwater design calculations shall follow the current Subdivision Regulations and Public Improvement Specifications for Owensboro/Daviess County and incorporate the "Stormwater Runoff Quality Treatment Standard" accepted by the City of Owensboro and Daviess County that follows below.

(c) Stormwater Runoff Water Quality Treatment Standard

In urban areas the first flush of runoff pollutants carries a heavy load of pollutants from impervious areas such as streets and parking areas that can negatively impact receiving streams by altering the water chemistry and water quality. Capturing the "First Flush" of pollutants is one way to improve water quality leaving the MS4. The goal of this stormwater runoff quality treatment standard is to establish the water quality volume (WQ_V) metric and provide treatment for the WQ_V.

The term "water quality volume" is generally used to define the amount of storm water runoff from any given storm that should be captured and treated in order to remove a majority of storm water pollutants on an average annual basis. Therefore, daily precipitation records were retrieved from the UK Ag Weather Station website (http://wwwagwx.ca.uky.edu/climdata.html) between 1971 and 2010 for the Henderson and Evansville climatology stations. The data was sorted by depth with zero or trace amounts removed and the total number of rainfall events was multiplied by 0.8 to determine the event depth at which 80% of the total number of events were equal to or less than. The resulting average depth between the two stations was **0.64 inches**.

Completing the exercise for the two stations provided a better assessment of area climatology. The determined depths showed no difference in the 80% event depth. Therefore, the depth of 0.64 inches determined from either station is a representative event depth to use as the rainfall basis for the stormwater runoff quality treatment standard for Owensboro and Daviess County.

The water quality volume (WQ_V) can then be calculated using the formula below:

$$WQ_V = \left(\frac{A * d}{43560\, ft^2 / ac * 12 in / ft} \right)$$

WQ_V = Ac•ft
A = Impervious area (ft^2)
d = 0.64 (in)

The calculated WQ_V shall be treated in combination or alone, by management measures that are designed, built, and maintained to treat, filter, flocculate, infiltrate, screen, evapotranspire, harvest and reuse stormwater runoff, or otherwise manage the stormwater runoff quality.

If the proposed BMP has a flow-based performance standard, the water quality treatment flow rate can then be calculated using the Rational equation below:

$$WQ_Q = C*I*A$$

WQ_Q = cfs
C = runoff coefficient for impervious surfaces = 0.9
I = intensity factor for 0.64" rainfall (2 yr, 10 min) = 3.99
A = impervious area (ac)

(d) Standards for Protection of High Quality Waters (HQW)

Further justification of the requirements for a defined water quality standard are identified in KRS statutes as they pertain to High Quality Waters. KYR10 follows 401 KAR 10:030, Section 1(3) (Antidegradation Policy – High Quality Waters), which says a surface water shall be classified as a high quality water (HQW) if the surface water is not listed as an outstanding national resource, an exceptional water, or does not meet the criteria for impaired water. Currently, ~90% of the waters of the Commonwealth are categorized as HQWs and are subject to antidegradation implementation procedures, which requires maintaining and protecting existing in-stream water uses and the level of water quality necessary to protect the existing uses.

Waters of the Commonwealth and Waters of the US are defined as follows:

1. Waters of the Commonwealth (from KPDES No. KYG200000) means and includes any and all rivers, streams, creeks, lakes, ponds, impounding reservoirs, springs, wells, marshes, and all other bodies of surface or underground water, natural or artificial, situated wholly or partly within or bordering upon the Commonwealth or within its jurisdiction.
2. Waters of the United States, as defined by the Clean Water Act, applies only to surface waters, rivers, lakes, estuaries, coastal waters and wetlands. Not all surface waters are legally Waters of the United States. Generally those waters include the following:
    a. All interstate waters
    b. Intrastate waters used in interstate and/or foreign commerce
    c. Tributaries of the above
    d. Territorial seas at the cyclical high tide mark, and
    e. Wetlands adjacent to all of the above.

Impaired Waterways in Daviess County are summarized in Exhibit 14.1

Areas of development and/or redevelopment inside a HQW watershed that result in new or expanded discharge from the MS4 shall:

1. Provide sufficient detention, storage, or infiltration BMPs to maintain or improve upon pre-construction flow in order to protect the existing in-stream designated water uses; and

2. Provide the necessary BMPs that focus on removal of pollutants most common to the type of development occurring in order to maintain the level of water quality that protects existing uses. BMPs selected for the site shall be approved by the City or County Engineer or their designee.

3. Areas of redevelopment will be required to meet the same water quantity criteria as new development, and will need to provide water quality treatment at a level equivalent to 20% of the requirement for new development. This shall be determined by calculating the required water quality volume and multiplying the result by 0.2. This reduction is allowed due to the inherent nature of redevelopment sites and the difficulty and limitations in retrofit options with redevelopment.

4. BMPs will be approved on a case-by-case basis by the local permitting authority to provide reasonable assurance that the BMPs selected are appropriate for the site and pollutants of concern.

(e) Exemptions for Providing Post-Construction Stormwater Management

Post-construction stormwater management measures must be implemented at construction sites meeting the criteria identified in the introduction of this chapter. The following activities may be exempt from the post-construction stormwater performance criteria:

(1) Any logging and agricultural activity which is consistent with an approved soil conservation plan or a timber management plan approved by the City of Owensboro and Daviess County, as applicable;
(2) Additions or modifications to existing single family structures;
(3) Repairs to any stormwater treatment practice deemed necessary by the City of Owensboro and Daviess County;
(4) Any emergency project that is immediately necessary for the protection of life, property or natural resource;
(5) Linear construction projects, such as pipeline or utility line installation, that do not result in the installation of any additional impervious cover, as determined by the City of Owensboro or Daviess County;
(6) Developments that result in less than ¼ acre of new impervious surface either through a single or multi-phase development plan.

(f) Waivers for Providing Post-Construction Stormwater Management

The minimum requirements for post-construction stormwater management may be waived in whole or in part upon written request of the applicant, provided that at least one of the following conditions applies:

(1) It can be demonstrated that the proposed development is not likely to impair attainment of the objectives of this chapter;

(2) The City Engineer of Owensboro or Daviess County Engineer finds that meeting the minimum on-site management requirements is not feasible due to the natural or existing physical characteristics of a site. Feasibility issues may involve one or more of the following:
   a. Cannot meet development requirements (setbacks, parking, sidewalks) for the zoned use while incorporating water quality BMPs
   b. Water table or rock preclude any effective infiltration BMP options
   c. Conventional BMPs cannot be implemented due to constraints with tying into existing infrastructure or waterways (depth, slope, adequate cover)
   d. Major Utility conflicts as determined by the City or County Engineer

Note: Project scheduling and/or budgets shall not be considered as rationale for waivers. Also, if the potential for impairment is likely, waivers or in-lieu compensation shall only be considered after all other options have been considered.

Where the City of Owensboro or Daviess County waives all or part of the minimum post-construction stormwater management requirements, or where the waiver is based on the provision of adequate stormwater facilities provided downstream of the proposed development, the applicant may be required to provide one of the following mitigation options as determined by the City of Owensboro or Daviess County:

(1) A monetary contribution may be required in-lieu of the post-construction stormwater management practices as established by the City of Owensboro or Daviess County in the Public Improvement Specifications. All of the monetary contributions shall be credited to an appropriate stormwater quality capital improvements program project or maintenance of existing public BMPs, and shall be made by the developer prior to the issuance of any Cut and Fill permit for the development. In lieu fees shall be calculated according to the following equation:

$$ILF = (WQ) * (BR) * (1.5) + M \qquad \text{where,}$$

ILF = in lieu fee ($)

WQ = Water Quality Volume (cu. Ft) OR Flow Rate (cfs)

BR = BMP design and construction Bond Rate ($/cu.ft or $/cfs)

M = 5-year maintenance lump sum = $5,000

Reference the Owensboro Public Improvements Surety Unit Costs for cu.ft. and cfs Bond Rate for impervious area.

(2) In lieu of a monetary contribution, an applicant may obtain a waiver of the required post-construction stormwater management by entering into an agreement with the City of Owensboro or Daviess County to perform off-site mitigation in the same watershed as the original project. The off-site facility shall be designed and adequately sized to provide a level of stormwater control that is equal to or greater than that which would be afforded by on-site practices, and the developer or applicant shall enter into a long-term operation and maintenance agreement for the stormwater practice.

(g) Procedure for Exemptions and Waivers

Exemptions or waivers from post-construction stormwater management requirements shall not result in development or re-development that undermines the purpose of the Stormwater Ordinance and this Chapter. Written requests for exemptions or waivers shall be submitted to the City of Owensboro or Daviess County for approval.

For any waiver request, the applicant must demonstrate to the satisfaction of the City of Owensboro or Daviess County that the construction project will not result in the following impacts to downstream waterways:

(1) Deterioration of existing culverts, bridges, dams, and other structures;
(2) Degradation of biological functions or habitat;
(3) Accelerated streambank or streambed erosion or siltation;
(4) Increased threat of flood damage to public health, life, or property.

(h) Low Impact Development Practices

Introduction
Low Impact Development (LID) is a storm water management strategy concerned with maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements. LID employs a variety of natural and built features that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground. By reducing water pollution and increasing groundwater recharge, LID helps improve the quality of receiving surface waters and stabilize the flow rates of nearby streams.

Conventional storm water management systems rely on collection and conveyance systems to remove water safely from developed areas and protect life, property, and health. The systems are engineered and designed according to estimates of post development storm water flows and volumes from pervious and impervious areas. LID storm water management systems can reduce development costs through reduction or elimination of conventional storm water conveyance and collection systems. LID systems can reduce the need for paving, curb and gutter, piping, inlet structures, and storm water ponds by treating water at its source instead of at the end of the pipe. Municipalities also benefit in the long term through reduced maintenance costs.

There are numerous design practices and technologies developers can use through the LID approach. For instance, developers can work together with municipal officials and the general public during the initial planning stages of development to identify environmental protection opportunities. Examples may include saving trees on the site, avoiding designated sensitive areas, and orienting roads and lots to allow for passive solar orientation of homes. LID technologies can be structural or nonstructural. Sand filters and dry wells are examples of structural technologies used for water quality. Nonstructural technologies often use natural features or are land use strategies. Disconnecting rain gutters from storm water drains and redirection of rainwater toward rain gardens or grass swales are examples of nonstructural technologies.

While LID may benefit all types of development, it is best suited for new, suburban residential development. Moreover, the LID practices and technologies are best integrated into a developer's existing land development process and practices. With some planning, the technologies can be integrated into today's land development projects. Developers can decide which technology or combination of technologies will offer the best cost and environmental benefits taking into account the site and also local ordinances.

Benefits of LID

LID takes a second look at traditional development practices and technologies and focuses on identifying project-specific site solutions that benefit the municipality, the developer, the home buyer, and the environment. Besides the fact that LID makes good sense, LID development techniques can offer many benefits to a variety of stakeholders as shown in Exhibit 14.2.

LID Design Strategies

In general, site design strategies for any project will address the arrangement of buildings, roads, parking areas, and other features, and the conveyance of runoff across the site. LID site design strategies achieve all of the basic objectives of site design while also minimizing the generation of runoff. Optimal LID site design minimizes runoff volume and preserves existing flow paths. This minimizes infrastructural requirements. Typical LID site design strategies include the following:

- Grade to encourage sheet flow and lengthen flow paths.
- Maintain natural drainage divides to keep flow paths dispersed.
- Disconnect impervious area such as pavement and roofs from the storm drain network, allowing runoff to be conveyed over pervious areas instead.
- Preserve the naturally vegetated areas and soil types that slow runoff, filter out pollutants, and facilitate infiltration.
- Direct runoff into or across vegetated areas to help filter runoff and encourage recharge.
- Provide small-scale distributed features and devices that help meet regulatory and resource objectives.
- Treat pollutant loads where they are generated, or prevent their generation.

List of BMPs that Qualify as LID Technologies

There are numerous BMPs included in this chapter that are LID practices. The BMP types listed below are examples of LID practices that may be applicable for use in Owensboro and Daviess County.

- Infiltration Systems (biofiltration swales, rain gardens, dry wells)
    - BMPs function by capture and infiltration in a static location similar to detention but with the primary dewatering device being the soil itself. May also be used with underdrains.
- Green Roofs
    - Function similar to Infiltration systems with regard to capture, but dewatering is through underdrain systems, evaporation and evapotranspiration.
- Flow through Conveyance (filter strips, grassed swales)

  - Function by infiltration as runoff is conveyed down slope. Dependent on soils, height of vegetation, and flow depth.
- Infiltration structures (media filters, media inlets, ex Silva cells, filterra units)
  - Function similar to green roofs with capture and slow release through underdrain systems

Environmental Practices and Planning: Credits up to 30% (from individual or a combination of practices below) of the required WQv or WQ_Q may be provided for the following practices:

- Open-space Preservation – not applicable to WQ standard compliance but application can be made to reduce the required WQ volume or flow rate required. For every 25% above the required amount as identified in the subdivision regulations, a 10% reduction in WQ_V or WQ_Q is allowed
- Trees, Shrubs, and Vines – not applicable to WQ standard compliance but application can be made to reduce the required WQ volume or flow rate required. For every 25% above the required amount as identified in the subdivision regulations , a 10% reduction in WQ_V or WQ_Q is allowed.
- Preserving existing trees – For every tree greater than or equal to 18" caliper that is adequately preserved (no disturbance or fill inside the drip line), a 5% reduction in WQ_V or WQ_Q is allowed.

Developers are encouraged to use these practices individually or in combined systems to effectively manage storm water runoff on-site. Other practices may be allowed upon approval of the City/County Engineer. Developers shall determine the applicability and appropriateness of BMPs based on the site location, pollutant potential, and BMP performance potential.

(i) Requirements for Stormwater Management Plan Approval.

(a) Stormwater Management Plan Requirements

The Stormwater Management Plan must be submitted for approval and shall include all of the following required information:

1. *Contact Information*

The name, address, and telephone number of all persons having a legal interest in the property and parcel number of the property or properties affected.

2. *Topographic Base Map*

A topographic base map of the site which extends a minimum of 100 feet beyond the limits of the proposed development and indicates existing surface water drainage including streams, ponds, culverts, ditches, and wetlands; current land use including all existing structures; locations of utilities, roads, and easements; and significant natural and manmade features not otherwise shown.

3. *Calculations*

Hydrologic and hydraulic design calculations for the pre-development and post-development conditions shall follow the requirements for the design storms specified in these OMPC PI Specifications for Owensboro/Daviess County. Such calculations shall include, as applicable, (i) description of the design storm frequency, intensity and duration, (ii) time of concentration, (iii) Soil Curve Numbers or runoff coefficients, (iv) peak runoff rates and total runoff volumes for the watershed associated with a stormwater control measure, (v) infiltration rates (as applicable), (vi) culvert capacities, (vii) flow velocities, (viii) data supporting the design of each stormwater control measure, (ix) documentation of sources for all computation methods and field test results, and (x) the Water Quality Volume calculation. Calculations shall be submitted and stamped by a PE licensed to practice in the State of Kentucky.

4. *Soils Information*

If a stormwater management control measure depends on the hydrologic properties of soils (e.g., infiltration basins), then a soils report shall be submitted. The soils report shall be based on on-site boring logs, soil pit profiles, or other methods approved in advance by the City of Owensboro or Daviess County. The number and location of required soil borings or soil pits shall be determined based on what is needed to determine the suitability and distribution of soil types present at the location of the control measure. Soils information obtained from soils maps are adequate for conceptual design and feasibility studies, but on-site testing is required for detailed and final design plans.

5. *Maintenance, Inspection, and Repair Plan*

The design and planning of all stormwater management facilities shall include detailed maintenance, inspection, and repair procedures to ensure their continued function. These plans will identify the parts or components of a stormwater management facility that need to be maintained and the equipment, skills, or training necessary. The Plan shall make provisions for the periodic review and evaluation of the effectiveness of the maintenance program and require the installer to document such activity and provide the information to the responsible party. Parties responsible for the operations, inspections, and maintenance shall retain all related records for at least three (3) years.

6. *Landscaping Plan*

The applicant must present a detailed plan for management of vegetation at the site after construction is finished, including who will be responsible for the maintenance of vegetation at the site and what practices will be employed to ensure that adequate vegetative cover is preserved.

7. *Maintenance Easements*

Prior to the issuance of any permit that has a stormwater management facility as one of the requirements of the permit, the applicant or owner of the site must execute a maintenance easement agreement that shall be binding on all subsequent owners of land served by the stormwater management facility. The agreement shall provide for access to the facility at reasonable times for periodic inspection (and repair if necessary due to non-compliance) by the City of Owensboro or Daviess County, or their contractor or agent to ensure that the facility is maintained in proper working condition to meet design standards and any other provisions established by this ordinance. The easement agreement shall be recorded by the City of Owensboro or Daviess County in the land records.

8. *Operations and Maintenance Agreement*

Maintenance of all stormwater management facilities shall be ensured through the creation of a formal operation and maintenance agreement that must be approved by the City of Owensboro or Daviess County and recorded into the land record prior to final plan approval. As part of the agreement, a schedule shall be developed for when and how often maintenance will occur to ensure proper function of the stormwater management facility. The agreement shall also include plans for annual inspections to ensure proper performance of the facility between scheduled cleanouts and submittal of annual reports to the City of Owensboro and Daviess County. An example maintenance covenant can be found at http://wwwiompc.org Responsibility of BMP maintenance in Residential developments shall follow the accepted policies of the City or County, as applicable, which will be discussed at the time of plan submittal.

Until such time as the developer is granted release from any maintenance bond and has issued a Notice of Termination on the construction permit, the responsibility of maintenance shall fall upon the developer.

The owner of the property on which the stormwater management facility is located, shall, at the written request of the city or county engineer, employ a licensed professional engineer to certify that the private storm sewer system is being maintained at the level of service for which it was originally designed. If a determination is made that the property owner is not maintaining the private system at or above the level of service indicated in the original design, a notice of deficiency shall be issued and the standard escalated process of enforcement initiated. It shall be unlawful for any person to refuse to maintain any part of a stormwater management facility that has been approved by the city engineer as part of the SWMP. The system shall be maintained at all times to the level of service it was designed for.

9. *Erosion and Sediment Control Plans for Construction of Stormwater Management Measures*

The applicant must prepare a SWPPP, as applicable to the project, per the City of Owensboro or Daviess County's Stormwater Ordinance, for all construction activities related to implementing any on-site stormwater management practices.

10. *Other Environmental Permits*

The applicant shall assure that all other applicable environmental permits have been acquired for the site prior to approval of the final Stormwater Design Plan

(j) Construction Inspection

The applicant must notify the City of Owensboro or Daviess County in advance before the construction of Post-Construction BMPs or Stormwater Management System. It shall be the responsibility of the contractor to conduct regular inspections of stormwater management system BMPs by qualified inspectors who are qualified through KEPSC qualification training or similar programs. All inspections shall be documented and written reports prepared that contain the following information:

(1) The date and location of the inspection;

(2) Whether construction is in compliance with the approved Stormwater Management Plan;

(3) Variations from the approved construction specifications;

(4) Installation date of all stormwater measures since the previous inspection; and

(5) Any violations that exist.

If any violations are found, the property owner shall be notified in writing of the nature of the violation and the required corrective actions. No added work shall proceed until any violations are corrected and all work previously completed has received approval by the City of Owensboro or Daviess County

(k) Surety

The City of Owensboro or Daviess County will require the submittal of surety before OMPC issues a final plat in order to ensure that the stormwater practices are installed by the permit holder as required by the approved Stormwater Management Plan. The surety shall contain forfeiture provisions for failure to complete work specified in the Stormwater Management Plan.

The surety shall be released in full only upon submission of a written certification by a registered professional engineer that the stormwater practice has been installed in accordance with the approved plan and other applicable provisions of the OMPC Public Improvement Specifications. The City of Owensboro or Daviess County will make a final inspection of the stormwater practice to ensure that it is in compliance with the approved plan and the provisions herein prior to any release of surety.

(l) BMP Selection, Installation, and Maintenance

Identify Site Considerations

The objectives in stormwater quality management for each property can vary widely. Therefore, a specific understanding of the site characteristics and nature of the completed project is essential for selecting and implementing BMPs. This information should be carefully assembled and reviewed early in the design process. Once these dynamics are defined, then specific BMPs can be selected. The BMP site considerations should include the following:

Site characteristics and proposed contractor construction sequencing will affect the BMP selection, installation, and protection methods used on the construction site. It is important to plan the project to fit the topography and drainage patterns of the site, and to protect areas that are designated for infiltration practices (to avoid over compaction and/or sediment overloading). During the BMP evaluation and selection process, these factors should be carefully considered:

1. Site conditions that affect erosion, sedimentation, and infiltration which include:
   a. Soil type, including underlying soil strata that are likely to be exposed
   b. Natural terrain and slope
   c. Depth to water table
   d. Proximity to utilities, well fields, natural features
   e. Location of concentrated flows, storm drains, and streams
   f. Existing vegetation and ground cover

2. Other Site conditions related to the proposed design, which include:
   a. Location of and amount of open space, including consideration of cluster-type development that allows for more open and contiguous open space.
   b. Final slopes and grades

3. Land Use considerations

4. Construction schedules, construction sequencing, and phasing of construction.

5. Size of construction project and area to be graded.

6. Location of the construction activity relative to adjacent uses and public improvements.

7. Cost-effectiveness considerations.

8. Nature of the ultimate receiving water and any buffer requirements.

Select BMPs

Once the site considerations are evaluated, it is necessary to identify the BMPs that are best suited to the site and the project needs. To determine where to place BMPs, a map of the project site can be prepared with sufficient topographic detail to show existing and proposed drainage patterns and existing and proposed permanent storm water control structures. The project site map should identify the following:

- Locations where storm water enters and exits the site. Include both sheet and channel flow for the existing and final grading contours.

- Identify wetlands, springs, sinkholes, floodplains, floodways, sensitive areas, or buffers, which must not be disturbed, as well as other areas where site improvements will not be constructed. Establish clearing limits around these areas to prevent disturbance by the construction activity.

- Identify the boundaries of tributary areas for each outfall location. Then calculate the approximate area of each tributary area. Also determine the proposed impervious areas within each drainage tributary.

With this site map in hand, categories of BMPs can be selected and located. Detailed planning before construction begins and phasing construction activities provides the best opportunity for success and the most cost-effective solutions.

BMPs that can achieve multiple BMP objectives may be utilized to achieve cost-effective solutions. For instance, a detention facility, if designed with a water quality forebay structure (flow through structural unit or wetland) can provide both water quantity and quality compliance needs. Developers shall utilize the tables, matrices, and Minimum Standards that follow to guide them through the BMP selection process. The selection process should follow three basic steps:

a. Identify the target pollutant(s), which are those most likely to be generated from the proposed land use
b. Assess the site and soil conditions for appropriateness of potential BMPs
c. Select BMPs based on target pollutant removal and site conditions

Target Pollutant(s): Identify the highest priority pollutants expected to be generated on the post-developed site based on land use from the table included as Exhibit 14.3. Exhibit 14.4 lists the event mean concentrations utilized to determine the pollutant generating potential rankings included in Exhibit 14.3.

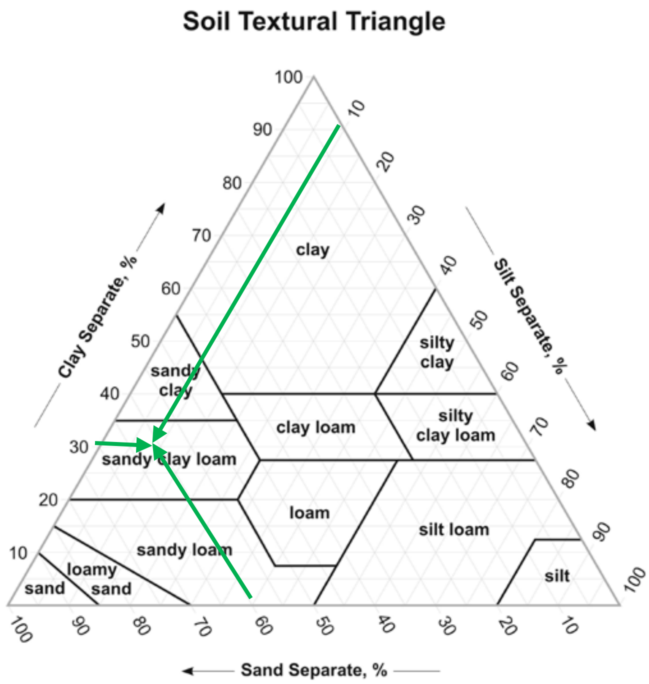
BMP Options: Identify BMPs from Exhibit 14.5 that are effective in treating the target pollutant(s) identified. High pollutant generation potential should be matched with full circle effectiveness BMPs for the specific pollutants. Medium pollution potential should be matched with half-circle effectiveness at a minimum. Low pollution potential may be matched with any effectiveness level.

Minimum Standards providing information on applicability, design, and maintenance for Low Impact Development BMPs are included at the end of this Chapter. For proprietary BMPs including, but not limited to, catch basin or manhole inserts, baffle boxes, oil/water separators, and media filters, the

Developer shall provide manufacturer's specifications and supporting design calculations to demonstrate BMP treatment performance based on the required water quality treatment flow.

Soils Characterization: From review of the County Soil Survey and/or through field testing, determine the percent sand, silt, and clay of the soil at the depth at which infiltration will take place (ex, if using a 24 inch underground detention system the soils shall be characteristic of those found at a depth of 24 inches or more, not the topsoil layer). Enter the USDA Textural triangle from each side at the corresponding percent makeup of the three soil particle classes (sand, silt, clay) and follow the gridded line along the same plane as the text for each particle class (see example). The point where the three lines intersect is the soil type.

Soils may be amended to encourage faster infiltration into the media bed of BMPs such as bioinfiltration practices, bioswales, and media filters. This serves to reduce the period of standing water, but does not modify the overall infiltration rate into the subsoil layer, which typically is the limiting layer. For design of amended soil blends, adjust the percent composition of sand, silt, and clay according to the additional materials added. For example, if a more permeable soil is desired, add sand to the parent soil and adjust the percent by weight accordingly.



Using the soil classification, go to the table of infiltration rates below and select the infiltration rate appropriate for the soil type for use in design calculations. Minimum and maximum rates correspond to the lowest and highest percent sand content within a soil type, respectively. Designers shall select a rate within a given range appropriate for the actual sand content of their soil type.

Soil Type	**Infiltration Rate (in/hr) Minimum**	**Infiltration Rate (in/hr) Maximum**
Sand	4.6	8.3
Loamy Sand	1.2	2.4
Sandy Loam	0.4	1.0
Loam	0.2	0.5
Silt Loam	0.2	0.3
Silt	0.13	0.25

Sandy Clay Loam	0.06	0.2
Clay Loam	0.04	0.1
Silty Clay Loam	0.04	0.06
Sandy Clay	0.025	0.05
Silty Clay	0.02	0.04
Clay	0.01	0.02

Exhibit 14.1 – 2010 Integrated Report: Impaired Streams in Daviess County

Panther Creek Watershed

Stream Name	County	River Miles	Pollutant
Burnett Fk. into N Fk. into Panther Cr.	Daviess	0.0 to 1.3	Nitrogen (Total)
Burnett Fk. into N Fk. into Panther Cr.	Daviess	0.0 to 1.3	Phosphorus (Total)
Cane Run into S. Fk. into Panther Cr.	Daviess	0.0 to 3.7	Nutrient/Eutrophication Biological Indicators
Cane Run into S. Fk. into Panther Cr.	Daviess	0.0 to 3.7	Phosphorus (Total)
Crooked Creek into Panther Creek	Daviess	0.0 to 3.0	Fecal Coliform
Deserter Cr. into S. Fk. Panther Cr.	Daviess	0.0 to 3.1	Fecal Coliform
Ford Ditch into Rhodes Creek	Daviess	0.0 to 3.3	Phosphorus (Total)
Ford Ditch into Rhodes Creek	Daviess	0.0 to 3.3	Total Dissolved Solids
Knoblick Cr. into Panther Cr.	Daviess	0.0 to 2.1	Fecal Coliform
N. Fk. Panther Cr. into Panther Cr.	Daviess	4.2 to 9.1	Fecal Coliform
N. Fk. Panther Cr. into Panther Cr.	Daviess	9.7 to 12.7	Phosphorus (Total)
Panther Creek into Green River	Daviess	0.1 to 3.0	Fecal Coliform
Panther Creek into Green River	Daviess	3.0 to 5.9	Fecal Coliform
Panther Creek into Green River	Daviess	17.9 to 20.4	Phosphorus (Total)
Rhodes Creek into Panther Cr.	Daviess	0.0 to 2.2	Phosphorus (Total)
Rhodes Creek into Panther Cr.	Daviess	2.2 to 7.5	Nutrient/Eutrophication Biological Indicators
Rhodes Creek into Panther Cr.	Daviess	2.2 to 7.5	Phosphorus (Total)
S. Fk. Panther Cr. into Panther Cr.	Daviess	0.0 to 2.4	Copper
S. Fk. Panther Cr. into Panther Cr.	Daviess	0.0 to 2.4	Fecal Coliform
S. Fk. Panther Cr. into Panther Cr.	Daviess	0.0 to 2.4	Nutrient/Eutrophication Biological Indicators
S. Fk. Panther Cr. into Panther Cr.	Daviess	0.0 to 2.4	Phosphorus (Total)
S. Fk. Panther Cr. into Panther Cr.	Daviess	9.55 to 14.0	Fecal Coliform
S. Fk. Panther Cr. into Panther Cr.	Daviess	9.55 to 14.0	Phosphorus (Total)
S. Fk. Panther Cr. into Panther Cr.	Daviess	14.0 to 18.3	Fecal Coliform
Sweepstakes Br. into S. Fk. Panther	Daviess	1.0 to 4.0	Nutrient/Eutrophication Biological Indicators
Wolf Br. Ditch into Rhodes Cr.	Daviess	0.0 to 4.1	Nutrient/Eutrophication Biological Indicators
Wolf Br. Ditch into Rhodes Cr.	Daviess	0.0 to 4.1	Phosphorus (Total)

Exhibit 14.2 – LID Benefits to Stakeholders

LID Benefits to Stakeholders
Developers
▪ Reduces land clearing and grading costs
▪ Reduces infrastructure costs (streets, curbs, gutters, sidewalks)
▪ Reduces storm water management costs
▪ Increases lot yields and reduces impact fees
▪ Increases lot and community marketability
Municipalities
▪ Protects regional flora and fauna
▪ Balances growth needs with environmental protection
▪ Reduces municipal infrastructure and utility maintenance costs (streets, curbs, gutters, storm sewers)
▪ Fosters public/private partnerships
Home Buyers
▪ Protects site and regional water quality by reducing sediment, nutrient, and toxic loads to waterbodies
▪ Preserves and protects amenities that can translate into more salable homes and communities
▪ Provides shading for homes and properly orients homes to help decrease monthly utility bills
Environment
▪ Preserves integrity of ecological and biological systems
▪ Protects site and regional water quality by reducing sediment, nutrient, and toxic loads to waterbodies
▪ Reduces impacts to local terrestrial and aquatic plants and animals
▪ Preserves trees and natural vegetation

Exhibit 14.3 – Pollutant Generating Potential by Land Use Categorization

Pollutant Generation Potential by Land Use (H = high, M = medium, L = low)								
Pollutant	***Low Density Residential***	***High Density Residential***	***Mixed***	***Industrial***	***Commercial***	***Roads***	***Open***	***Agric.***
Total Suspended Solids	**L**	**L**	**M**	**L**	**H**	**H**	**L**	**H**
Fecal Coliforms	**M**	**M**	**L**	**L**	**L**	**L**	**M**	**H**
Total Nitrogen	**M**	**M**	**M**	**M**	**M**	**M**	**L**	**H**
Total Phosphorus	**M**	**M**	**M**	**L**	**M**	**L**	**M**	**H**
Oil & Grease	**M**	**M**	**M**	**H**	**H**	**H**	**L**	**L**
Metals	**M**	**M**	**M**	**M**	**H**	**H**	**L**	**L**

Exhibit 14.4 – Pollutant Concentrations by Land Use Categorization

Event Mean Concentrations (EMC) of Pollutants for Different Land Uses

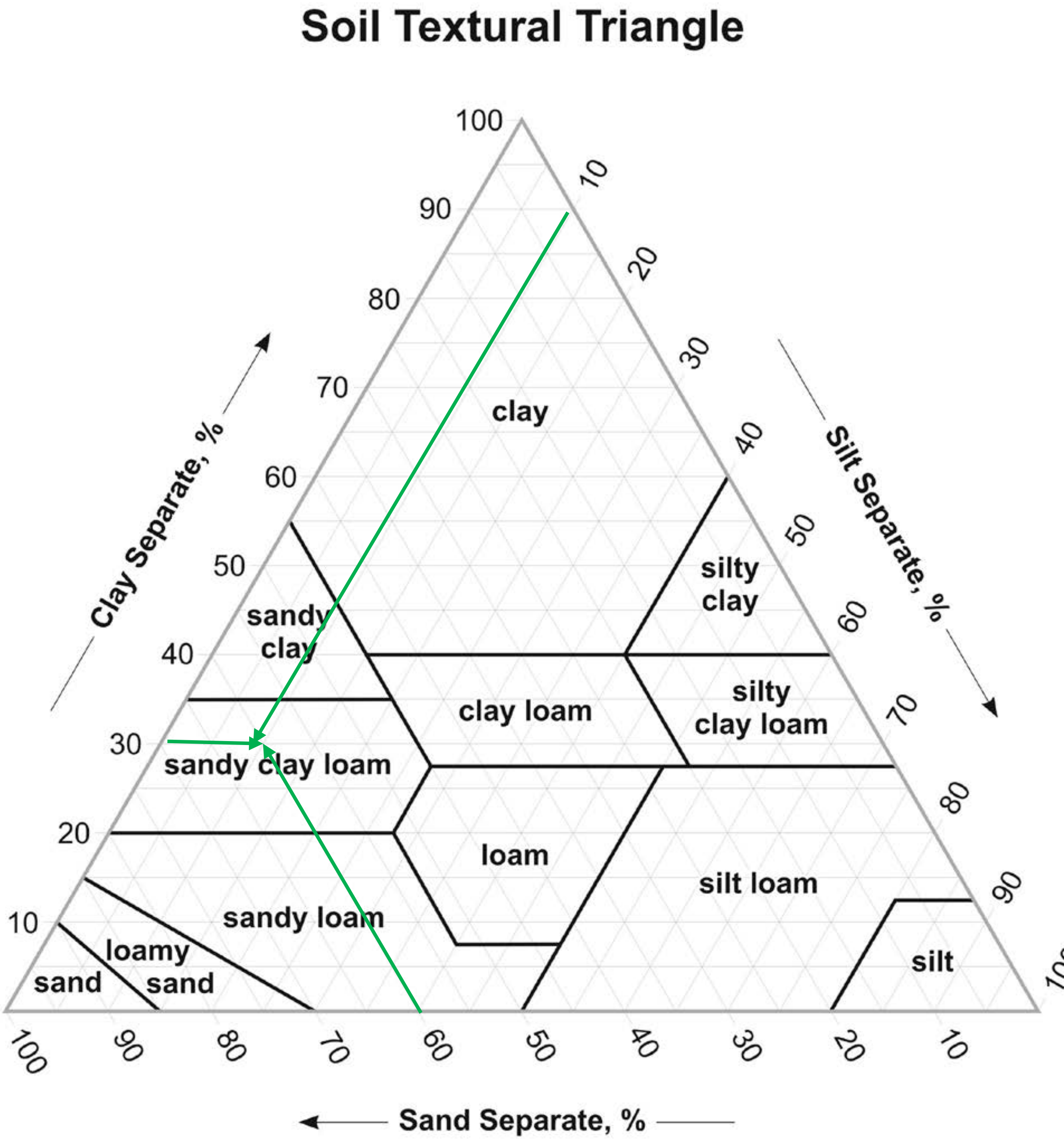
Pollutants	LOW DENSITY RES.	HIGH DENSITY RES.	MIXED	INDUS.	COMM.	ROADS	OPEN	AGRICUL
Total Suspended Solids (mg/L)	47	51	59	43	81	99	49.00	107
Fecal Coliforms (ppm)	7500	8000	5091	4500	2500	1700	7200	26000
Total Nitrogen (mg/L)	1.95	2.05	2	2.2	2.1	2.3	1.33	4.4
Total Phosphorus (mg/L)	0.29	0.31	0.27	0.22	0.3	0.25	0.31	1.3
Oil & Grease (mg/L)	3	3.2	3.5	4.7	4	8	0.00	0
Metals (mg/L)	0.097	0.103	0.11	0.12	0.3	0.28	0.05	0.02

Exhibit 14.5 - BMP Effectiveness for Pollutant Removal

Significant Benefit ●, Partial Benefit ◑, Low or Unknown Benefit ---

Water Quality Treatment (WQ) Name of BMP	#	Targeted Constituents: Sediment	Nutrients	Heavy Metals	Toxic Materials	Oil & Grease	Bacteria & Viruses	Organics/BOD	Floatable Materials	Construction Waste
Infiltration Basin *LID*	**14.01**	●	●	●	●	●	●	●	●	---
Infiltration Trench *LID*	**14.02**	●	●	●	●	●	●	●	●	---
Roof Downspout System (Dry Well) *LID*	**14.03**	(no targeted constituents)								
Permeable Pavement *LID*	**14.04**	---	●	●	◑	●	◑	◑	---	---
Constructed Wetlands *LID*	**14.05**	●	◑	●	●	●	●	●	●	---
Vegetated Filter Strip *LID*	**14.06**	●	–	●	◑	●	–	◑	---	---
Grass Swales	**14.07**	◑	---	◑	◑	◑	–	◑	---	---
BioSwales	**14.07**	◑	◑	●	●	◑	---	●	◑	---
Bioretention & Rain Gardens	**14.08**	●	◑	●	●	●	●	●	●	---
Bioretention Filters *LID*	**14.09**	●	◑	●	●	●	●	●	●	---
Vegetated/Green Roofs *LID*	**14.10**	---	●	●	---	---	---	---	---	---
Manufactured Systems	**14.11**	●	◑	●	---	◑	---	---	●	◑

Exhibit 14.6 – Soil Textural Triangle

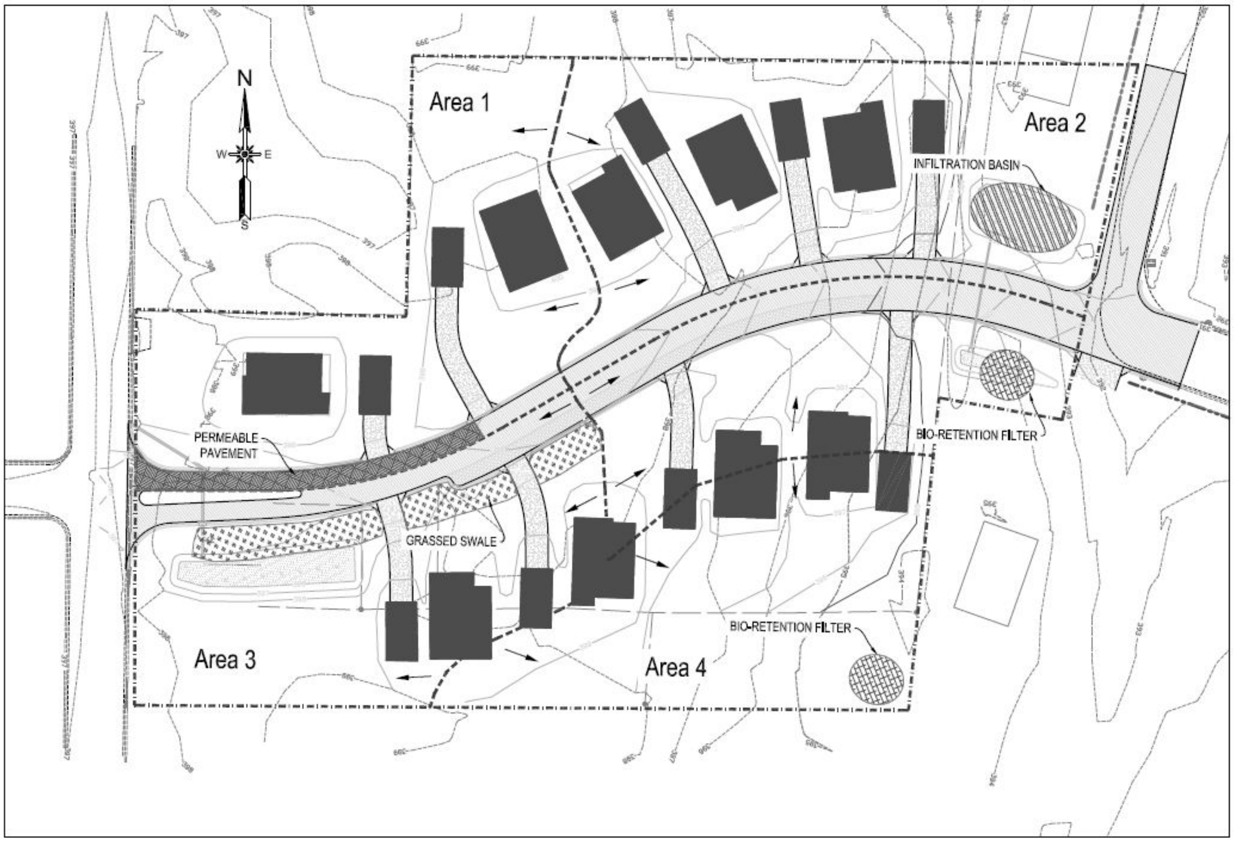


Appendix A: Design Examples

- Example 1 – Residential Development
- Example 2 – Commercial Development

Design Example No. 1: Residential Development

This is a BMP sizing example for a small residential subdivision on the west side of Owensboro. The layout of the subdivision is shown in Figure 1.



The following information was determined from field measurement and /or proposed design data:

- Total Site Area = 3.28 acres
- Four sub-watersheds
- Soil type is 100% Elk Silt Loam

Soil Symbol	Soil Name	Hydrologic Soil Group	Unified Soil Classification	CBR	% SAND	% SILT	% CLAY	Saturated hydraulic conductivity (*in/hr*)	Depth to Water Table (*ft*)
EkA	Elk Silt Loam	B	ML	3 to 5	7	63	30	0.75	> 6

Site soils were determined from the United States Department of Agriculture Natural Resources Conservation Service Web Soil Survey website:
http://websoilsurvey.nrcs.usda.gov/app/

California Bearing Ration (CBR) determined from the Kentucky Transportation Cabinet Pavement Design Guide (2007 Revision).

Primary pollutants for Roadways from Exhibit 14.3 are Total Suspended Solids (TSS), Oil/Grease, and Metals. It was assumed that offsite drainage areas were stabilized and runoff would follow overland flow over grassed surfaces, minimizing TSS and leaving oil/grease, and metals as the pollutants of concern. From Exhibit 14.5, Permeable Pavement (refer to Minimum Standard 14.04) is shown to provide significant benefit for removal of these pollutants of concern.

Area #1
Permeable Roadway – Level 1 Design with Underdrain (see Min. STD 14.04)
This example represents a roadway made of permeable pavement with a contributing impervious drainage area consisting of the following:

- 2,851 ft^2 of house roofs
- 1,028 ft^2 of garage roofs
- 1,554 ft^2 of driveways & sidewalks and 50% of permeable pavement area

The contributing pervious drainage area consists of the following:

- 1,352 ft^2 permeable roadway (actual area 2,704 ft^2 , but permeable pavements can only credit 50% as pervious)
- 22,952 ft^2 lawn area

This will be a Level 1 design since contributing drainage area consists of more than just the permeable pavement area.

The permeable pavement reservoir will be sized to store the water quality treatment volume <u>and</u> the 10 year 24 hour design storm event (4.74inches) to attenuate site peak discharge to help meet detention storage requirements (if desired – see note in step 2).

<u>Step 1.</u>
Calculate the water quality volume (WQ_v) using the formula below:

$$WQ_V = \left(\frac{A * d}{12 in.} \right)$$

Where:
WQ_V = Design Storm Volume in (ft^3)
A = Impervious area (ft^2)
d = 0.64 (depth in inches)

Criteria:

- Size for the 80% rainfall event.
  (80% rainfall event for Owensboro is 0.64 inches)

Total Area: 30,737.56 ft^2

$$WQ_V = \left(\frac{(6{,}433\, ft^2) * (0.64 in.)}{12 in.} \right) = 343.09\, ft^3$$

Impervious Area: 6,433 ft^2

<u>Step 2*.</u>
Calculate the storage volume needed to attenuate design storm event using the formula below:

$$DS_V = \left(\frac{A * d}{12 in.} \right)$$

Where:
DS_V = Design Storm Volume in (ft^3)
A = Impervious area (ft^2)
d = depth in inches

Impervious Area: 6,433 ft^2

$$DS_V = \left(\frac{(6{,}433\, ft^2) * (4.74 in.)}{12 in.} \right) = 2{,}541\, ft^3$$

Since this is a Level 1 design due to the contributing drainage area consisting of more than just the permeable pavement area, underdrains need to be accounted for in the design.

*This step is not required for effective design for WQv; it is for providing an options for additional storage to help meet water quantity control requirements.

<u>Step 3.</u>
Use **Equation 14.04-3** to approximate the outflow rate from the underdrain.

$$q_u = k * m$$

Where:

q_u = outflow through the underdrain (per outlet pipe, assumed 6-inch diameter (*ft./day*)
k = *hydraulic conductivity for the reservoir layer (ft./day – assume 100 ft./day)*
m = *underdrain pipe slope (ft./ft. – assume 1ft./200ft.)*

$q_u = (100\, ft./\, day) * (1\, ft./\, 200\, ft.) = 0.5\, ft./\, day$

Step 4.

Use **Equation 14.04-4** to determine the depth of the reservoir layer needed to store the design storm accounting for the outflow rate through the underdrain.

$$d_p = \left(\frac{(d_c * R) + P - (i / 2 * t_f) - (q_u * t_f)}{V_r} \right)$$

Where:

d_p = depth of reservoir layer (*ft.*)

d_c = depth of runoff from contributing drainage area (not including the permeable paver surface) for the water quality volume (Level 1 = 0.64 *in*) or other design storm (*ft.)*

$R = A_c/A_p$ = ratio of the contributing drainage area (*Ac*, not including the permeable paving surface) to the permeable pavement surface area (A_p)
(R = 6,433*sf* /1,352 *sf* = 4.76)

P = rainfall depth for water quality volume (Level 1 = 0.64 *in* (0.053*ft*)) or other design storm (*ft.)*

i = field-verified infiltration rate for native soils (*ft./day*)

t_f = time to fill the reservoir layer (day) – typically 2 *hours* or 0.083 *day*

V_r = void ratio for the reservoir layer (0.4)

q_u = outflow through the underdrain (*ft./day*)

Water Quality Volume Reservoir Layer Depth with Underdrain

$$d_p = \left(\frac{(0.053\, ft * 4.76) + 0.053\, ft - (1.5\, ft / day / 2 * 0.083 day) - (0.5\, ft / day * 0.083 day)}{0.4} \right)$$

$$d_p = 0.50\, ft$$

10 Year Storm Event Reservoir Layer Depth with Underdrain

$$d_p = \left(\frac{(0.4\, ft * 4.76) + 0.4\, ft - (1.5\, ft / day / 2 * 0.083 day) - (0.5\, ft / day * 0.083 day)}{0.4} \right)$$

$$d_p = 5.5\, ft$$

Step 5.
Use **Equation 14.04-5** to calculate the maximum allowable depth of the reservoir layer which is constrained by the maximum allowable drain time:

$$d_{p-\max} = \left(\frac{(i/2 * T_{\max}) + (q_u * T_{\max})}{V_r} \right)$$

Where:

$d_{p\text{-}max}$ = maximum depth of the reservoir layer (*ft.*)
i = field-verified infiltration rate for native soils (*ft./day*)
V_r = void ratio for the reservoir layer (0.4)
T_{max} = maximum allowable time to drain the reservoir layer, typically 2 days (*days*)
q_u = outflow through the underdrain (*ft./day*)

$$d_{p-\max} = \left(\frac{(1.5\,ft./\,day/\,2 * 2day) + (0.5\,ft./\,day * 2day)}{0.4} \right) = 6.25\,ft.$$

Since the reservoir layer depth for the 10 year storm event (d_p = *5.5ft.*) is less than the allowable maximum reservoir layer depth ($d_{p\text{-}max}$ = 6.25*ft.*), the minimum depth of the reservoir is 5.5 *ft.* Of the 5.5 *ft*. reservoir depth 0.5 *ft*. is needed to store the water quality volume and the remaining 5 *ft*. is used for storing the 10 year storm event.

Note: If the reservoir layer necessary to temporarily store the design storm volume is less than the depth necessary to support structural loads then the Structural support requirements will dictate the depth of the underlying stone reservoir.

Step 6.
Calculate the area needed under the permeable pavement for the storage reservoir:

Required area = design storm volume/ required reservoir layer depth/ void ratio for the reservoir layer

$$2{,}541\,ft^3 / 5.5 / 0.4 = 1{,}155\,ft^2$$

Therefore, *1,155* ft^2 of the 2,704 ft^2 planned for permeable pavement will be required to have a minimum reservoir depth of 5.5 *ft*.

Area #2
Infiltration Basin (refer to Minimum Standard 14.01)

This example represents an infiltration basin with a contributing impervious drainage area consisting of the following:

- 4,199 ft^2 of house roofs
- 1,542 ft^2 of garage roofs
- 2,338 ft^2 of driveways & sidewalks
- 3,020 ft^2 of roadway

The contributing pervious drainage area consists of the following:

- 26,526 ft^2 lawn area

<u>Step 1.</u>
Calculate the water quality volume (WQ_v) using the formula below:

$$WQ_V = \left(\frac{A * d}{12in.} \right)$$

Where:
WQ_v = Design Storm Volume in (ft^3)
A = Impervious area (ft^2)
d = 0.64 (depth in inches)

Criteria:

- Size for the 80% rainfall event.
  (80% rainfall event for Owensboro is 0.64 inches)

Total Area: 37,625 ft^2 $\quad WQ_V = \left(\frac{(11{,}099\ ft^2) * (0.64in.)}{12in.} \right) = 592\ ft^3$

<u>Step 2.</u>
Calculate the design infiltration rate using the formula below:

$$f_d = 0.5 * f$$

f_d = design infiltration rate(ft/hr)

f = infiltration rate (ft/hr) determined from the soil analysis (Elk Silt Loam, 0.75 in/hr = 0.0625 ft/hr)

$$f_d = 0.5 * (0.0625\, ft./hr) = 0.031\, ft./hr$$

<u>Step 3.</u>
Calculate the maximum ponding time and depth using the formula below:

$$d_{\max} = f_d * T_{\max}$$

Where:
d_{max} = maximum depth of the facility (*ft.*)
f_d = design infiltration rate of the basin area soils (*ft./hr*)
T_{max} = maximum allowable drain time (48*hrs*)

$$d_{\max} = (0.031\, ft./hr) * 48hrs = 1.49\, ft.$$

<u>Step 4.</u>
Calculate the minimum surface area of the facility bottom using the formula below:

$$SA_{\min} = \left(\frac{WQ_v}{f * T_{\max}} \right)$$

Where:
SA_{min} = minimum basin bottom surface area (ft^2)
WQv = water quality volume requirements (ft^3)
f_d = design infiltration rate of the basin area soils (*ft/hr*)
T_{max} = maximum allowable drain time (48hrs)

$$SA_{\min} = \left(\frac{592\, ft^3}{(0.031\, ft./hr) * (48hrs)} \right) = 398\, ft^2$$

From the calculations an infiltration basin designed to treat the water quality volume of 592ft^3 needs to have a maximum depth of 1.49ft and a minimum bottom surface area of 398ft^2. This is the minimum infiltration basin design for water quality enhancement. Designers can incorporate a larger surface area if desired to reduce the drain time and ponding depth without sacrificing performance. The infiltration basin still must provide an overflow or spillway for the bypass of large storms. Chapter 8 provides the procedures for the design of the riser and barrel system and the emergency spillway design procedures.

Area #3

Grassed Swale (Refer to Minimum Standard 14.07)

This example represents an infiltration basin with a contributing impervious drainage area consisting of the following:

- 1,974 ft^2 of house roofs
- 975 ft^2 of garage roofs
- 1,456 ft^2 of driveways
- 4,512 ft^2 of roadway

The contributing pervious drainage area consists of the following:

- 19,840 ft^2 lawn area

Step 1.
Calculate the water quality volume (WQ_v) using the formula below:

$$WQ_V = \left(\frac{A * d}{12in} \right)$$

Where:
WQ_v = Water Quality Volume in (ft^3)
A = Impervious area (ft^2)
d = 0.64 (depth in inches)

Criteria:

- Size for the 80% rainfall event.
  (80% rainfall event for Owensboro is 0.64 inches)

Total Area: 28,757 ft^2

$$WQ_V = \left(\frac{(8{,}917\, ft^2) * (0.64 in.)}{12 in.} \right) = 496\, ft^3$$

Impervious Area: 8,917 ft^2

Step 2.
Design a trapezoidal swale to have a bottom width, depth, length, and slope necessary to store the WQ_v with a maximum of 4 inches of ponding.

From the site plan there is 200ft available for the swale at 1% slope. For a trapezoidal section with a bottom width of 6ft, a WQ_v average depth of 4inches, 4:1 side slopes, compute a cross sectional area with the following equation:

$$A = bd + zd^2$$

Where:
A = area (ft^2)
b = bottom width (*ft.*)
d = depth (*ft.*)
z = channel side slope

$$A = (6\,ft. * 0.33\,ft.) + (4\,ft. * (0.33\,ft.)^2) = 2.42\,ft^2$$

Check swale for WQ_v capacity.
2.42 ft^2 * 200*ft.* = 484 ft^3 > WQ_v of 476 ft^3 {ok}
Step 3.
Determine the number of check dams required to detain the $WQ_{V.}$

For the swale at 1% slope, and maximum depth of 4 inches place check dams at: 0.33*ft.*/0.01 = 33*ft.* Six check dams spaced 33*ft.* apart are required.

Step 4.
Check the two-year velocity erosion potential. From hydrology information, the two-year flow is 1.11*cfs.* From separate computer analysis using a Manning's n value of 0.15 for flow depths at or below 4 inches (See figure 14.07-4 for other Manning's values for depths above 4 inches) and a slope of 1%, the two-year velocity will be 0.44*ft/s* at a depth of 0.35*ft.* Two year velocity of 0.44*ft/s* is less than 4*ft/s* allowed {ok}.

Step 5.
Check the ten-year velocity erosion potential. From hydrology information, the ten-year flow is 1.44*cfs.* From separate computer analysis using a Manning's n value of 0.15 for flow depths below 12 inches and a slope of 1%, the ten-year velocity will be 0.47*ft/s* at a depth of 0.40*ft.* Ten year velocity of 0.47*ft/s* is less than 7*ft/s* allowed {ok}. Total channel depth of one foot provides 0.6*ft.* of freeboard for the ten-year event which is greater than 0.5*ft.* of freeboard required.

Area #4
Bioretention Filter (Refer to Minimum Standard 14.08)

This example presents a Bioretention Filter with a contributing impervious drainage area consisting of the following:

- 3,521ft^2 of house roofs
- 1,026 ft^2 of garage roofs
- 1,622 ft^2 of driveways & sidewalks
- 3,988 ft^2 of roadway

The contributing pervious drainage area consists of the following:

- 36,077 ft^2 lawn area

<u>Step 1.</u>
Calculate the water quality volume (WQ_V) using the formula below:

$$WQ_V = \left(\frac{A * d}{12in} \right)$$

Where:
WQ_v = Water Quality Volume in (ft^3)
A = Impervious area (ft^2)
d = 0.64 (depth in inches)

Criteria:
- Size for the 80% rainfall event.
  (80% rainfall event for Owensboro is 0.64 inches)

Drainage area 4 is split in two with 47% of the area draining to the north west and 53% draining to the north east. The WQ_v for the two areas is determined as follows:

<u>WQv draining to the northwest</u>

Total Area: 21,730 ft^2 $$WQ_V = \left(\frac{(7{,}421\, ft^2) * (0.64 in.)}{12 in.} \right) = 386\, ft^3$$
Impervious Area: 7,241 ft^2

<u>WQv draining to the northeast</u>

Total Area: 24,504 ft^2 $$WQ_V = \left(\frac{(2{,}916\, ft^2) * (0.64 in.)}{12 in.} \right) = 156\, ft^3$$
Impervious Area: 2,916 ft^2

<u>Step 2.</u>
Determine the required floor area of the bioretention filter. The floor surface area is determined by dividing the volume of water to be treated by the maximum ponding depth (max 6”). Calculate the required floor area using the formula below:

$$FA = \left(\frac{WQ_V}{D} \right)$$

Where:

FA = required floor surface area (ft^2)
WQv = volume stored in bioretention filter (ft^3)
D = depth of water in bioretention filter (ft)

Required floor area for the northwest bioretention filter

$FA = (386\ ft^3) / (0.5\ ft) = 772\ ft^2$

Required floor area for the northeast bioretention filter

$FA = (156\ ft^3) / (0.5\ ft) = 312\ ft^2$

Step 3.
Determine the planting soil for the bioretention filter.

If native soils are to be used for the planting soil they must have a permeability of at least 0.25 *in./hr*, otherwise a prepared soil bed should be designed. A prepared soil bed shall contain a planting soil mixture of 50% sand, 30% leaf compost (fully composted, NOT partially rotten leaves), and 20% topsoil. Topsoil shall be sandy loam or loamy sand of uniform composition containing no more than 5% clay. Typical permeability for a mixture of this type ranges from 1 to 6 inches per hour.

Native soil for this site is Silt Loam with 30% clay which precludes its use in the planting soil bed. A prepared soil bed using suitable material must be used.

Step 4.
Determine the depth of the planting soil for the bioretention filter.

Provide a planting soil bed with a minimum depth of 3 feet (4 to 5 feet is preferable) over the entire floor area required for the bioretention filter. Place planting soil in lifts of 12 to 18 inches and loosely compact or tamp lightly with backhoe bucket.

Step 5.
Determine the rate of water flow through the bioretention filter planting bed.

The rate at which water moves through the planting bed can be estimated using Darcy's Law a well established equation used to determine the movement of groundwater.
Darcy's Law is calculated using the formula below:

$$q = \left(\frac{K * \Delta H}{L} \right)$$

Where:

q = flow per cross sectional area (*ft/hr*)
K = hydraulic conductivity for planting bed media (0.083 *ft/hr*)
ΔH = change in head (height of water) (*ft.*)
L = thickness of planting bed media (3 *ft.*)

$$q = \left(\frac{0.083\,ft./hr * 3.5\,ft.}{3\,ft.} \right) = 0.097\,ft./hr \text{ (per unit area)}$$

Multiply by the area of the bioretention filter determines the total flow through the planting bed media. Flow through the planting bed media is calculated using the formula below:

$$Q = q * FA * \left(\frac{1hr}{3600s} \right)$$

Where:
Q = flow through planting bed media (ft^3/s)
q = flow per cross sectional area (*ft/hr*)
FA = required floor surface area (ft^2)

<u>Flow through planting bed media of the northwest bioretention filter</u>

$$Q = (0.097\,ft./hr) * (772\,ft^2) * \left(\frac{1hr}{3600s} \right) = 0.02\,ft^3/s$$

<u>Flow through planting bed media of the northeast bioretention filter</u>

$$Q = (0.097\,ft./hr) * (312\,ft^2) * \left(\frac{1hr}{3600s} \right) = 0.008\,ft^3/s$$

<u>Step 6.</u>
Determine the size of the bioretention filter underdrain pipes. The pipes must be selected so that they drain water from underdrain area substantially faster than water enters from the soil fill layer above. As a factor of safety design for pipes to remove 5 to 10 times the amount of water that flows thru the soil planting bed.

Use the Manning Equation to determine the number of underdrain pipes and their associated diameter. The equation is given below:

$$D = 16 * \left(Q * \frac{n}{S^{0.5}} \right)^{3/8}$$

Where:
D = diameter of pipes (inches)
Q = flow to be carried (cfs)

n = Manning coefficient (0.014 for single wall corrugated pipe, 0.011 for smooth-walled pipe)
S = slope of pipe (0.5% minimum)

Apply a factor of safety and size the pipe system to carry at least 10 times the flow draining thru the planting bed media.

<u>Flow through planting bed media of the northwest bioretention filter</u>

$$Q = 0.02\, ft^3 / s * 10 = 0.2\, ft^3 / s$$

<u>Flow through planting bed media of the northeast bioretention filter</u>

$$Q = 0.008\, ft^3 / s * 10 = 0.08\, ft^3 / s$$

Determine the size of the underdrain pipes.

<u>northwest bioretention filter</u>

$$D = 16 * \left(0.2\, ft^3 / s * \frac{0.011}{0.005^{0.5}} \right)^{3/8} = 4.35 inches$$

Therefore, at least two 4 inch smooth-walled pipes are needed or one 6 inch pipe.

<u>northeast bioretention filter</u>

$$D = 16 * \left(0.08\, ft^3 / s * \frac{0.011}{0.005^{0.5}} \right)^{3/8} = 3.08 inches$$

Therefore, one 4 inch smooth-walled pipe is needed.

<u>Step 7.</u>
Determine the size of the overflow weir using the weir equation below:

$$Q = Cw * L * H^{3/2}$$

Q = peak flow from design storm (*cfs*)
Cw = weir coefficient (use 3)
H = height of water above weir (*ft.*) (typ. 0.17’, max. 0.5’)
L = weir length (*ft.*)

From a separate hydrological analysis for the site the following discharge rates were calculated:

<u>10-year discharge rate</u>
Northwest bioretention filter = 1.88 ft^3/s
Northeast bioretention filter = 2.15 ft^3/s

<u>25-year discharge rate</u>
Northwest bioretention filter = 2.08 ft^3/s
Northeast bioretention filter = 2.37 ft^3/s

Determine the weir lengths necessary to bypass both the 10-year and 25-year storm events. Rearranging the weir equation to solve for length:

$$L = \left(\frac{Q}{Cw * H^{3/2}} \right)$$

<u>northwest bioretention filter</u>

$$L_{10yr} = \left(\frac{1.88 cfs}{3*(0.17\,ft)^{3/2}} \right) = 1.52\,ft.$$

$$L_{25yr} = \left(\frac{2.08 cfs}{3*(0.17\,ft)^{3/2}} \right) = 1.69\,ft.$$

<u>northeast bioretention filter</u>

$$L_{10yr} = \left(\frac{2.15 cfs}{3*(0.17\,ft)^{3/2}} \right) = 1.75\,ft.$$

$$L_{25yr} = \left(\frac{2.37 cfs}{3*(0.17\,ft)^{3/2}} \right) = 1.92\,ft.$$

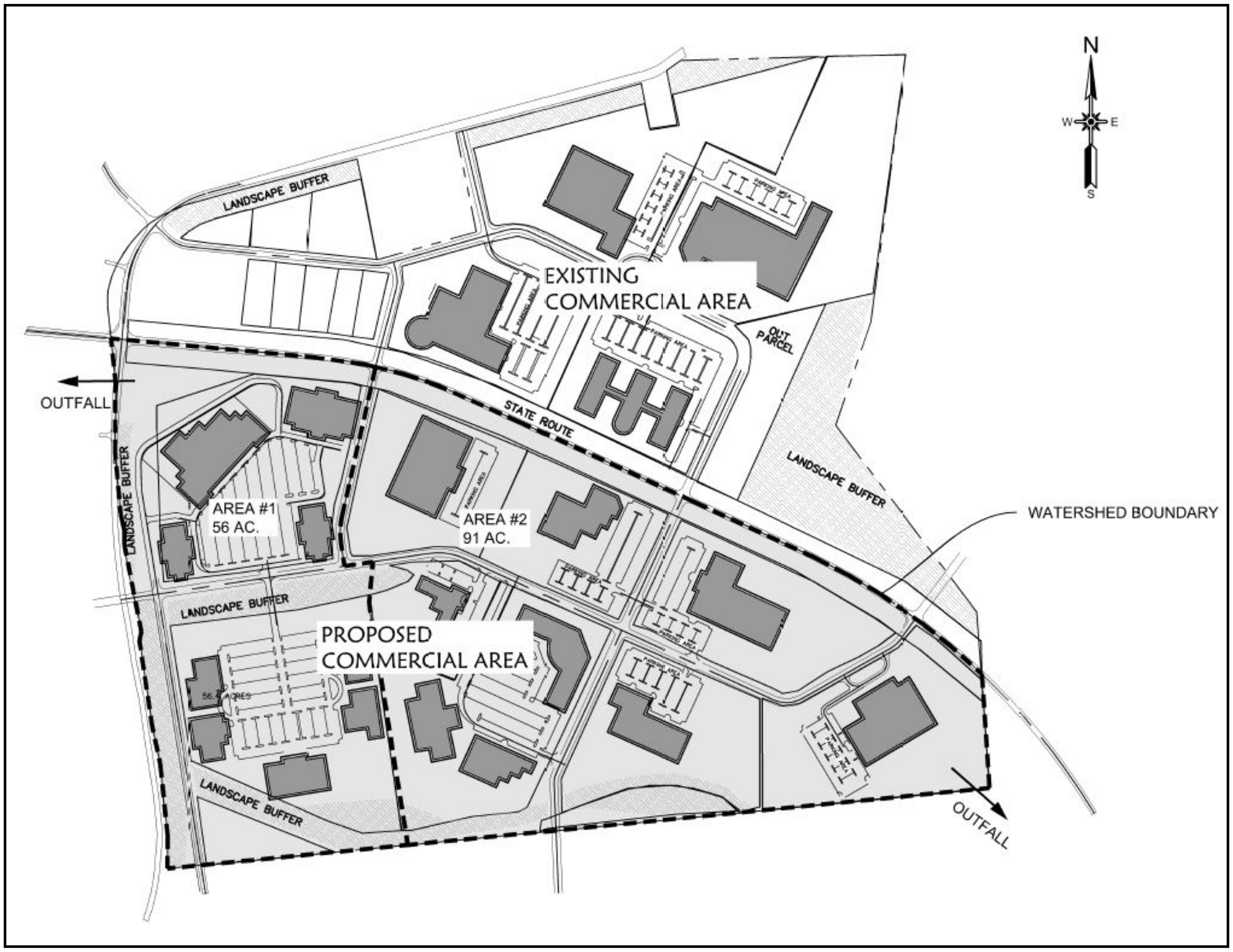
Determine an appropriately sized circular riser pipe to use as the overflow structure. Try an 8-inch circular riser pipe.

Circumference = 3.14 * diameter of catch basin
= 3.14 * (8”/12”) = 2.09*ft.*

An 8-inch circular riser pipe has a circumference of 2.09’ which is greater than the necessary weir lengths calculated. Use 8-inch riser pipe with a domed grate as the overflow weir elevated 0.17’ (2inches) above the maximum ponding depth.

Design Example No. 2: Commercial Development

This is a BMP sizing example for a commercial development in Owensboro. The site is split into two distinct watersheds labeled Area 1 and Area 2 on the development layout plan of shown in Figure 1 below.



The developer intends to treat the water quality volume (WQ_v) from the site with two manufactured BMP systems, one installed in each watershed. Drainage from Area 1 flows to the northwest corner and discharges from a single outfall location. Drainage from Area 2 flows to the southeast corner and discharges from a single outfall location.

The following information was determined from field measurement and/or proposed design data:

Area #1

- Total Area = 56 acres (0.088mi^2)
- Impervious area =35 acres
- Pervious area = 21 acres
- Time of Concentration = 18minutes (0.3*hr*)
- Effective CN = 87
- Water quality treatment depth = 0.64 inches

Area #2

- Total Area = 91 acres (0.14 mi^2)
- Impervious area =35 acres
- Pervious area = 21 acres
- Time of Concentration = 24minutes (0.4 *hr*)
- Effective CN = 88
- Water quality treatment depth = 0.64 inches

The WQ_v discharge is used to select an appropriately sized manufactured BMP system. The WQ_v discharge is determined using the SCS TR-55 graphical peak discharge method for small watersheds (NRCS 1986). The peak discharge is calculated by the formula below:

$$q_p = q_u * A_m * Q * F_p$$

Where:

q_p = *peak discharge (cfs)*
q_u = unit peak discharge (csm/in)
A_m = *drainage area* (mi^2)
Q = WQ_v *(in)*
F_p = pond and swamp adjustment factor = 1 (no ponds or swamps in watershed)

Step 1.

In order to determine the unit peak discharge (q_u) the ratio of initial abstraction (I_a) to WQv rainfall depth (P) in inches is needed. This is defined as:

$$\left(\frac{I_a}{P}\right) = \left(\frac{0.2S}{P}\right)$$

Where:

S = potential maximum retention after runoff begins (*in*)

$$S = \left(\frac{1000}{CN}\right) - 10$$

Area #1

$$S = \left(\frac{1000}{87}\right) - 10 = 1.49 inches$$

$$\left(\frac{I_a}{P}\right) = \left(\frac{0.2 * 1.49 inches}{0.64 inches}\right) = 0.47$$

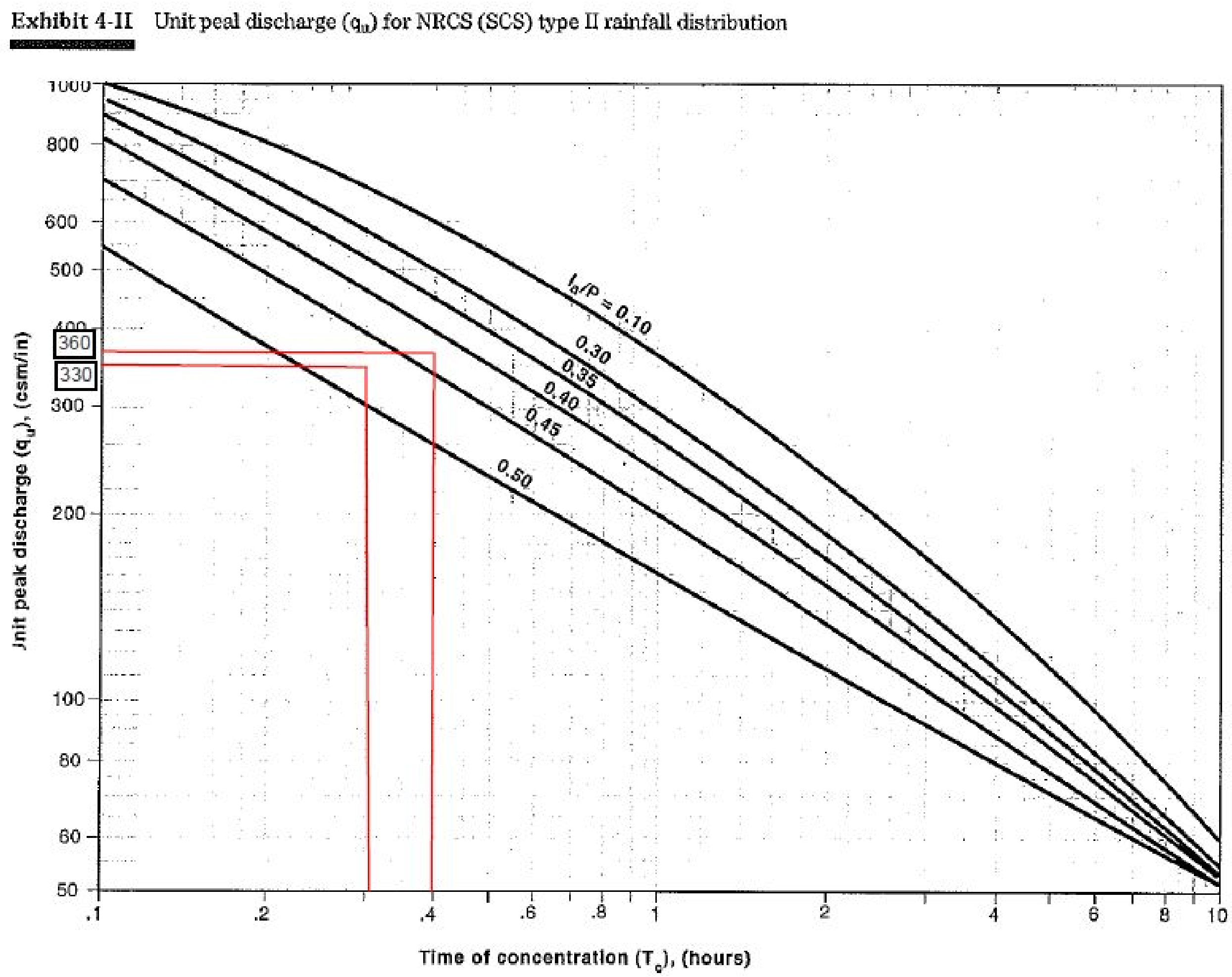
Area #2

$$S = \left(\frac{1000}{88}\right) - 10 = 1.36 inches$$

$$\left(\frac{I_a}{P}\right) = \left(\frac{0.2 * 1.36 inches}{0.64 inches}\right) = 0.43$$

<u>Step 2.</u>

Using the determined time of concentration and I_a / P ratio under SCS Type II storm conditions, the unit peak discharge (q_u) is determined graphically using Exhibit 4-II from NRCS 1986.



Area #1

$q_u = 330 csm / in$

Area #2

$q_u = 360 csm / in$

Step 3.

Determine the peak WQ_v design discharge to the manufactured BMP system:

Area #1

$$q_p = (330 csm/in) * (0.088 mi^2) * (0.64 in) * 1 = 19 cfs$$

Area #2

$$q_p = (360 csm/in) * (0.14 mi^2) * (0.64 in) * 1 = 32 cfs$$

<u>Step 4.</u>

Determine the appropriate size of manufactured BMP system to treat the peak WQ_v design discharge.

The City of Owensboro has pre-approved the use of the Nutrient Separating Baffle Box® as manufactured by Suntree Technologies Inc. for use as a manufactured BMP system. Below is a table of available Nutrient Separating Baffle Box® sizes for the peak treatment and peak design flow rates.

Model #	Pipe Size Range	Peak Treatment Flow	Peak Design Flow
3-6-84	up to 12"	2 *cfs*	5 *cfs*
4-8-84	up to 24"	8 *cfs*	12 *cfs*
6-12-84	up to 42"	24 *cfs*	46 *cfs*
8-16-96	up to 60"	45 *cfs*	75 *cfs*

Area #1

The peak WQ_v design discharge is 19 *cfs* so select Model # 6-12-84.

Area #2

The peak WQ_v design discharge is 32 *cfs* so select Model # 8-16-96.

If the peak WQ_v design discharge rate is greater than the peak treatment flow of available manufactured BMP systems then use two or more units as necessary to meet the required WQ_v discharge rate.

Appendix B: BMP Minimum Standards

1.Infiltration Basin
2.Infiltration Trench
3.Roof Downspout System
4.Permeable Pavement
5.Constructed Stormwater Wetland
6.Vegetated Filter Strip
7.Grassed Swale – Bioswale
8.Bioretention Basin Practices
9.Bioretention Filters
10.Vegetated Roof
11.Manufactured BMP Systems