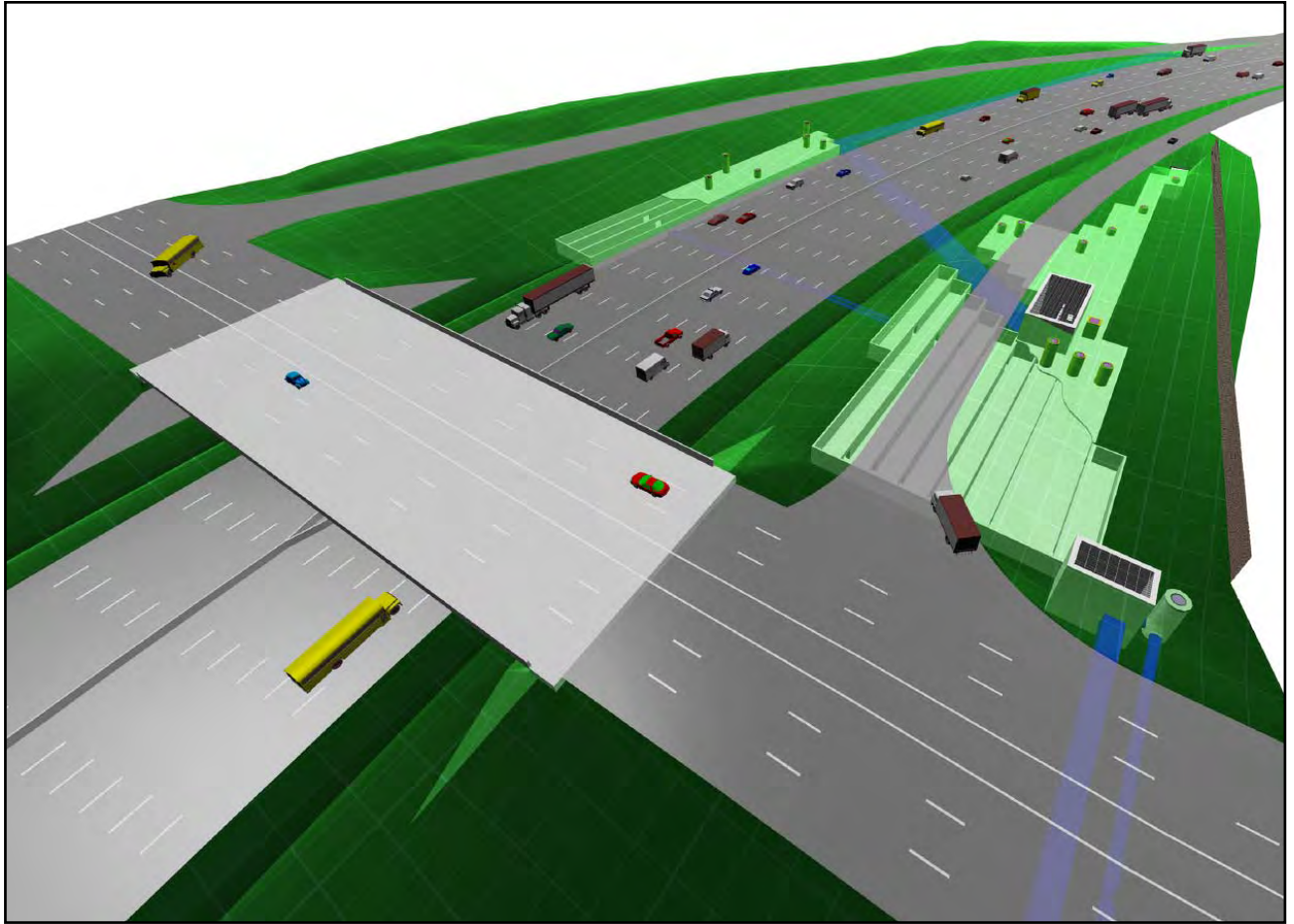


## Executive Summary



***A 3-D rendering of the underground detention pond designed for the Page Avenue Extension. A detailed depiction of the underground facility can be found on pages 8 and 9.***

On a project the magnitude of the Page Avenue Extension, unsuspected circumstances are bound to arise that test the engineers who are charged with finding a solution. Such was the case when the Missouri Department of Transportation (MoDOT) determined that conditions along a stretch of the new highway would result in potential flooding that could not be mitigated by standard highway drainage applications.

Crawford, Murphy & Tilly, Inc. (CMT) was called in and responded with a design for an innovative underground detention “pond” that accommodates a large volume of stormwater in the limited right-of-way that was available. The pond is comprised of a configuration of reinforced concrete box culverts (RBC) that are interconnected to act as a single unit. The total volume of approximately 10 ac. ft. is much larger than a typical underground facility and conveyance is controlled exclusively by gravity. The drainage system results in a zero increase in the rate of runoff into the outfall creek despite the highway’s conversion of 31 acres to impervious pavement.

The use of RBC in underground detention ponds provides a model for drainage systems on future projects. Its flexible design provides benefits in terms of cost, safety, maintenance, and operations in comparison to open-air ponds.

## Project Description

### ■ Role of CMT in the Project

CMT designed a complete drainage system for the Page Avenue Extension from the I-270 interchange to Creve Coeur Park. The project included the preparation of a drainage report, preliminary and final plans for a stormwater drainage system, and sanitary system relocation.

A primary element of the project was the design of an underground stormwater detention pond. The unique conditions surrounding the project precluded the use of traditional designs. CMT responded with a detention pond design that employs a unique application of both techniques and materials, and one that will serve as a case study for future projects.

The design of the project was completed in December of 2000 and construction was finished by 2003.

### ■ Subconsultants Role

CMT did not require the services of a subconsultant on this project.

### ■ Original or Innovative Application of New or Existing Techniques

During construction of the Bennington Place interchange as part of the Page Avenue Extension, Missouri Department of Transportation (MoDOT) officials realized that there were significant stormwater drainage issues. MoDOT therefore pursued a design that would meet the more stringent requirements necessary for a permit from the Metropolitan Sewer District (MSD). Since highway projects do not typically require such permits, MoDOT called upon Crawford, Murphy & Tilly, Inc. (CMT) to provide a suitable solution that would mitigate potential flooding and meet permitting requirements.

To meet requirements, CMT was charged with developing a stormwater drainage system that would result in zero-increase of stormwater runoff into the nearby creek drainage area despite 31 acres of the 217-acre watershed being converted to impervious pavement as part of the highway project construction. MSD also required that CMT account for drainage from the entire watershed, not merely that from the local tributary area of the highway. The low elevation of the highway, MoDOT's requirement that flow be controlled exclusively by gravity, and the limited right-of-way available for a suitable open-air detention pond necessitated that an innovative approach be developed.

CMT's solution was an underground detention pond using Reinforced Concrete Box Culverts (RBC). With a total volume of approximately 10 ac. ft., it is significantly larger than traditional facilities and represents a new measure for the utilization of underground facilities on highway projects. The 10 ac.-ft. volume is also 1.5 ac. ft. larger than the predicted detention volume from an active 100-year storm event.



*The use of RBC for large-scale, underground detention provides a flexible solution for tightly constrained areas.*

Underground detention facilities are typically designed to handle volumes of less than one acre-foot and are usually constructed with circular pipe. MoDOT expressed concerns over the use of metal pipes due to corrosion. To meet the needs of this project, CMT engineers turned to RBC as an alternative and realized their potential to offer an effective, economical, and long-life solution.

An added benefit of RBC as demonstrated on this project is its modular design. Culverts can be arranged in customized configurations and connected by pipe to fit a project's needs in terms of volume and available right-of-way. This offers a great deal of flexibility to accommodate unforeseen field conditions.

The underground pond consists of approximately 3,380 lineal feet of 10 ft. high x 12 ft. wide RBC. It was determined that casting the culverts in place was more economical than having pre-cast culverts delivered to the site. The RBC were arranged horizontally and interconnected by 7 ft square openings and 36 in. diameter openings at several locations and elevations to allow them to act as a single storage system.

The RBC system flows into a 50 ft. x 28 ft. x 32 ft. release structure. Run-off is released from the pond through a 12 in. diameter orifice designed to accommodate low flow conditions and the allowable two-year release rate. A backup orifice that can be opened at ground level was also included in the event that the main orifice becomes blocked. The 100-year flow will be conveyed through a 30 ft. long by 2.12 ft. high combination weir/orifice opening. Flow from the release structure will be conveyed to the watershed outfall through three 4 ft. high x 6 ft. wide RBC that are sized to carry 133 percent of the maximum 100-year runoff volume from the tributary watershed area.



*Project costs were reduced by casting the RBC in place rather than having pre-cast culverts delivered to the site.*



*Flow from this release structure is designed to convey 133 percent of the maximum runoff from a 100-year storm encompassing a 217-acre watershed.*

While the use of RBC in place of metal pipe will significantly maximize the design life and reduce the maintenance requirements of the facility, additional features were also included to ensure that the drainage system operates freely. Grating was placed over the opening of the two inlet pipes into the pond to filter debris from entering the system. A steel bulkhead was built into one of the RBC to provide access for maintenance equipment. Large openings were incorporated between each row of RBC units so that a small maintenance vehicle such as a Bobcat can maneuver throughout the system.

*An added feature of the project is this steel bulk head that is large enough for a small utility vehicle to enter the detention pond and perform maintenance functions.*



## ■ Future Value to the Engineering Profession

As the space between suburban and urban regions begins to diminish, the construction of highway infrastructure through already developed areas presents many challenges. Chief among these is the ability to provide adequate drainage on sites with limited right-of-way. This project demonstrates that a high-volume below ground detention pond is a viable and economical alternative under these conditions.

The use of RBC, normally used for conveyance purposes, as a means for detention illustrates a creative application of a material that is familiar to the industry. The low-maintenance quality of concrete combined with the ability to interconnect units in a variety of configurations makes RBC a functional solution that can be adapted to the specific needs of a project.

This design will offer another option for engineers when traditional highway drainage systems do not meet the needs of the project in terms of economics, operation, and safety.

The public had voiced numerous concerns throughout the long history of the Page Avenue Extension project. Among these were concerns about potential flooding and the disturbance of the existing environment. CMT provided a *context sensitive solution* that successfully addressed both of these issues in the design of the stormwater drainage system that serves a four mile section of the extension.

The system maintains the pre-highway construction level of flow from the watershed to the drainage creek and is designed to handle stormwater runoff in excess of the volume predicted for a 100-year storm event. To help prevent pollution of Creve Coeur Park Lake, an area of intense public concern, the system is designed to pick-up runoff from the highway and channel it back and away from the lake.

The use of an underground detention pond is an inconspicuous solution that doesn't interfere with the existing ascetic environment. The pond is located in close proximity to a residential area and it was important to not introduce a facility that would be unappealing or unsafe to those living there.

## ■ Social, Economic, and Sustainable Design Considerations

**Space Compatible** - The underground detention pond did not require the acquisition of additional right-of-way. The structure's location on both sides of the highway between the mainline and its on and off ramps effectively used what would otherwise amount to dead space in order to meet the stormwater management regulations. What would have been an unsightly concrete structure has been embedded in such a way as to enhance the aesthetic quality of the area.

**Flood Control** - MoDOT's chief criteria for retaining the services of CMT was to minimize flooding of downstream areas despite more than 31 acres of turf and grass being converted to impervious pavement. The system designed for this project is designed to handle a stormwater flow in excess of that projected during a 100-year storm event. Flow into the creek is less today than before construction of the highway despite the additional impervious pavement created.



*The underground pond offers significant safety benefits, especially important given the project's proximity to a residential area.*

**Safety** - The underground pond protects against health and safety concerns that can arise as the result of an open-air pond. Given the site's close proximity to a residential area, an open-air pond would have presented a hazard in terms of drowning or other accidents. In addition, stagnate water in an open-air pond can lead to mosquito infestation that can result in the spread of disease.

## ■ Complexity

**Permitting** - MoDOT does not routinely obtain an MSD stormwater management permit, but due to the nature of the watershed and the large acreage of pavement to be added it was determined that obtaining a permit on this project would be prudent.

**Vertical Clearances** - At its low point, the highway alignment was barely above the creek outfall. The roadway could not be raised due to the clearance of the existing Bennington Place overpass located a few hundred feet upstream of the outfall. This prevented the use of large diameter pipes or tall RBC that are needed to drain such a large paved area. Instead, several runs of small diameter pipe and short RBC were used in the pavement drainage system.

**Changing Field Conditions** - A unique feature of the underground detention pond served to effectively address an unforeseen problem that arose during construction. A 32-unit apartment complex is located within 50 ft. of the area that was excavated to a depth of approximately 50 ft. for the construction of the underground facility. Unforeseen soil conditions along with a wet construction season required that 1,000 ft. of the excavation along the temporary shoring be back-filled before the RBC structure was constructed. This eliminated more than 40 percent of the space needed to accommodate the pond.

*Forty percent of the space needed for the pond was lost when 1,000 ft. of excavation along the temporary shoring had to be back-filled. Project designers responded by moving a section of the pond to the opposite side of the highway.*



The original system design called for all of the RBC to be located in the area between the west-bound ramp onto Page and the highway mainline. The modular design of the pond allowed CMT, who was subsequently hired by the contractor, to adjust for the altered conditions and quickly design the relocation of three rows of RBC to the north side of the highway. This resulted in two separate sections of the pond that were then connected with three 36 in. diameter pipes that enables the two sections to act as a single unit.

**Leachate Control** - The presence of leachate from an old landfill was detected during the project. CMT tested the discharge for hazardous materials and found it to be safe. A collection system was designed to collect the leachate and deposit into a culvert before it could seep out onto the highway.

## ■ Exceeding Client/Owner Needs

MoDOT sought out the services of CMT in order to obtain an MSD permit to protect against possible flooding conditions. The detention facility designed by CMT met the requirements for receiving an MSD permit and the needs of MoDOT for this project.

CMT worked closely with MoDOT staff throughout the project and offered multiple options for the detention pond. An open-air pond with an operating water depth of 10 feet was offered as an alternative. In order to accommo-



*CMT met 100 percent of MoDOT’s goals with its design of a drainage system for the Page Avenue Extension.*

date the existing grades, however, the pond would have had to be built 27 ft. deep. MoDOT rejected this alternative due to safety concerns and opted for the more economically favorable option of the underground facility. The cost for the open-air pond was estimated to be \$1 million more than the underground pond.

Final costs for the drainage system were in line with the original estimate and no major additional costs were incurred. The project met 100 percent of the client’s goals with regard to permitting, flood protection, safety, economics, aesthetics, operations, and maintenance.

On the client project evaluation form, MoDOT rated CMT highly in all categories including “excellent” ratings for communication, technical creativity, and meeting design objectives.