2016

Restoring Habitat in Densely-Populated Suburbs in the Northeast: A Demonstration Project

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Abstract
Researchers have documented the decrease in populations of native birds and other wildlife, as well as the fact that this decrease correlates with loss of natural habitat in the suburbs. Suburban sprawl has also led to increased stormwater runoff, which carries road and lawn chemicals into local streams and erodes stream banks. Suburban homeowners may be unaware of these problems or unsure of how they can remedy the situation. While model pollinator gardens and rain gardens exist, they are often in out-of-the way places such as nature centers, where the average person will not see them without special effort. Furthermore, the models often lack design appeal, appearing as a random collection of plants.

In order to provide an accessible model of appealing landscaping using native plants, a multi-year project to re-landscape the gardens was begun at Trinity Presbyterian Church, Berwyn, Pennsylvania, in 2015. Church members embraced the plan to beautify the property while improving the ecosystem function of the church's gardens and reducing stormwater runoff. The project thus had the dual purpose of improving the property's ecosystem function and appearance, and of providing an example for the congregation and the local community to emulate.

A key element of the project has been to get congregation members involved in the planning, funding, and actual installation of rain gardens, terraced beds, and pollinator gardens. Installation of the first rain garden provided an opportunity to also get the larger community involved: A local public garden (Jenkins Arboretum and Gardens) donated over 100 plants, and the project became the Eagle Scout project for a local Boy Scout, Connor Bryan. In the second year (2016), more plants were added and the gardens were expanded, successfully enlisting more active involvement from the congregation. The next step of the project is to create a brochure that could be shared with congregations, schools, and municipalities interested in pursuing a similar project.

Disciplines
Environmental Sciences | Physical Sciences and Mathematics

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A Demonstration Project

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Master of Environmental Studies
Resource Management/Education and Advocacy

Fall 2016

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ABSTRACT

Researchers have documented the decrease in populations of native birds and other wildlife, as well as the fact that this decrease correlates with loss of natural habitat in the suburbs. Suburban sprawl has also led to increased stormwater runoff, which carries road and lawn chemicals into local streams and erodes stream banks. Suburban homeowners may be unaware of these problems or unsure of how they can remedy the situation. While model pollinator gardens and rain gardens exist, they are often in out-of-the way places such as nature centers, where the average person will not see them without special effort. Furthermore, the models often lack design appeal, appearing as a random collection of plants.

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Acknowledgements

Heartfelt thanks to the many people who have guided and sustained me through this endeavor:

To Sally Willig for advice and encouragement throughout the project.

To David Vann for laboratory access, help analyzing water quality, and useful discussion regarding water degradation.

To Kate Doms for getting me started learning about the local watershed and pointing me to resources along the way.

To Catherine Smith at Redbud Native Plant Nursery for encouragement and advice on what to plant.

To all the folks at Trinity Presbyterian Church who encouraged me to take on this project and supported me every step of the way; especially to Elisabeth Hartwell, Don Tokash, Donna Hutchison-Lang, and Joe Carlin, who were my initial supporters and partners, and to Heather Dibble and John Wunderlich IV who joined the cheering team the second year; to Patty Roseberry and Wendy Mauchly, who helped with the early and seemingly unending weeding; to Jim Hatfield and Terry Walmsley, who helped calculate runoff; and to Don Bovais and Pam Koch, who continue to be there with strong backs, shovels, and good humor. Thanks to the neighbor who walked by and stopped to help weed – good therapy, as she said! Thanks also to Tom Hartigan and the Buildings and Grounds crew who willingly provided extra muscle when needed.

To Connor Bryan and Boy Scout Troop 219 for weeks of labor and a job well done.

To Steve Wright at Jenkins Arboretum and Gardens, who provided hundreds of plants for the gardens from the Jenkins plant nursery.

To Suzi Alrutz and the preschool staff for their enthusiasm. May there be many more seasons of flowers and pollinators for the kids to visit!

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1 Introduction

Many authors have lamented the increasing loss of natural habitat as suburbs expand (Ehrlich & Ehrlich (1981) and Tallamy (2009) are examples). The Pennsylvania Audubon Society web page, 'Why Birds?' states that 2.1 million acres of wildlife habitat are converted to residential use annually in the United States. Tallamy predicts that, if current land-use policies are not reversed, we could see the extinction of 95% of the species that inhabited North America when Europeans first came here (p. 36). The loss of species threatens not just our enjoyment of nature, but our very existence if the web of nature that sustains us collapses.

In addition to habitat loss, development of cities, suburbs, and large farms has presented a second environmental challenge – that of degraded water quality as chemical- and sediment-laden stormwater enters waterways.

It seems that development, if done using environmentally friendly techniques such as reducing impervious surfaces, clustering houses close together to leave more open space, and including bio-retention ponds in subdivisions, can avoid watershed degradation (Dietz & Clausen, 2007). Dietz & Clausen found that a low-impact development with these characteristics had stormwater runoff and pollutant-export numbers "consistent with values from forested watersheds (p. 560)" while traditional development increased the property's runoff/pollutant-export numbers more than two orders of magnitude.

Given the preponderance of conventionally-developed suburbs, can the damage be undone? Research cited by Dovel, Kemp, and Welker (2014) going back to the 1980s shows that stormwater-control measures such as rain gardens can reduce the volume of stormwater runoff. Rainwater diversion in rain gardens and the like is also much less expensive than building and maintaining stormwater sewers and detention basins (Locicero 2015). Changing the way suburban landscapes are planted could also increase the habitat value for birds and pollinators, possibly even providing needed connectors between forested areas (Tallamy 2009). Adding 'green' features such as rain gardens and native plantings also provides a way to involve local residents in the care of their own watershed (Locicero 2015). Institutions such as churches and schools have the opportunity to involve the community in a meaningful way in the greening of the property through installation of such features.

In March, 2015, I presented a plan to install native plants and rain gardens at Trinity Presbyterian Church (Trinity) in Easttown Township, Chester County, PA. The proposal was received enthusiastically by the church community. Most people saw re-landscaping with native perennials as a chance to stop spending large sums of money on flowering annuals that need replacing every season. Some also saw the project as a way to create an attractive alternative to the usual suburban landscaping, at once creating a more environmentally-friendly landscape and creating demonstration gardens visible to people who pass by. Rain gardens were seen as a way to bring the serious stormwater runoff problem under control. A long-term church goal for the re-landscaping project was that it would serve as a link to the neighborhood. Thus an outworking of the immediate sproject will be to produce a guide that would help other churches, schools, or municipal entities rework their landscaping to provide ecological services while attracting people as well.

This report details the background research that motivated the project, outlines what was done on the Trinity property, and highlights takeaway lessons that should go in a guide. Because keeping water on the property became a major focus of the project, **Section 2** reviews relevant research regarding rain gardens and bioremediation. **Section 3** describes the Trinity Presbyterian Church site and the development and execution of the project. **Section 4** discusses results, and **Section 5** highlights the important detail of getting other people involved while expanding the project to a more general initiative to improve the church's stewardship of land and resources. The **Conclusion** outlines the proposed guide for public use.

2 Background: What do rain gardens do? The basic rain garden provides a basin, planted with grasses, forbs, and shrubs, where water can slowly sink into the soil. Soil amendments such as sand are added as needed to loosen the texture of the soil to increase infiltration. Typically, a layer of mulch is added to prevent erosion, control weeds, and provide an initial source of nutrients for plants and micro-organisms.

As noted in **Section 1,** rain gardens can be effective at reducing runoff. Dovel, Kemp, and Welker (2015) name high levels of runoff due to impervious surfaces as the principal cause of watershed degradation. They note that reducing runoff alone will not necessarily restore degraded and eroded urban and suburban streams, which need to have wooded slopes, stony or gravelly bottoms, and clear water flowing at more-or-less even rates in order to provide habitat for fish and invertebrates. However, stormwater reduction is a necessary first step toward restoring those waterways and protecting the bays and estuaries downstream.

Where stormwater runoff is high, combined nutrient and sediment loads make their way into streams, and from there into bays and estuaries. In cities like nearby Philadelphia, where sewage and stormwater share the same sewer lines, it is even more important to keep stormwater off the streets and out of the sewers to reduce the chance that the combined storm- and waste-water sewers will overflow, dumping raw sewage into rivers such as the Delaware (Philadelphia Water 2016).

As for actually improving the water quality, rain gardens can take advantage of natural processes in the soil – especially soil that is densely planted (Glick (2010), Locicero (2015)) – that degrade or remove many substances from water that might otherwise make their way into streams. Micro-organisms in such soil are key to these processes (Lowenfels & Lewis 2010).

The basic rain garden, where standing water does not persist more than a few hours, provides an *aerobic* environment for nutrient metabolism and plant growth (though earthworms do provide anoxic conditions in their guts (Mehring & Levin)). A more complicated bioremediation structure includes an *anaerobic* environment in the form of a retention basin under the surface rain garden. There the water is held, giving anaerobic bacteria a chance to further metabolize pollutants. Li, Swapp, Kim, Chu, & Sung (2015) studied field bioretention cells (like rain gardens) of both types – those with an internal water-storage layer (IWS) and those without – along a Texas highway. Their results showed that both types of bioretention cells were able to reduce levels of most nutrients and pollutants to some degree, but the IWS increased the ability of the bioretention cell to remove all kinds of pollutants, especially nitrogen and phosphorus.

Thus in a situation where pollutant levels are high, it would be appropriate to add an IWS to a rain garden installation.

Contrary to the results found by Li *et al.* (2015), Deitz and Clausen (2005) found that two test rain gardens collecting water from a shingled roof did control storm water, but did *not* reduce pollutants. These different results might be attributable to the fact that their rain gardens were not simply infiltration basins, but also included under-drains connected to the stormwater sewer system. A rain garden without such an under-drain could be expected to reduce pollutants better, because water would be in contact with soil microbes for a longer time. In addition, without an under-drain carrying water to the sewer system, the rain garden would contribute to ground-water recharge as well.

3 Moving into the project

3.1 Description of the project site. Trinity Presbyterian Church ('Trinity') is located one block south of Rte. 30 (Lancaster Avenue – the dividing line locally between Tredyffrin and Easttown Townships), at 640 Berwyn Avenue, between Waterloo and Main Avenues **(Fig. 1)**. Parts of the building complex are 150 years old. Massive slanted roofs produce huge amounts of runoff in a rainstorm **(Photo 1. See Appendix D for photos)**. Before this project began, most of the runoff was directed underground but often overflowed downspouts or bubbled out of the underground holding areas **(Photo 4)**. In the winter of 2014-2015, water ran onto sidewalks and froze, making two entries to the church unusable.

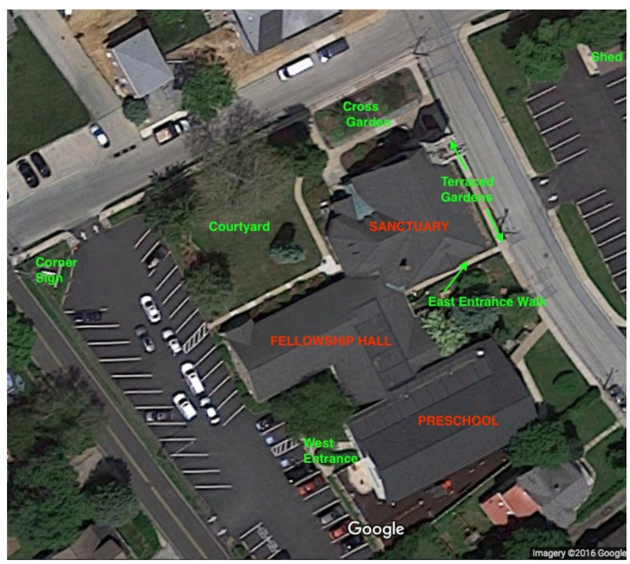

Fig. 1 Trinity Presbyterian Church property in Berwyn, PA. Buildings are labeled in red; parts of the grounds important to this discussion are labeled in green.
Image from maps.google.com.

Between the church building and the parking lots, over half of the church property is covered with impervious surfaces. Runoff from these surfaces has contributed to the stormwater flowing into street-side drains and from there into the local creek **(Photo 5)**. This creek is a first-order tributary near the headwaters of Darby Creek, much of which is classified as 'impaired', largely because of runoff and non-point source pollution along its length, according to Kevin McAghon, Easttown Township Engineer (personal communication, 6 September 2016, substantiated by reports from the late 1990s and 2013 provided by Alan Everett at Pennsylvania Department of Environmental Protection).

When this project began, landscaping at Trinity consisted of lawn edged with non-native shrubs. Invasive species such as Japanese yew *(Taxus cuspidata)*, Japanese barberry *(Berberis thunbergii)*, vinca (*Vinca minor)*, and English ivy *(Hedera helix)* abounded. More desirable plants included one large sycamore *(Platanus occidentalis),* many azaleas (*Rhododendron spp.* of uncertain provenance*)*, two flowering dogwoods *(Cornus florida)*, an American holly (*Ilex opaca)*, an ornamental (non-native) cherry *(Prunus sp.)*, two crabapples *(Malus spp.)*, and four non-native spruces *(Picea spp)*. A row of burning bush (*Euonymus alatus)* flanked the east side of the sanctuary and covered the stained-glass windows.

3.2 Using local reference sites to decide what to plant. Research at the University of Delaware confirms the hypothesis that native plants work much better than non-natives to maintain biodiversity, as measured by numbers of *Lepidoptera* and avian species present (Tallamy, D. & Shropshire, K. (2009), Brughardt, K., Tallamy, D., & Shriver, G (2008), Burghardt, K., Tallamy, D., Philips, C., and Shropshire, K. (2010)). Other research indicates that alien plants actually change the character of the soil by interacting with fewer soil mycorrhizae than do the natives, thus leaving an impoverished soil biome for the native vegetation (Jordan *et al.* 2012). When considering native plants for the Trinity property, the first step was to note what grows in nearby natural areas with healthy ecosystems that include plants native to the area. The two that were chosen are shown on the map in **Figure 2:** Crabby Creek Park (accessible at 89 Walnut Lane, Berwyn, PA 19312), and Jenkins Arboretum and Gardens (631 Berwyn Baptist Road, Devon, PA 19333). Each of these sites is within two miles of Trinity. Both differ from the flat Trinity property in that they include steep hillsides, but they do also contain some areas of more level land. Both contain wetlands on the borders of a creek. The Trinity land is at the top of a ridge rather than the bottom, but the native soil is similar in all three sites (see **Appendix A** for the geology and Soil Web Survey details). Since one goal was to use rain gardens to mitigate runoff from the expansive roofs of the church, it seemed prudent to note what plants do well in the flood zones at Jenkins and Crabby Creek. A final similarity between the sites is that all are under some pressure from surrounding developed land, not only from stormwater runoff, but from invasive species.

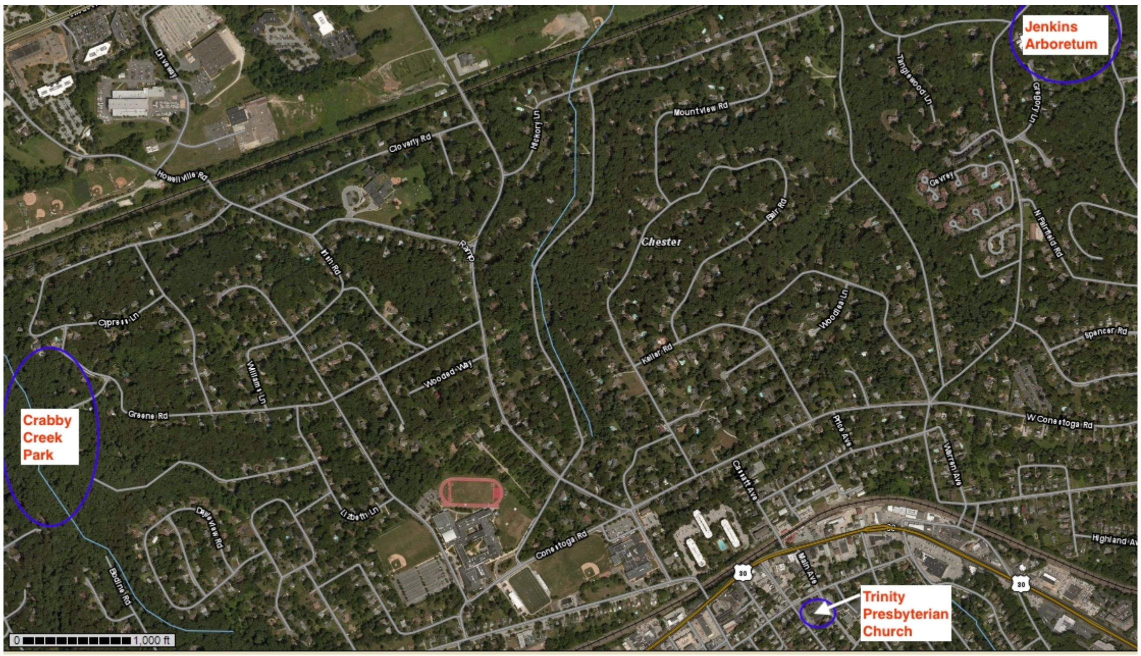

Fig. 2 Locations of Crabby Creek Park and Jenkins Arboretum in Tredyffrin Township, and Trinity Presbyterian Church in Easttown Township, Chester County, Pennsylvania.

Why not choose models that are more similar in topography? The first reason is that none could be found locally where public access was permitted. Second, these two sites contain plants that are common in the area. Jenkins Arboretum in particular is a good example of a location where a conscious effort is made to create and enhance locally-appropriate plant communities. In addition, the staff members and volunteers at Jenkins have recently done extensive planting to restore the flood-plain at the foot of the hillside property. Crabby Creek Park, an open space that for the most part reflects un-designed plant communities, serves as a repository of what might grow naturally in this area, though it is true that the soil types in Crabby Creek Park are not quite the same as those in Jenkins Arboretum and the Trinity property (see **Appendix A**).

Both Crabby Creek Park and Jenkins Arboretum have the advantage of space that the small unpaved areas at Trinity do not have.[1] While both those settings allow for extended plant communities to fit varying niches, at Trinity the options are more limited. The goal here has been to create multiple *designed plant communities* (Rainer & West, 2015) that are visually appealing while also providing the ecosystem services that are lost with traditional suburban landscaping. **Appendix C** lists plants included in the gardens to date.

3.3 The process

Analysis and constraints

Spring 2015 was devoted to assessing the landscaping at Trinity, including the evidence of water problems and other issues that would need to be considered in a re-landscaping plan.

Land-and-people constraints. Church members and committees helped to establish the goals and priorities of the project, especially how those goals would mesh with the 'people' uses of the property that would need to be respected. The preschool housed at the church uses the main courtyard for outdoor activities in the summer, and it uses a side yard for outdoor activities year round. Preschool concerns were the following:

- The proposed courtyard rain garden should not encroach on yard space needed for outdoor activities.
- Depth of water in the rain garden should not present a safety hazard to small children, for whom it would be an attractive nuisance.

1Crabby Creek Park is by no means an undisturbed ecosystem, but it does include many native canopy and subcanopy trees, as well as some shrubs and forbs. However, deer pressure eliminates most understory growth in the park. Reforestation of disturbed areas means planting trees and using tree-tubes to protect them. Jenkins Arboretum, which is fenced and does not have deer to contend with, displays a rich variety of native canopy and subcanopy trees, shrubs, and forbs, in addition to an expanse of lawn which is much larger than that at Trinity but which occupies a small fraction of the space at Jenkins. With its ferns, shrubs, and flowerbeds bordering the lawn, Jenkins gives us a good model for how to combine natives in an attractive landscape.

- Any stormwater measures in the preschool yard should not create standing water or shrink the area used for children at play.

Two priorities were established in discussion with the Buildings and Grounds Committee:

1. **Address unkempt areas most visible to the public**: A bed at the street corner, one along the walk to the east entrance, the 'Cross Garden' on the north side of the sanctuary, and the perimeter beds edging the large church courtyard. New plantings along the east side of the Sanctuary needed to not cover the stained-glass windows. Plantings at the street corner (marked Corner Sign in **Fig. 1**) needed to leave the sign visible and allow access to the sign for weekly changing.
2. **Address stormwater runoff**, especially the runoff from the collection basin in the courtyard and the runoff from the east side of the sanctuary roof. (A number of other stormwater issues became apparent during the course of the project; repair of these issues entailed replacing leaky gutters and downspouts and adding downspout extensions to direct water to existing garden beds.)

In addition to these global concerns, a number of individuals in the congregation stated personal requests. One wanted to add a tree as a memorial; another wanted to see at least some evergreens added (both requests easily accommodated). One individual wanted allocation of space for a future memorial garden/columbarium. In consultation with church staff, we agreed to leave an area directly north of the Sanctuary for that future project. A fourth individual wanted a meditation labyrinth. We were not able to agree on the exact spot for such a feature, so that discussion is on hold at present. It was important to consider all these requests as part of including everyone in the plan, to allow for future development of some features, and to be flexible with the plan if other needs arose.

Legal constraints. Planting at the street corner (Corner Sign, **Fig. 1**) was limited by the legal requirement that nothing block visibility at the intersection. Township zoning laws restrict building and planting in the 40-ft. street right-of-way, which at the corner of Berwyn and Waterloo Avenues means ten feet on either side of the 20-ft-wide road. The existing garden bed was outside that right-of-way, but to preserve visibility only ground-cover plants and low-growing flowering plants were chosen to go in front of a three-foot-high stone wall set in the corner garden. Taller plants, including three red chokeberry (*Aronia arbutifolia)* shrubs, were chosen to add seasonal color and visual focus. Chokeberry can be expected to grow slowly to about nine feet tall, but locating the shrubs behind the stone wall would keep them out of the line of sight at the intersection.

If we had planned any deep digging where there were likely to be power lines, we would have needed to get the power company to mark the location of lines, but as the power lines are above ground, this was not a problem. The only sewer-like line to keep in mind was the underground perforated pipe from the building downspout to the rain-garden location. It was easy to locate that pipe because it ends in the bubbler that was to feed the rain garden.

Rain-garden constraints. Given the need to keep much of the Courtyard lawn intact for church and preschool activities, the space available for the rain garden was limited to an area measuring about 18 feet (about 5.5 meters) in diameter at the outside edge of the Courtyard **(Fig. 3)**. This in fact was the location of the outflow spout that brought water from gutters draining over 5,000 ft^2 (1524 m^2) of roof, so creating a rain garden at this spot was the obvious choice. The decision was to follow instructions provided by the Partnership for the Delaware Estuary (PDE 2016): Determine the location and size of the rain garden, then dig out and amend the existing soil as needed to provide 12 – 24 inches of an absorbent soil mixture. The soil returned to the garden basin should sit below the surface level around it to allow for ponding before water soaks into the soil.

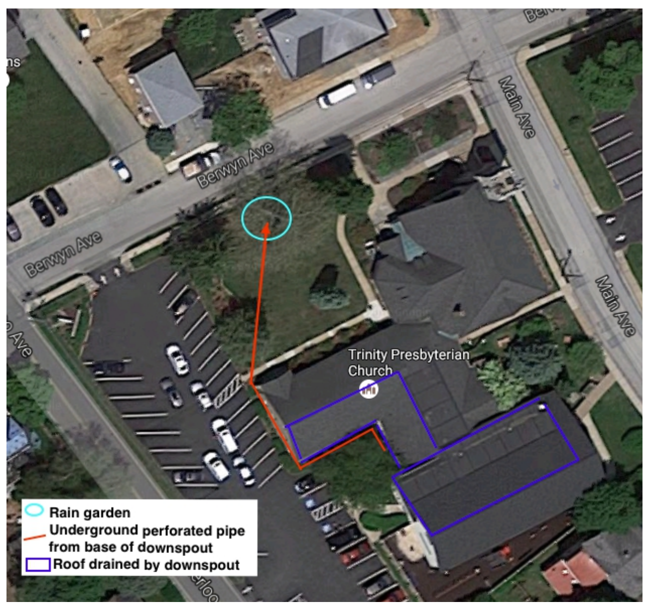

Fig. 3. Location of the rain garden at the upper (north) edge of the Courtyard is marked in aqua. Underground pipe (orange) brings water to the rain garden from roofs on the southwest side of the building complex (outlined in purple). Perforated pipe extends begins 10 ft. from the building and extends 60 ft. across the Courtyard.

Would the garden be able to absorb all the water that would be directed into it? The calculation for a one-inch (2.5 cm) rain storm was that the church roofs could funnel about 42 cu. ft. (182,880 cu. cm.) of water through the underground pipe to the garden area. A basin measuring 18 ft. in diameter, in well-draining soil with at least the center 10 ft. in diameter dug 20-24 in. (50.8-60.96 cm) deep and amended, might hold that much water. (A cylinder 10 ft. in diameter and 2 ft. deep is about 157 cu ft. To hold 42 cu ft of water, porosity would have to be high.) A possibly-mitigating factor was that water is brought across the Courtyard via 144 ft. of 6-inch pipe, 60 ft. of which is perforated and could be expected to provide some leaching and to reduce final volume. A second factor could be that, except for heavy rain on already-saturated soil, water should sink into the ground fairly quickly if the top 20-24 inches were loose soil mixed with sand.

We might not be able to keep every drop of rainwater on the property, but we could make a start.

The constraint of limited funding and labor. Though church members were enthusiastic about the re-landscaping project, the ability of members to help with the physical labor was limited by the age (over 60) of most members who might have time to commit to the project. Younger members tended to be busy with jobs or children. In addition, any funding for materials or labor would have to come through donations, as there was no fund designated for the project. Thus the project would need to take advantage of plant donations and would need to find volunteer labor such as Boy or Girl Scouts or other service groups.

3.4 Getting underway. The project started in March of 2015 with soil sampling, weeding, and testing for soil permeability. Planting of perimeter beds was undertaken beginning in May. In August, the first rain garden was installed to make use of the water that is directed from the education building underground through perforated pipes (see **Photos 6-10** in **Appendix D)**. As noted in **Section 3.3**, the rain garden replaced an overflow drain at the edge of the courtyard that previously directed stormwater onto the street. The rain garden served as the Eagle Scout project for Connor Bryan of Troop 219, Wayne, PA. Jenkins Arboretum and Gardens of Devon donated over 100 plants (17 different species) for the garden.

The rain garden basin (the center 10 ft. (about 3.5m) in diameter) was dug to a depth of 20-24 inches (about 60 cm). The sandy-loamy soil in the top 12-18 inches (30.48-45.72 cm) was set aside to add back later; the clay and rock encountered below were removed and used to create a berm at the back (downhill) end of the basin. The reserved soil was then returned to the basin along with two inches (5.08 cm) of sand, mixing the two to create sandy, permeable soil. Turfgrass was then removed in the remaining area to take the diameter to about 18 ft (5.5m), and the exposed soil was shaped to form a bowl centered at the water inflow pipe and allowing for outflow at the back in case of a large (say, two-inch) storm in a short time. The garden was planted with forbs and shrubs donated by Jenkins Arboretum and Gardens and was mulched with shredded (undyed) root mulch purchased from Main Line Gardens in Paoli, PA.

In October of 2015, terraced beds were installed along the east side of the sanctuary where the burning bushes had been removed (**Photos 13 & 14, Appendix D)**. Removing turfgrass and weeds, adding soil, and planting with native shrubs and herbaceous plants took us into December.

To highlight the purpose of the changes in the landscape, signs were installed by the rain garden and the terraced gardens explaining their ecological function to visitors. Plant labels were added throughout the property so people could identify species that they would like to plant in their yards.

Spring and summer of 2016 brought the addition of grasses and forbs to the Cross Garden, a long stretch of land between the front of the church and the street. This bit of property has historically looked rather dismal. Except for two crabapple trees planted in memory of deceased relatives of church members, not much had been planted there. Initially this may have been out of a desire to not obscure the front of the church; but in fact, the current church members enter by a door on the parking-lot side of the church, so the street view has been pretty much forgotten. On the other hand, people passing by on the sidewalk notice that aspect of the church first – in fact, most people approaching the church for the first time assume that the front of the Sanctuary is the main entrance to the church. Yet the view from the front was anything but inviting: The landscape was heavily mulched in an attempt to hold down weeds but otherwise was barren. The grasses and flowering plants that have been put in since 2015 have drawn considerable favorable comment from passers-by, who also comment that the front of the church used to look awful. Further planting in coming years will turn this area into a welcoming, meadow-like butterfly garden.

Maintenance of the existing beds in the Courtyard was much easier in 2016, and these gardens began to attract notice from both churchgoers and passers-by as the plantings from the previous season grew and flowered. Possibly because of the visible results, we were able to establish a regular weed-and-plant crew of three, meeting weekly. With that crew as the core of the workers, it was possible to address a remaining stormwater problem: water from the east parking lot was pooling six to eight inches deep against the north wall of a garage/utility building (marked SHED in **Fig. 1).** We dug a trench, created a small basin, amended the compacted soil with sand left over from Vacation Bible School, and formed a retention wall using broken concrete and cut logs salvaged from various cleanup projects on the property (**Photos 15-17, Appendix D)**.

4 Results of the project

Two years into the project, its success can be evaluated by looking at three factors: (1) ecosystem functions of the landscape, (2) control of stormwater, and (3) appeal to people.

4.1 Ecosystem functions. We can see the beginnings of a more productive ecosystem on the church property. Bees, both native species and the non-native honeybees, visit the flowering *Asteraceae* – asters goldenrods, Joe-Pye weed, ironweed, coneflowers, and more – in profusion. Other plant species also attract pollinators and nectar seekers, including bees, butterflies, and a few humming birds. These species include beardtongue penstemon (*Penstemon digitalis)*, blazing star (*Liatris spicata),* great blue lobelia (*Lobelia siphilitica),* cardinal flower *(Lobelia cardinalis),* mountain mint (*Pycnanthemum muticum),* scarlet bee balm *(Monarda didyma),* anise hyssop (*Agastache foeniculum,* and obedient plant (*Physostegia virginiana).*

The native plants have proven to be more resilient to temperature and weather than non-native annuals. In the second year (2016), when rainfall was well below normal and temperatures hit record highs, the native shrubs and forbs did not show signs of drought stress. Watering was done once during the hottest part of the summer, more as a preventative measure than because there were any signs of drought stress.

4.2 Control of rainwater. After a summer of regional drought, heavy rainfall on 19 September 2016, measuring two inches of rainfall in two hours, finally provided a chance to see the rain gardens in action (**Photos 18-20, Appendix D)**. Rain filled the main rain garden and trickled around the berm at one point in the back, pooling there but not running onto the sidewalk. Within three hours of rain cessation, all the water had soaked into the garden. Once the ground had dried, the end of the retention berm was extended to prevent overflow in a similar storm.

The more impromptu rain-collection basin behind the garage also experienced water overflow around one end in this storm, easily fixed by extending the retaining wall. Water soaked into that basin within three hours as well.

The terrace gardens, which use water directly from the roof downspouts, contained the water nicely; no standing water was noted. A bit of the flow was redirected to enable it to reach the base of thirsty water-loving shrubs.

The rain storm also provided an opportunity to evaluate water quality in order to answer these questions: Is the water entering the rain gardens collecting airborne pollutants from the roofs, leaching lead or copper from the old copper gutters and downspouts, or picking up large amounts of salt and petroleum products from the paved parking lots? Should our rain gardens include an anoxic layer to provide for further breakdown of pollutants? Should we be planting specific species that uptake heavy metals? Are pH, hardness, or alkalinity problematic?

Water samples were collected on 19 September and again on 29 September (see **Appendix B** for details, discussion, and tables showing results). ICP (Inductively-Coupled Plasma) mass spectroscopy was used to test water samples for twelve minerals. For water collected on church property, levels of most minerals were quite low, both in an absolute sense and when compared to rain water collected in a rain gauge. Anion composition and parameters such as pH, hardness, carbonate alkalinity, and conductivity were assessed using an automatic titration system. In general, the results showed low levels of ions tested (fluoride, chloride, nitrite, bromide, sulfate, nitrate, and phosphate) for water collected on church property. All ion and conductivity levels were within the range for potable water in the United States (compared with numbers from Fondriest Environmental, Inc. 2014). Alkalinity, pH, and hardness numbers were also unexceptional, with water samples from church property falling in the 'soft' category according to USGS (2016) comparison tables. Thus we can say that, at Trinity Presbyterian Church, a conventional rain garden whose main purpose is to prevent flow of water off the property is sufficient.

On the other hand, water samples taken at the outfall pipe from the storm sewer into the Darby Creek tributary nearest Trinity indicated elevated levels of most minerals, with especially high numbers for sodium, calcium, magnesium, and potassium. The water also showed high levels of sedimentation. Anion conductivity test results from the two dates showed some variation but overall showed elevated numbers for all substances, especially chloride, nitrite, bromide, and sulfate. Results were varied with regard to hardness and alkalinity depending on the date and location of sampling (see **Appendix B).** While anion conductivity tests should probably be repeated, the test results do indicate that the stormwater problem is one that needs to be addressed by properties all around Trinity Presbyterian Church, as well as by the municipal water authorities.

4.3 Appeal to people. This section focuses on the appeal of the landscaping to church members and to passers-by (getting people involved in the actual work is discussed in **Section 5).** It has been quite rewarding to have people comment on the beauty of the gardens every day when the work crew is out. People stop to talk, which provides an opportunity to explain the goals of the project. Church members also go out of their way to comment on the positive change, noting not just flowers but the large numbers of pollinators visiting them.

In 2016, people from an office building across the street came to the Courtyard to sit on the benches there for small meetings (**Photo 12)**. Passers-by have been seen sitting on the terrace stones **(e.g. Photo 13)** and admiring the flowers along the east wall of the church. In the summer and fall of 2016, teachers led preschool groups on visits to the terraced gardens to look for flowers and pollinators. All of this activity is new, and while it is just a start, it does show that the new landscaping is serving the purpose of giving Trinity a more attractive presence in the neighborhood.

5 Getting people involved, and expanding the project

5.1 Progress toward getting people involved. A major goal of this project as presented to the Session (the governing body of the church) was that it would become a project of the church, involving other individuals and church groups in the planning and execution of the re-landscaping. Keeping the congregation informed has been an important part of the project from the beginning. Posters highlighting the native plants to look for in the gardens, signs to explain the purpose of the gardens themselves, and occasional short messages given in church helped to keep people informed.

As for involvement of others, the church Sexton provided great help in removing invasive species and planting larger shrubs as the project got under way in 2015. On two occasions church members helped with weeding the perimeter garden beds, prior to those beds being planted with natives. At one point, a resident in the neighborhood noticed the weeding activity and proceeded to come by and help over the next two weeks. Donations of money came in steadily.

Yet it was something of a disappointment that first summer, when so much labor needed to be done, that no regular corps of interested and able volunteers developed. This failing could be attributed to two factors: First, though the gardens were looking different, they weren't yet looking eye-catching. Second, no regular schedule of when to work in the yards had been established; I tended to see what was needed and just do it rather than planning ahead to work on particular days or at particular times. This made it hard for people who might have been interested in helping to plan to do so.

The second summer of the project (2016) saw great strides in this regard. The project continued to be supported by financial donations from church members (much less was needed in the way of funding, since almost all the planting and landscaping had been done in 2015). Comments were enthusiastic as both church attendees and neighbors saw the gardens coming alive with native plants and pollinators. Two members of the church family came regularly one day a week to help with maintaining the gardens. Calls to the Building and Grounds committee members brought out four or five people to work on larger projects such as building a compost bin and mulching flower beds.

By the end of 2016, the gardens and the small team of volunteers had become well established. Going forward, additional projects can be tackled, including removing invasives at the perimeter of the property and controlling more stormwater. How the project can serve as a starting point for outreach to the larger community remains to be seen, but a possibility is to connect with the larger faith-based ecological movement.

5.2 The faith-based ecological movement as a means of expanding the project. Pope Francis' encyclical of 24 May, 2015, *Laudato Si,* developed the long-standing position of the Catholic Church that respect for and protection of God's creation is a part of the calling of believers. Such a position is not limited to the Catholic Church. A list of hundreds of faith-based ecological projects, grouped under the headings of eleven world religions, can be found at the website of the Forum on Religion and Ecology at Yale. (The link, www.yale.edu/religionandecology no longer works; go instead to http://fore.yale.edu/about-us/). These are projects of "religious institutions that are inspiring and grounding environmental concerns in practical programs, outreach, and education."

The Presbyterian Church USA (PCUSA), of which Trinity Presbyterian Church is a part, has its own environmental programs, and it collaborates with other eco-faith groups through the National Council of Churches and the World Council of Churches as well. Under the PCUSA umbrella are the Environmental Stewardship Task Force and the Presbyterians for Earth Care, through which individual churches can be certified as Earth Care Congregations. PCUSA and other faith groups participate in leadership and certification programs sponsored by a group called GreenFaith Interfaith Partners for the Environment. The National Council of Churches Center for Eco-Ethics, and the World

Council of Churches, link environmental and social justice in a focus on 'eco-justice.' The National Council of Churches Eco-Justice Program publishes an eight-page flyer entitled 'Tending the Garden: Stewardship of Biodiversity and Endangered Species.' This flyer includes suggestions to plant native plants and create a nature path on church property.

In September of 2016 I met with Session (the church governing body) to suggest that it might be appropriate to expand our environmental focus at the church. I pointed out that we had already met some of the goals for certification as an Earth Care Congregation: We had installed rain gardens and planted native plants; we had had an energy audit performed by PECO and had exchanged conventional light bulbs and tubes for energy-efficient compact fluorescent fixtures; we had installed double-paned windows throughout the church building (except for in the sanctuary, where windows are stained glass); and we had taken out the inefficient gas stove in the kitchen, replacing it with induction burners and a small electric oven. My question was this: Whether or not we wanted to go for Earth-Care Congregation certification, could we raise the bar a bit and bring ecological concerns to a more central position in church life?

The Session reacted with immediate approval. A three-person task force was set up to explore ways that each committee within the church (education, worship, buildings and grounds, hospitality, and others) could develop a more ecological focus. By November, 2016, small changes were beginning to take place:

- The choir director stopped buying bottled water for the choir members and was discussing mounting a mug rack in the choir room so members can bring their own mugs for water;
- A compost pail was placed in the kitchen, with food scraps and coffee grounds from it going into an outdoor compost bin. (Getting people who use the kitchen to actually put food scraps and coffee grounds in the pail is an ongoing effort.) Some members also brought in their lawn clippings and raked leaves to add to the compost pile – admittedly not the best solution, since they could be using that material in their yards, but a step in the right direction;

- The administrative assistant, who already re-used scrap paper to make note pads, went the lookout for recycled paper to purchase for the copier;
- A 'paperless' service was held on 12 November, 2016. No bulletins were printed. The people in charge of coffee hour used ceramic mugs instead of disposable foam cups.

The first visible change, that of re-landscaping the church property, seems to have provided the impetus for other changes to take place in the daily life of the church. The committee continues to coordinate these efforts so that the church can meet all the criteria needed to apply for Earth-Care Congregation designation. Receiving this designation will provide an avenue for working with other congregations and reaching out to the neighboring community.

5.3 Lessons learned for working with people. The purpose of this ongoing project has been twofold: to improve the ecological footprint of Trinity Presbyterian Church, and to provide native-plant landscaping and rain gardens as an example for others to learn from and emulate. The first goal required careful background research, planning, and execution. The second goal, which included gaining initial acceptance of the project and ongoing support as it developed, has required working *with* people rather than leaving them out or even worse, alienating them. This could not have been a one-person project. Here are pointers for how to develop a team and give the project a chance of continuing and growing, a list which will surely find its way into the **Guide**:

- **Put the environmental focus in the context of the larger goals of the group** (in the case of a church, stewardship of creation and care for 'the least of these').
- **Avoid accusing; start with acknowledgement of progress made.** Acknowledge the strong points and efforts of individuals and groups.
- **Expect to find – and acknowledge – strengths that others can bring to the effort.** Examples: One person contributed plants from her garden to the landscaping effort. In the Session meeting, that same person and another took the lead in explaining how composting works. Another person said that at her school, they have instituted composting and recycling and that the kids are involved in

lunchroom duty to collect recyclables. She also said that she personally has eliminated use of plastics in her kitchen. These people could be instrumental in getting these efforts going in the current context.

- **Graciously accept help and contributions even if they don't quite meet strict standards.** Example: The Sexton brought two sacks of bulbs to add to the gardens. The bulbs were not natives (and probably not even perennial, but time will tell), but once they flowered, they drew admirers to the gardens. Passers-by would frequently stop to admire them and the rest of the gardens, which provided an opening to explain about the project, its purpose, and the value of including natives (as well as bulbs) in the landscaping.
- **Don't become discouraged when changes in the landscaping don't immediately look great.** Give new plantings time to mature and soften the edges of rock walls and fences. Be willing to move plants that overgrow their space, flop onto walks or hide signs, or otherwise become the wrong plant for the space.
- **Be sure to point out to the public (the congregation, the users of the municipal building, passers-by, etc.) any signs that the new plants are attracting birds and pollinators, and that the new rain gardens or similar features are making use of water on the property while avoiding runoff**. Posters and short messages in a bulletin work well for this. In a church setting, a 'minute for missions' message is appropriate for explaining how the gardens are furthering the church's mission to exhibit responsible stewardship. Attractive signage can be added to the gardens. These should be signs that can be updated as seasons and concerns arise.

Conclusion. The project at Trinity Presbyterian Church began the process of reworking the landscaping to provide better habitat and to control stormwater. Future goals include adding shrubs, trees, and more herbaceous plants; addressing stormwater problems in the preschool yard and off the parking lots; and adding native plants at the west entrance.

The project has also served to start the conversation within the church of how to improve the church community's environmental footprint in general. Initial contacts have been made with members of neighboring St. Monica's Catholic church, where a project involving both churches could be developed. Contact with a member of a Lutheran church in Narberth, PA could lead to a project to collect stormwater on that property for irrigation of their community garden. The existence of other Presbyterian Earth Care Congregations in this region suggests another avenue for spreading the message.

For these and future collaborations, as well as independent projects, a guide outlining what was done here, giving tips, and outlining lessons learned could be useful. **Table 1** (p. 21) compares the steps taken here as outlined in this report with what would be useful in such a guide.

Table 1

Comparison of Steps Undertaken at Trinity with Topics to Include in a Guide

Steps taken at Trinity / Information in this report	**Topics be included in a Guide**
Introduction/motivation	Context needed to explain the purpose of the project. Include general environmental concerns and local concerns.
Planning and execution	Pointers for presenting the project, establishing constraints, developing a team, partnering with volunteer labor, setting a schedule, expanding the project.
Geological and soils information	In-depth geology not necessarily needed, but interesting. Most people would like to learn more about their local geology and soil character. Include references to web tools.
Soils samples	Include steps for self-analysis of soil health and permeability. Include references for where to send soil samples, with the warning that fertilizer recommendations are probably not applicable if native species are to be planted.
Stormwater, water quality, watershed health	Include a discussion of *watershed*, finding the local watershed boundaries, finding where stormwater goes. How to judge water quality without expensive tests; when to seek professional advice (e.g., if the property abuts a factory, or if plants show signs of pollution stress).
Controlling stormwater	List options, including rain barrels, planted strips, both involved and simple rain gardens.
Rain garden design and installation	How-to guides abound. Discuss important pointers such as establishing soil permeability. Include a diagram. Include references.
Plant choices, where to find plants	Include discussion of plant associations and plant choices for various sites & exposures. Explain invasives and non-natives vs. natives. Discuss when to keep some non-natives. List references with annotations. List local native-plant suppliers; explain dangers of shopping for plants and planting materials at hardware, gardening, or discount stores.
Examples	Include plans and photos for the gardens at Trinity, as well as references for more ideas.

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Appendix A: Trinity Presbyterian Church Site Assessment Information

1. Geological and topographic information for Trinity. Trinity Presbyterian Church ('Trinity') sits on a roughly one-acre lot in a residential neighborhood a block south of Rte. 30 (Lancaster Ave.) in Berwyn, PA. The site is on a ridge about 540 ft. above sea level that runs parallel to Rte. 30 and is about two blocks wide. Land drops off steeply to the south (Sugartown Road is 380 ft. above sea level where it passes one mile south of Trinity). To the north, the 550 ft. contour line is at Conestoga Ave., 0.5 miles from Trinity. Land then drops steeply to 300 ft. at Hickory Lane (1.2 mi. north), and to 200 ft. at Rte. 202 (2 mi. north). (Numbers are from Google Maps and the USGS topographic map for Valley Forge.)

The underlying geology at the church is mapped as the Octoraro Formation, a phyllite containing some schist in the Upper Piedmont Region. See http://www.gis.dcnr.state.pa.us/geology/index.html

2. Summary of comparative soils information for Trinity Presbyterian Church property, Jenkins Arboretum and Gardens, and Crabby Creek Park, with notes about plant species in Jenkins and Crabby Creek Park.

Like Trinity, Jenkins Arboretum and Gardens and Crabby Creek Park both sit on the Octoraro Formation. The soils are similar, being for the most part residuum weathered from mica schist, though Crabby Creek Park does have some soil classified as alluvium derived from sandstone and shale along the creek itself (**Table 2).**

The **Trinity property** soils are designated **UrmB – Urban land-Glenelg complex, 0 to 8 percent slopes**. The Web Soil Survey site gives the pH of UrmB as varying from acid (4.2) to neutral (6.6) with some variation depending on depth (see **Table 1**). The soil test results from Penn State (**Table 2**) give pH figures between 6.6 and 7.3 for the five samples sent in April, 2015. Thus Trinity is at the high end of the spectrum for Glenelg soils, probably because of the history of leaf removal, liming, and fertilizing on the site.

Jenkins Arboretum and Gardens soils are designated **Glenelg (GgC and GgD)** and **Urban/Glenlg 8-25% slopes (UrmD).** That is, both Trinity and Jenkins soils are Glenelg, but the Jenkins property sits on a steep hillside. GgC and GgD soils are listed as having an expected pH of 5.5, which is slightly more acidic than the soils at Trinity. The soil at Jenkins is quite rocky. The Trinity site does not have much rock in the upper foot of soil on most of the property, possibly because of years of decayed bark mulch but also because the property is flat rather than sloping, so soil stays put rather than eroding.

The land along the Jenkins branch of sTrout Creek is designated **Baile silt loam (Ba**), local alluvium over residuum weathered from mica schist. Baile is listed as having a pH of 4.9, which is much more acid than any soils on the Trinity property.

Table 2 Web Soil Survey Information for Crabby Creek Park, Jenkins Arboretum and Gardens, and Trinity Presbyterian Church
http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Location Address	Acres*	Soil-type Symbol	Soil Name (acres)	Soil pH	Parent Material
Crabby Creek Park 89 Walnut Ln Berwyn, PA 19312 40.0521, -75.4666	54.4	MaF	**Manor loam, 35-60% slopes (33.7 acres)**	4.8	Residuum weathered from mica schist
		UrmD	**Urban-Glenelg cplx, 8-25% slopes (6.6 acres)**	----	Glenelg: Residuum weathered from mica schist
		GgC	**Glenelg silt-loam, 8-15% slopes (5.1 acres)**	5.6	Residuum weathered from mica schist
		Ho	**Holly silt loam (4.8 acres)** Characteristics: $CaCO_3$ 0- 5%. Along Crabby Creek. Frequently flooded; occasional ponding. Hydric. Hydric soil group B/D.	6.5	Alluvium derived from sandstone and shale
		CtB	Conestoga silt loam, 3-8% slopes (4.1 acres)	6	Residuum weathered from limestone and/or residuum weathered from schist
Jenkins Arboretum 631 Berwyn Baptist Rd Devon, PA 19333 40.0601, -75.4373	16.1	GgC	Glenelg silt loam, 8-15% slopes (9.1 acres)	5.5	Residuum weathered from mica schist
		GgD	Glenelg silt loam, 15-25% slopes (3.0 acres)	5.5	
		Ba	Baile silt loam (2.4 acres) Along Trout Creek. Depth to water table 0 to 6 inches, but no flooding or ponding. Hydric. $CaCO_3$ 1%.	4.9	Local alluvium over residuum weathered from mica schist
		UrmD	Urban/Glenelg complex, 8 – 25% slopes (1.6 acres)	----	Glenelg: Residuum weathered from mica schist
Trinity Presbyterian Church 640 Berwyn Ave Berwyn, PA 19312 40.04581, -75.4408	1.2	UrmB	Urban land-Glenelg complex, 0 – 8% slopes	0-8" depth, 4.2 – 6.6 8-26" depth, 4.5-6.5 26-60" depth, 4.5-6.5	Glenelg: Residuum weathered from mica schist

* This is the number of acres in the Area of Interest selected on the Web Soil Survey website.

As for plants present on the arboretum property, listing them would mean listing a catalog of most of the species native to the mid-Atlantic region, as Jenkins has planted quite a variety, including many trees, shrubs, and herbaceous flowering plants. The native forest canopy is dominated by tulip-poplar *(Liriodendron tulipifera)* and oaks. A few chestnut *(Castanea dentata)* stumps still send up sprouts here and there.

Crabby Creek Park soils show more variety than those of Trinity and Jenkins Arboretum (**Table 2).** The strip of land next to Crabby Creek, designated **Ho** on the WebSoilSurvey map, was dug up around 2012 to re-lay storm-sewer pipes. The strip has been re-planted with hundreds of trees in tree-tubes as well as black willow (*Salix nigra)* and red-twig dogwood (*Cornus sericea)* along the creek. Great blue lobelia (*Lobelia siphilitica)* and turtle-head (*Chelone glabra),* along with *Asteraceae spp.,* also grow there. A seep near the railroad overpass features showy aster (*Eurybia spectabilis*) and eastern skunk cabbage *(Symplocarpus foetidus).*

As is the case at Jenkins, the soil in Crabby Creek Park is very rocky. On the steep slopes we can probably get a good idea of the plant species native to the area – or at least those that survive deer browse. The rocky soil is covered with a deep layer of leaf litter and supports a mix of trees, shrubs, and some herbaceous vegetation. The forest is dominated by American beech (*Fagus grandifolia)*, tulip poplar *(Liriodendron tulipifera),* and oaks including Northern red, black, white, and chestnut oak *(Quercus rubra, Q. velutina, Q. alba,* and *Q. montana* or *prinus).* Also present are sycamore (*Platanus occidentalis),* Canada hemlock *(Tsuga canadensis),* eastern red-cedar *(Juniperus virginiana),* black cherry *(Prunus serotina),* hackberry *(Celtis occidentalis),* American holly *(Ilex opaca),* northern catalpa *(Catalpa speciosa)* and *Aralia sp. (*either *A. speciosa,* Hercules'-club, or *A. elata,* Japanese angelica-tree) along the old dirt road where the sewer line is laid. Understory trees/shrubs include witch-hazel (*Hamamaelis virginiana)* and musclewood (*Carpinus caroliniana).* The herbaceous layer has been depleted by deer browse but does include Christmas fern *(Polystichum acrostichoides)* and silvery glade fern *(Deparia acrostichoides)* as well as various sedges and *Asteraceae*. Occasional patches of greenbrier *(Smilax rotundifolia* or poison ivy *(Toxicodendron radicans)* appear on the hillsides next to the dirt road. On a steep ridge within the park are numerous mountain laurels (*Kalmia latifolia)* as well as other shrubs in the *Ericacae* family.

That is an overview of the native species in Crabby Creek. The usual non-native invasives are also present, though not overwhelming: Norway maple (*Acer platanoides),* bush honeysuckle *(Lonicera mackii)*, *Rubus spp.,* including wineberry *(Rubus phoenicolasius)*, Burning bush (*Euonymus alatus),* Japanese barberry (*Berberis thunburgii)*, garlic mustard (*Alliaria petiolata),* perilla (*Perilla frutescens*), and Japanese honeysuckle *(Lonicera japonica).*

3. Soil tests. Since the Trinity property is in a densely-populated residential neighborhood (densely populated as suburbs go), has been conventionally landscaped until the current native-landscaping project began, and may have been subject to various chemical insults in its 150-year history, I thought it prudent to conduct soil tests. Specifically, I wanted to know whether two landscaping practices I had observed had affected the soil: the use of dyed wood mulch, and the use of chemical fertilizers and herbicides. I also wondered whether the soil in the corner garden by the parking lot (CORNER SIGN on the labeled image of Trinity property) might have been damaged from salt runoff from the parking lot.

Soil samples from five areas targeted for planting were sent to Penn State in March of 2015. Penn State's recommendations were for 'unspecified garden crop' (their term) and include the use of chemical fertilizers. Even though I stated that we were putting in a native-plant garden, their recommendations seem to have been based on their experience with crops such as corn and turfgrass. I chose to disregard the fertilizer recommendations.

A summary of the Penn State evaluation is in **Table 3.**

Table 3 Soils Tests Interpreted Results from Penn State

Soil test results 14 April 2015 Trinity Presbyterian Church: Evaluation from Penn State Agr. Anal. Svcs. Lab.

Plot ID-location	Soil pH	Soil pH Evaluation	Phosphate Eval.	Potash Eval.	Magnesium eval.	Calcium eval.	Nitrate-N ppm	N ppm evaluation	NPK recommendations	CEC (Cation exchange capacity)	CEC (Cation exchange capacity) evaluation
1 NW Corner mulched	6.7	Optimum	Way below optimum	Low optimum	Above optimum	On line between below and optimum	17.6		0.33 lb/ 100 sq ft UREA, 1.5 lb/100sq ft 0-46-0	15.5	
2 NW Corner no mulch	7	Optimum	Way below optimum	Below optimum	Above optimum	Optimum	23.2		2.5 lb/100 sq ft 5-10-5, 1 lb / sq ft 0-46-0	14.9	
3 NE Corner no mulch	6.8	Optimum	Way below optimum	Low optimum	Above optimum	Optimum	18.3	No reliable test to eval amt N available to crops over season - no recommendations given.	0.33 lb/ 100 sq ft UREA, 1.5 lb/ 100 sq ft 0-46-0	14.5	If less than 15.0, add 1" organic matter. If pH greater than 7.0, use acid peat moss as the organic matter source.
4 Cross Garden	7.3	Optimum	Below optimum	Optimum	Off-the-chart above optimum	Optimum	18.7		0.33 lb/ 100 sq ft UREA, 0.5 lb/ 100 sq ft 0-46-0	17.3	
5 By Street Sign	6.6	On line between optimum and below optimum	Off-the-chart above optimum	Optimum	Above optimum	Optimum	31		0.33 lb/ 100 sq ft UREA	19.4	
6 West Entrance	7.2	Optimum	Below optimum	Optimum	Above optimum	Optimum	16		0.33 lb/ 100 sq ft UREA, 1.0 lb / 100 sq ft 0-46-0	14.3	

Appendix B: Water Testing Process and Results

Water samples were collected during a rainstorm on 19 September, 2016 and kept in clean glass jars until they could be analyzed in the Earth and Environmental Science Lab at the University of Pennsylvania. Because the samples were not refrigerated during the week between when they were collected and when they were tested, there was some question regarding whether the results would be accurate. Thus four more samples were taken in a second rainstorm on 29 September, kept in clean glass jars, and refrigerated until testing a week later. In **Tables 4 and 5**, test results are sorted by location where the water was collected, with samples from the two dates next to each other to facilitate comparison.

In order to evaluate the water coming into the Courtyard Rain Garden, samples were taken from the roof that feeds it (Samples 1 and 2). Water for samples 3 and 4 was collected at the outflow into the rain garden, where water exits after passing through an underground pipe to the Rain Garden. Sample 5 was water from the Sanctuary roof downspout where it enters the Terrace Gardens on the east side of the Sanctuary. Water runs off the Shed roof (Sample 6, Garage Downspout) and joins water from the parking lot (Sample 7). Water from the downspout and parking lot is contained in a retention basin behind the Shed, so it was of interest to learn whether the water contained high levels of road salt or vehicle chemicals.

Stormwater from the neighborhood runs in storm sewers and empties into a tributary of Darby Creek at Midland Ave. and Eastwood Rd. Samples 8 and 10 were taken to assess the water at that outfall. Water was collected for Sample 9 at the next street crossing (Lakeside Ave.), about 0.5 miles downstream.

Comparison samples were also taken from a rain gauge at 978 Old Lancaster Road, about 1 km. from the church property (Samples 11 and 12). Shoemaker Green Cistern data are included also for comparison (SG Cistern, from University of Pennsylvania property on 33rd St. between Walnut and Spruce Sts.).

Water samples were filtered and measured in glass equipment that had been cleaned with deionized water. Samples were analyzed for metal cation content using a Genesis ion-coupled plasma spectrograph (ICP, Spectro Analytical Instruments GmBh, Kieve, Germany).

Test results (**Table 4)** showed low levels of tested minerals from all samples on church property – levels roughly equivalent to those found in the rain-gauge samples. Levels in the Darby Creek tributary (highlighted in blue) were elevated for sodium, calcium, magnesium, and potassium, as might be expected from a tributary that collects the combined runoff from a neighborhood where streets are salted in the winter and lawn chemicals are used in the summer. Those elevated numbers are similar to the numbers found in the Shoemaker Green sample.

Table 4
ICP (Inductively-Coupled Plasma) Mass-Spectroscopy Water Test Results

ICP (Inductively-Coupled Plasma) Mass-Spectroscopy Water-Test Data. Values in PPM (mgL^{-1} or $\mu g\ mL^{-1}$)

Samples marked aqua were collected on 19 September 2016.

Samples marked pink were collected on 29 September 2016.

		Al 396.152 mg/l	Na 589.592 mg/l	Ca 317.933 mg/l	Mg 279.553 mg/l	K 766.491 mg/l	Fe 239.562 mg/l	Ni 221.648 mg/l	Zn 213.856 mg/l	Pb 220.353 mg/l	Cr 205.552 mg/l	Si 251.612 mg/l
1	Ed. Wing Downspout Pinhole	0.339	3.806	0.629	0.034	0.421	-0.001	0.073	0.09	0.018	0.002	0.167
2	Education Wing Roof	0.656	1.51	5.335	0.212	0.3	0	0.071	0.017	0.018	0.002	0.04
3	Rain garden	0.354	1.593	0.733	-0.048	0.321	0.001	0.065	0.001	0.015	0.002	0.24
4	Rain garden	0.75	1.737	7.329	0.138	0.311	-0.002	0.062	0.01	0.019	0.002	0.221
5	Terrace Garden Downspout	0.347	1.673	1.918	0.014	0.296	-0.002	0.084	0.013	0.017	0.002	0.033
6	Garage Downspout	0.405	2.218	2.327	1.686	3.977	0.005	0.052	0.03	0.018	0.002	0.016
7	Parking Lot	0.34	2.125	1.412	0.551	0.482	0.023	0.06	0.035	0.013	0.005	0.041
8	Darby Ck Trib. Outfall	1.054	15.264	14.405	3.855	2.05	0.147	0.347	0.021	0.016	0.002	0.053
9	Darby Ck Lakeside Dr.	0.903	11.376	11.043	3.066	1.71	0.012	0.271	0.067	0.014	0.002	0.038
10	Darby Ck Trib. Outfall	0.608	39.588	24.59	7.811	3.146	0.06	0.36	0.054	0.023	0.003	0.039
11	Rain Gauge	0.338	2.128	0.307	0.078	0.445	0.007	0.063	0.024	0.014	0.001	0.21
12	Rain Gauge	0.363	1.705	0.424	0.086	0.571	0.009	0.025	-0.001	0.021	0.002	0.045
	SG cistern	0.703	37.374	35.872	8.328	5.014	0.017	0.391	0.102	0.023	0.004	0.044

Numbers are ± 0.001 ppm. Any negative values can be considered zero.

Mercury (Hg): below detection limits

Anion composition and parameters such as pH, hardness, carbonate alkalinity, and conductivity were assessed using an automatic titration system (Titration Excellence System, Mettler Toledo, Singapore) coupled to an anion chromatograph (ICS 2100, Dionex Corp., Sunnyvale, CA). Results are shown in **Table 5.** Sample 1, taken from a pinhole in a downspout on the Education Wing, was too small to be tested using this equipment. The purpose of that sample had been to collect water from the roof feeding the Courtyard rain garden. To provide enough water for the anion conductivity test, a second sample was taken on 29 September from the roof itself instead of from the downspout (Sample 2).

Numbers from the IC Anion Conductivity Test generally indicate that water collected on church property shows low levels of ions tested (fluoride, chloride, nitrite, bromide, sulfate, nitrate, and phosphate). Why the Education Wing Roof shows a slightly high value for chloride (7.279 ppm) is unclear. Another puzzling result is that the Courtyard Rain Garden results from 29 September show considerably higher conductivity (169 µS/m) than the rain garden results from ten days earlier (17.6 µS/m), and the highest conductivity of any samples taken on church property. Perhaps ions leached into the water through the perforated pipe that passes through the soil in the Courtyard, emptying into the rain garden. The first sample may have showed less conductivity and lower ion numbers because the ground the pipe runs through would have been dry after a month of dry, hot weather. The second sample may have included some water that had passed through the moist soil and into the perforated pipe. However, even the high conductivity number in the Courtyard Rain Garden sample is within the range of potable water in the United States (50-800 µS/mL, according to Fondriest Environmental, Inc. 2014).

Conductivity was higher in the samples from the Darby Creek Tributary, with the sample taken on 29 September registering 626 µS/m (or µ TDS). The comparable number from the Shoemaker Green cistern was 532.8.

Numbers for pH show a range from neutral to slightly alkaline for all samples. The United States Geological Service (USGS) map of Total Alkalinity (µeq/l) of Surface Waters for the Continental United States shows that surface waters in the region that includes Chester County, PA can be expected to have alkalinity of greater than 400 µeq/l (USGS 2016).

Hardness numbers are low for the water from church property, but somewhat elevated for water from the Darby Creek tributary outfall. USGS (2016) gives the following classifications for water hardness (measuring calcium carbonate):

- 0 to 60 mg/L: soft
- 61 to 120 mg/L: moderately hard
- 121 to 180 mg/L: hard
- >180 mg/L: very hard.

The conversion factor 1ppm – 1mg/L gives the result that all the samples from church property, as well as the rain gauge samples, fall in the 'soft' range, while the second Darby Creek tributary outfall sample (169 ppm) falls in the 'hard' range, as does the Shoemaker Green Cistern sample (113 ppm).

Because of the wide range of results for some of these parameters, it would be useful to continue to take and analyze anion conductivity measurements.

Table 5
Anion Conductivity Water Test Results

	Ion Chromatography (IC) Anion Conductivity Test Data. Anion values in parts per million (PPM)											
	Samples marked aqua were collected on 19 September 2016.											
	Samples marked pink were collected on 29 September 2016.											
		Fluoride	Chloride	Nitrite	Bromide	Sulfate	Nitrate	Phosphate	Conductivity µS/m (µT.D.S.)	pH	Alkalinity mEq/L	Hardness ppm
2	Education Wing Roof	0.014	7.279	0.012	0.922	0.101	0.016	n.d.*	50.7	8.1	0.81	12
3	Courtyard Rain Garden	0.010	0.107	0.001	0.240	0.043	0.007	n.d.*	17.6	8.13	0.68	11
4	Courtyard Rain Garden	1.681	2.696	2.541	3.716	9.161	2.604	n.d.*	169.5	7.99	0.81	no data **
5	Terrace Garden Downspout	0.020	1.930	0.012	1.494	0.642	0.012	n.d.*	54	6.9	0.9	14
6	Garage Downspout	0.192	2.017	n.d.	7.321	1.091	0.019	1.312	72.1	7.15	0.75	18
7	Parking Lot	0.002	0.447	0.004	0.851	0.050	2.318	n.d.*	12.3	8.4	0.68	7
8	Darby Creek Trib. Outfall	0.028	36.445	0.056	17.576	5.153	0.018	n.d.*	248	7.25	1.41	63
9	Darby Creek Lakeside Dr.	0.034	27.291	0.033	12.966	4.075	0.025	n.d.*	190.7	7.08	1.21	39
10	Darby Creek Trib. Outfall	0.474	88.881	0.058	71.132	9.492	0.164	0.289	626	6.42	1.96	169
11	Rain Gauge	n.d*.	0.185	n.d*.	0.403	0.049	0.003	n.d.*	10.4	8.5	0.68	8
12	Rain Gauge	0.019	1.083	0.008	1.168	0.475	0.005	n.d.*	38.9	7.6	0.68	13
	Shoemaker Green cistern	0.003	109.851	0.035	35.443	6.302	0.053	0.014	532.8	6.79	1.41	113
	Samples showed trace quantities of acetate, formate and possibly other organic anions. The lab does not have standards for these, so no values were calculated.											
	All samples showed carbonate in roughly the same amount. The lab does not have standards for carbonate (it is very difficult to make them, as they are pH dependent and are not stable).											
		* Not detected			** No data due to an instrumental error				T.D.S. = Total Dissolved Solids			

Appendix C Trinity Presbyterian Church Plant List

Table 6 Courtyard, Cross Garden, and Corner Sign Garden Plant List Summer 2016

Symbol in ALL CAPS = shrub; lower case = herbaceous.

Symbol	Latin name	Common name	Location	Wetland Classification
Ae tr	*Arisaema triphyllum*	Jack in the pulpit	Shade garden	FACW
Ag ar	*Ageratina aromatica*	Lesser snakeroot	West wall Fellowship Hall	none
Aq ca	*Aquilegia canadensis*	Columbine	Shade garden	FAC
AR AR	*Aronia arbutifolia*	Chokeberry	Corner Sign garden	FACW
As ca	*Asarum canadense*	Wild ginger	Under benches, Courtyard	FACU
As in	*Asclepias incarnata*	Swamp milkweed	Rain garden	OBL
As tu	*Asclepias tuberosa*	Butterfly milkweed	Sun garden	none (possibly threatened)
Ba au	*Baptisia australis*	Blue wild indigo	Sun garden	FACU
CE OC	*Cephalanthus occidentalis*	Button bush	Rain garden	OBL
Ch vi	*Chrysogonum virginianum*	Green-and-gold	Sun garden	endangered
CO AL	*Cornus alternifolia*	Alternate-leaf dogwood	Courtyard, between spruce and fence NW corner (deer protected)	FAC
Co ve	*Coreopsis verticillata*	Whorled tickseed, thread-leaf coreopsis	By walk in Courtyard	none
Di cu	*Dicentra cucullaria*	Dutchman's breeches	Shade garden	none
Di ex	*Dicentra eximia*	Bleeding heart, turkey corn	Shade garden	none
Ec pu	*Echinacea purpurea*	Eastern purple cone flower	Sun garden	none
Er sp	*Eragrostis spectabilis*	Purple love grass	Cross garden	UPL
Eu di	*Eurybia divaricata*	Dwarf white wood aster	Shade garden	none
Ge cl	*Gentiana clausa*	Bottle gentian	West entrance & rain garden	FACW
Ge ma	*Geranium maculatum*	Spotted geranium, cranesbill	Corner Sign garden & Cross garden	FACU
He au	*Helenium autumnale*	Sneezeweed	Sun garden	FACW
Ir ve	*Iris versicolor*	Blue-flag iris	Rain garden	OBL

Symbol	Latin name	Common name	Location	Wetland Classification
IT VI	*Itea virginica*	Virginia sweetspire	Rain garden	OBL
LI BE	*Lindera benzoin*	Northern spicebush	Rain garden	FAC
Li sp	*Liatris spicata*	Marsh blazing star	Rain garden	FAC
Lo ca	*Lobelia cardinalis*	Cardinal flower	Rain garden	FACW
Lo se	*Lonicera sempervirens*	Trumpet honeysuckle	Fence behind sun garden	FACU
Mu ca	*Muhlenbergia capillaris*	Hair-awn muhly grass	Cross garden	FACU
On se	*Onoclea sensibilis*	Sensitive fern	Shade garden & rain garden	FACW
Pa Au	*Packera aurea*	Golden ragwort	Shade garden	FACW
Pe di	*Penstemon digitalis*	Foxglove beardtongue	Sun garden & west wall, Fellowship Hall	FAC
Ph su	*Phlox subulata*	Moss pink	Sun garden & Corner Sign garden	none
Ph vi	*Physostegia virginiana*	Obedient plant	Rain garden & west wall, Fellowship Hall	FAC
Py mu	*Pycnanthemum muticum*	Mountain mint	Corner Sign garden & Cross garden	FACW
RH AR	*Rhus aromatica 'Lo Gro'*	Fragrant sumac 'Lo gro'	Corner Sign garden	FACU
Ru hi	*Rudbeckia hirta*	Black-eyed Susan	Sun garden	FACU
Si an	*Sisyrinchium angustifolium*	Blue-eyed grass	Cross garden & Corner Sign garden	FACW
So ca	*Solidago caesia*	Blue-stem goldenrod	Shade garden	FACU
So fl	*Solidago flexicaulis*	Zig-zag goldenrod	Shade garden	FACU
So ru	*Solidago rugosa*	Wrinkle-leaf goldenrod 'Fireworks'	Sun garden & Cross garden	FAC
Sy co	*Symphyotrichum cordifolium*	Blue wood aster	Shade garden	none
Sy la	*Symphyotrichum laeve*	Smooth blue aster 'Bluebird'	Sun garden & Cross garden	FACU
Sy no	*Symphyotrichum novi-belgii*	New York aster	Sun garden	FACW
Sy pu	*Symphyotrichum puniceum*	Purple stem aster	Rain garden	OBL
Ve no	*Vernonia noveboracensis*	New York ironweed	Sun garden	FACW

Table 7 Terrace Garden and East Entrance Plant List Summer 2016

Symbol	Latin name	Common name	Size/character	Wetlands classification
Ag fo	*Agastache foeniculum*	Anise hyssop	herbaceous	none
Am hu	*Amsonia hubrichtii*	Amsonia, blue-star	herbaceous	none (native to OK and AK)
AM ST	*Amelanchier stolonifera*	Running serviceberry	shrub	FACU
CA FL	*Calycanthus floridus*	Carolina allspice, sweetshrub	shrub-tree	FACU
CE OC	*Cephalanthus occidentalus*	Button bush	tall shrub	OBL
CL AL	*Clethra alnifolia*	Sweet-pepper bush	shrub	FAC
Co ce	*Conoclinum coelestinum*	Foam flower	herbaceous	FAC
Co ve	*Coreopsis verticillata*	Threadleaf coreopsis	herbaceous	none
Eu ma	*Eutrochium maculatum*	Joe Pye weed	herbaceous (shrub-like in size)	FACW
He au	*Helenium autumnale*	Sneezeweed	herbaceous	FACW
Hy fr	*Hypericum frondosum*	St. John's Wort	shrub	none
IL GL	*Ilex glabra*	Inkberry holly	shrub	FAC
Li sp	*Liatris spicata*	Marsh blazing star	herbaceous	FACW
Lo ca	*Lobelia cardinalis*	Cardinal flower	herbaceous	FACW
Mo di	*Monarda didyma*	Scarlet bee balm	herbaceous	FAC
Py mu	*Pycnanthemum muticum*	Mountain mint	herbaceous	FACW
Ra pi	*Ratibida pinnata*	Gray- headed coneflower	herbaceous	none
RH AR	*Rhus aromatica 'Lo Gro'*	Fragrant sumac	prostrate shrub	FACU
RH AR	*Rhus aromatica*	Fragrant sumac	shrub	FACU
Si an	*Sisyrinchium angustifolium*	Blue-eyed grass	herbaceous ground cover	FACW
Sy la	*Symphyotrichum laeve*	Smooth aster	herbaceous	FACU
Sy no	*Symphyiotrichum novi-belgii*	New-York aster	herbaceous	FACW (threatened in PA)
Tr vi	*Tradescantia virginiana*	Spiderwort	herbaceous	FACU
Ve no	*Vernonia noveboracensis*	New York ironweed	herbaceous	FACW
VI TR	*Viburnum trilobum*	Cranberry viburnum	shrub	none; rare

Appendix D
Site and Project Photos

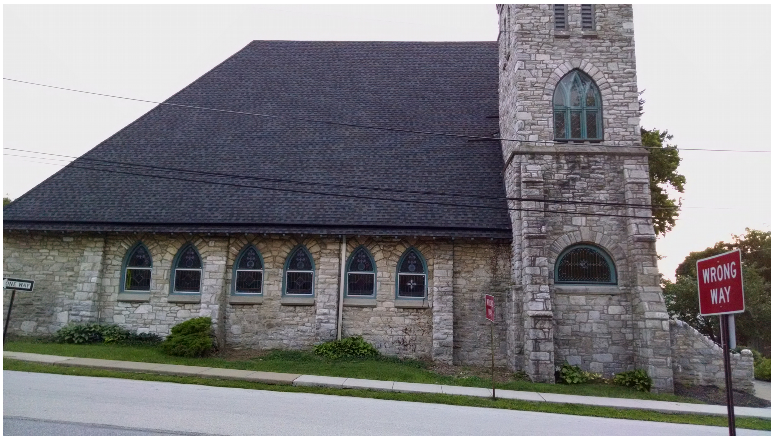

Photo 1
East side of the Sanctuary in 2015 before the terracing project began. Winged euonymus shrubs had been removed. Water poured down the steep roof, bypassing the gutter and falling onto the ground; some soaked into the soil, but some ran onto the sidewalk. Two downspouts took some water into the ground, presumably intended to be dumped into the street, but exit pipes had been paved over. Photo taken August, 2015.

Photo 2
The northwest corner of the Courtyard featured a heavy growth of English ivy and poison ivy which together smothered everything, including this spruce tree. Photo taken May 2015.

Photo 3
Three benches in the northwest corner of the Courtyard were never used. They were overgrown with moss, their feet were buried in mulch, and the holly behind them dropped prickly leaves on anyone who tried to approach. Surrounding beds contained a few azaleas, some forlorn bulbs, and many weeds. Photo taken May, 2015.

Photo 4
Before the rain garden project, water bubbled up in this river-rock bed and ran to the edge of the property, often flooding the sidewalk before finding a storm sewer. Photo taken 27 June 2015.

Photo 5
Stormwater from the streets around Trinity Presbyterian Church enters this tributary of Darby Creek through culverts at the intersection of Midland Ave. and Eastwood Drive. Stormwater has eroded the banks and pollutes the creek near its headwaters. Photo taken 19 September 2016 after two inches of rain in two hours.

Photo 6
Connor Bryan (front) and members of Boy Scout Troop 219 from Wayne, PA begin the process of installing the Courtyard rain garden by removing the river-rock around the outflow pipe that brings water across the courtyard. A hose was laid out to indicate the perimeter of the garden. The center would be dug down 20–24 in. and edges sloped to the center. Bags of peat moss (left over from earlier gardening practices on the property) and sand wait to be mixed in to the rain-garden soil.

Photo 7
An overnight rain made it easier for Connor and his dad Dave Bryan to dig out the compacted clay in the center portion of the rain garden area. Troop members also cleared away the English ivy, leaving a large space ready for planting. Photo 11 August 2015.

Photo 8
A mix of soil, sand, and peat moss was returned to the hole leaving the surface about eight inches below grade. Photo 11 August 2015.

Photo 9
Scouts begin the work of removing turfgrass to extend the rain garden from the center to the edge of the designated area. Soil was then dug away to slope the entire area to the center. Clay from the original excavation was used to form a berm at the outside (street) edge of the garden. Photo 12 August 2015.

Photo 10
Scouts put the final design touches on the rain garden. Plants donated from Jenkins Arboretum and Gardens were grouped with ones preferring wetter soil near the center, ones preferring full sun near the front (out of the shade of the overhanging sycamore). Scouts decided to re-use the river rock to create an artistic spiral.

Photo 11
A year later, restored benches with stone pavers, cardinal flower, and a sign explaining the rain garden make a welcoming corner of the Courtyard. Photo August, 2016.

Photo 12
Neighbors from the office building across the street come over to the Trinity Courtyard to hold their morning meeting. Photo 19 October 2016.

Photo 13
Neighbors stop to enjoy a snack on the stonework where terraced gardens were being installed September, 2015.

Photo 14
The terraced gardens in bloom, August, 2016. Shrubs were planted all along this side of the church, but to fill in the space until they grow, flowers were added as well. Blue mist flower proved to be a show-stopper. These gardens attract the most attention of any on the church property, since they border a sidewalk that gets frequent use.

Photo 15
A third area where water was a problem was at the corner of the garage used as a shed at the downslope end of the east parking lot (marked SHED in Fig. 1). Rain water had been forming a lake for years. Silt had formed a thick layer at the corner. Tree roots had filled it and crawled up the downspout. Photo late summer 2015.

Photo 16
In 2016, we chopped out the roots and dug a trench. Using scrap wood that had been collecting behind the garage, we created a simple detention basin where water could collect and seep in. Here, helper Pam Koch puts the finishing touches on the whimsical retaining wall.

Photo 17
A few weeks later two inches of rain fell in two hours. The detention basin held the water, though water did sneak around the edge farthest from the tree, showing that the barrier needed to be extended. Water soaked in within two hours. Photo 19 September 2016.

Photo18
The rainstorm on 19 September, 2016 dropped two inches of rain in two hours. One hour later, the Courtyard rain garden was full of water. There was evidence that some water had escaped past the berm and had pooled by the shrubs below; that was easily repaired by extending the berm after the ground had dried.

Photo 19
After another hour, most of the water had sunk into the rain garden. In this photo the pipe that brings water from the church roofs is visible, with its cap blown off due to the force of the flow.

Photo 20
One hour later, all the water has soaked into the soil.