VACANT BASEMENTS FOR STORMWATER MANAGEMENT FEASIBILITY STUDY

CITY OF MILWAUKEE
OFFICE OF ENVIRONMENTAL SUSTAINABILITY, MILWAUKEE, WISCONSIN
CITY CONTRACT C523130516

July 2, 2014

PREPARED FOR

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FORWARD

Every challenge placed before us is an opportunity to find new solutions. Like many American cities, Milwaukee is faced with many challenges. Two of these intersecting challenges are the risk of flooding from extreme weather events, and the foreclosure crisis. With climate change, extreme weather appears to be becoming a new normal for our region, with the City experiencing flooding and basement backups from storms in 2008, 2009, and most severely in 2010. The City of Milwaukee call center received 11,600 reports of water in basements in 2010. Meanwhile, the City is experiencing a foreclosure crisis that is centered in the same part of the city that experienced the most reported basement backups.

In 2010, the Common Council passed a resolution creating a Flooding Study Task Force to find solutions to the problem. I was privileged to serve as Mayor Barrett's appointee to the Flooding Study Task Force (Council file 100663). The Task Force made a series of recommendations, many of which have been implemented. As the report noted, it will take a variety of strategies to reduce the risk of flooding.

Since the time the Flooding Study Task Force completed its work, new attention was placed on the foreclosure crisis. The City's *Strong Neighborhoods Plan* is coordinating an overall approach to the situation. As a result of foreclosures, the City is razing hundreds of blighted houses that cannot be economically saved, in addition to providing strategies to save many others. The HOME GR/OWN program, a catalytic project approved in the *Refresh Milwaukee* Plan, has highlighted the opportunity to convert vacant lots in these areas to productive urban agriculture use. In addition, the Milwaukee Metropolitan Sewerage District outlined its *Regional Green Infrastructure Plan*, calling for 740 million gallons of new stormwater capture through green infrastructure by 2035 across their service territory.

The Office of Environmental Sustainability (OES) has been involved in all of these efforts, either in the initial planning or as an implementation partner. Then it occurred to me:

1) If basement backups have occurred in the same areas that we now have a large number of foreclosures; and if the physical properties of basements put them at risk of flooding, then would it be possible to reduce the risk of basement backups in occupied homes by directing more stormwater to cisterns built in what are now vacant basements?
2) When the City razes a blighted property, could we retain the basement cavity and convert it to an underground stormwater management cistern, thereby saving costs on demolition of the house and new construction of the stormwater feature?

3) Could this stormwater management strategy be made into a community asset by utilizing it for rainwater harvesting to support urban agriculture as envisioned by the HOME GR/OWN program?

After discussing the idea with the Mayor's Office, city departments including DCD, DPW, OES, and DNS, the Milwaukee Metropolitan Sewerage District, funding agencies, and informally with engineering firms, all parties agreed the idea was worth exploring. All parties wanted to understand whether the approach could be designed to be effective, affordable compared to the alternatives, safe for neighbors and the community, durable for the long-term and compliant with existing stormwater management law.

To address these concerns, OES, with support from DPW, commissioned the engineering firm HNTB to conduct this feasibility study converting the basement of an actual city property that is scheduled for demolition into a cistern. The project was funded by an existing green infrastructure planning grant from the Fund for Lake Michigan.

You will find in this report that the idea (let's call it a "BaseTern") is indeed feasible.

If implemented a BaseTern can be one strategy to:

• Manage larger quantities of stormwater more reliably than other strategies such as rain barrels
• Help protect occupied homes from basement backups
• Help the City do its part in meeting MMSD's regional green infrastructure goals, especially in light of our significant constraints on buildable space.
• Provide a water source for urban agriculture
• Help the City become more resilient and help the city adapt to a changing climate.

Thank you to all of the people that collaborated on the idea and suggested ways to improve it. I am now pleased to present this report to policy makers, philanthropic organizations, and the community. The designs in this report are conceptual and can be modified to incorporate new insights and suggestions from experts and the community. I look forward to working with the community to identify funding and a location to construct Milwaukee's (and possibly the world's) first BaseTern.

Sincerely,

Erick Shambarger

Deputy Director
City of Milwaukee Office of Environmental Sustainability

EXECUTIVE SUMMARY

At the request of the City of Milwaukee Office of Environmental Sustainability, HNTB conducted a study to determine the feasibility of converting the basement of a foreclosed home in the city of Milwaukee to a combination stormwater management facility/community garden. Such a facility could potentially provide stormwater detention, groundwater recharge and/or rainwater harvesting in support of the City's green infrastructure and flood mitigation programs. The feasibility study examined three "Conversion Options" (fill types) and four "Re-Purposing Alternatives" that explore how the structure can be used in different ways to manage stormwater. The conversion options and re-purposing alternatives can be mixed and matched depended on the particular situation.

The following three options were evaluated to convert an existing basement into a stormwater storage facility and community garden: (1) Stone Fill, (2) Stormwater Harvesting Cells, and (3) Green Roof. Options 1 and 2 assume that the resulting structure is at existing grade. The Green Roof option, which consists generally of converting the existing floor of the house to a green roof, was found to be the most cost-effective, but protrudes three feet above grade. Under all scenarios, the structure is covered with topsoil to prevent public hazards.

Several combinations of basement conversion option and stormwater management function, or "basement re-purposing alternatives", were evaluated under this study. These basement re-purposing alternatives were: (1) Rainwater Harvesting, (2) Groundwater Recharge, (3) Multi-Purpose, and (4) Stormwater Detention (metered back to combined sewer). The total construction costs for these four re-purposing alternatives evaluated under this study ranged from $34,200 to $79,200, and from $0.77 to $2.91 per gallon of storage capacity.

However, cost of the alternatives is not the only factor that should be considered. The combination ultimately used at a particular location would be based on several factors, including cost, the desired volume reduction, and site-specific constraints or limitations. For example, a particular location may be suitable for collecting only roof runoff, or "rainwater harvesting", while another location may only be suitable for collecting stormwater, that is, runoff from streets and alleys. Stormwater from streets and alleys must be pretreated to remove contaminants before infiltrating the stormwater in to the ground, whereas roof runoff does not require pre-treatment. Ultimately, the City may choose to select the design that best

fits the particular project site, project goals (i.e. water quality, flood management, and/or urban agriculture), and budget.

The Rainwater Harvesting and Stormwater Detention Alternatives were found to be cost-effective in helping to reduce combined sewer overflows when compared to MMSD's rain barrel and rain garden approaches to this problem. However, these two alternatives could be matched with the Green Roof or Stone Fill basement conversion options to reduce costs. In addition, although the latter two of the basement re-purposing alternatives evaluated under this study are more expensive than MMSD's cost for rain barrels and rain gardens, it is important to note that all the basement re-purposing alternatives would serve as more reliable forms of runoff storage. They would be owned and operated by the City and provide substantially more capacity to assist with flood management that either rain barrels or rain gardens. As a result of the study, we do not anticipate hazards to the community from these structures, but rather view them as a feasible approach for effectively managing stormwater in the community.

BASEMENT CONVERSION

Sample Basement The basement of the abandoned house at 3046 N. 21st Street was selected for evaluation under this study. The City owns the property and determined that the blighted house should be potentially razed. Between 2008 and 2010, the City received seven "backwater" calls to its call center from houses located on that block. The existing basement walls are constructed of masonry block which are in generally good condition. Moisture was noted on the inside of the walls indicating they are not watertight. At the top of the walls the floor joists bear on the masonry blocks and the voids between joists are filled with bricks and mortar. There are several windows at the top of the basement walls that extend down to approximately the existing grade outside. The basement floor is poured concrete and is in generally good condition. There are various utilities and drain pipes which penetrate the floor. The inside dimensions of the basement are approximately 25 feet wide by 40 feet long (1,000 square feet). The floor of the basement is approximately six feet below existing grade.

Conversion Options The following four options were initially considered as feasible methods to convert the existing basement to a stormwater storage facility and community garden: (1) Stone Fill, (2) Stormwater Harvesting Cells, (3) Green Roof, and (4) Concrete Roof. However, the cost to construct a concrete roof over the existing basement was found not to be economically feasible. Therefore, this option was not evaluated further. Under the remaining three options, the existing basement would be completely covered to avoid safety issues. The first basement conversion option consists generally of filling the basement with stone, and covering it with 18 inches of topsoil to sustain a garden. Under this option, the foundation walls would be removed down to existing grade, and the surface of the topsoil would be one foot above existing grade. The stone fill is assumed to have 33% void space for water storage. For the subject basement, the effective water storage depth would be 5.5 feet. As shown in Table 1, the storage capacity of this basement conversion option is 13,400 gallons. The estimated construction cost to just provide the storage capacity is $15,700, and the capital cost per gallon of water stored is $1.17. A detailed break-down of this cost estimate is shown in Table 2.

Under the second option, the stone fill under Option 1 is substituted with modular tanks made from recycled materials, or stormwater harvesting cells. Under this option, the foundation walls would be removed down to existing grade, and the surface of the topsoil would be one foot above existing grade. These cells have 95% void space, but require 12" of gravel cover in addition to the topsoil, thereby reducing the effective storage depth for the subject basement to 4.5 feet. As shown in Table 1, the storage capacity of this basement conversion option is 31,600 gallons. The estimated construction cost to just provide the storage capacity is $47,800, and the capital cost per gallon of water stored is $1.51. A detailed break-down of this cost estimate is shown in Table 2.

The third option consists of converting the existing floor of the house to a green roof. The roof conversion would consist generally of structural improvements, waterproofing and six inches of topsoil. Under this option, the surface of the green roof is approximately three feet above grade, terminating at the top of the existing foundation. This option would have an effective storage depth of six feet. As shown in Table 1, the storage capacity of this basement conversion option is 44,400 gallons. The estimated construction cost to just provide the storage capacity is $19,500, and the capital cost per gallon of water stored is $0.44. A detailed break-down of this cost estimate is shown in Table 2.

STRUCTURAL CONSIDERATIONS

Existing Structural Loads In order to determine if settlement of the soil beneath the foundation will be an issue, a conceptual structural analysis was performed. The basement as it currently exists carries the weight of the house and its contents. These loads are applied along the basement walls by floor joists and the house walls and to the floor by intermediate posts. The soil underneath the basement supports the combined weight of the house and basement. It is reasonable to assume that soil was excavated during the original house construction and so the soil supporting the basement was unloaded by the excavation and reloaded with the house construction. This soil has had many years to consolidate and adapt to the applied loading.

Under each of the conversion options, it is assumed that the house will be demolished which will relieve some loading on the basement. A common way of disposing of abandoned houses is to demolish the house structure and to fill in the basement with soil. According to the Department of Neighborhood Services, when a house is razed, the cost to the demolition budget is at least $2,000 to fill in the basement. This served as a conceptual baseline for the conversion options evaluated under this study. A typical soil unit weight is 120 pounds per cubic foot (pcf). This soil would be a permanent load. Therefore, the soil underneath the basement will always see this load and could settle under its influence depending on the net change in load from the removal of the house structure to the addition of soil fill.

Structural Loads After Conversion The structural loading and support conditions of the basement will be altered under each of the conversion options. For each option, the new loads on the basement consist of the weight of storage media (varies depending on the conversion option), stored water (62.4 pcf), new topsoil covering the basement (120 pcf), and the live loading of people (no vehicles). Live loads for design can be chosen with the aide of *ASCE 7 Minimum Design Loads for Buildings and Other Structures*. This standard lists minimum uniformly distributed live loads depending on the use of the given space. For roof gardens the load is 100 psf. For reference an office lobby is also subject to 100 psf. Therefore 100 psf is taken as the design live load for the purposes of preliminary analysis.

For comparison, this is less weight than 1 ft of fill soil (120 pcf). It can be seen from this discussion that the new loads on the basement will be less than what would be applied if the basement was filled with soil. Therefore any settlement resulting from a conversion alternative should be less than what would result from the baseline of filling the basement with soil. Also, the new loading on the basement is not the total change in load since the house structure will be removed. The basement will see the new loading minus the weight of the existing house structure.

Each of the conversion options must be able to carry the new vertical loading into the basement. The vertical loading on the storage media itself will consist of live loading (100 psf), topsoil (120 pcf), and the self-weight of the media. Assuming 18 inches of topsoil, the applied service loading in excess of self-weight would be 100 psf + 120pcf * 1.5 ft = 280 psf. The stone fill has a high shear strength and will easily carry the load to the basement floor just as buildings and highways are supported by gravel layers. The rainwater harvesting cell system is advertised as having a 38 pounds per square inch (psi) load bearing weight and as being able to carry vehicular loading. This load bearing weight converts to 5,472 psf and provides a generous factor of safety of almost 20 (5472 psf / 280 psf = 19.5) which is more than adequate for the intended purpose.

The top of the basement walls is currently joined with the floor joists. It is possible that the joists and floor system are acting to brace the tops of the basement walls. Under the first two conversion options, once the joists are removed there could be some movement of the basement walls into the empty space. This movement, if it occurs, would happen under any scenario where the house is demolished. For the stone fill conversion alternative, once the stone is in place it would resist any further wall movement and the wall would be effectively braced along its height. Similarly the stormwater harvesting cell system has lateral strength and could resist wall movement. These two options would effectively bury the basement and render it nonstructural. There is no wall movement anticipated under the green roof conversion option .

BASEMENT RE-PURPOSING ALTERNATIVES

The following four alternative functions for the converted basement were evaluated: (1) Rainwater Harvesting, (2) Groundwater Recharge, (3) Multi-Purpose, and (4) Stormwater Detention. Under all four alternatives, the basement walls would be water-proofed to prevent any seepage to adjacent properties. The basement floor must also be lined if runoff from streets or alleys is stored, to prevent potential groundwater contamination. If groundwater recharge is needed, the basement floor would not be lined. However, runoff from streets or alleys must be treated prior to infiltration. Roof runoff typically need not be treated prior to infiltration.

For rainwater harvesting, rooftop runoff from adjacent properties would discharge into the converted basement (see Figure 1). As shown in Table 3, the estimated construction cost to provide rainwater harvesting at the subject basement is $39,000, and the capital cost per gallon of water stored is $2.91. A detailed break-down of this cost estimate is shown in Table 4.

For the groundwater recharge alternative, runoff from nearby rooftops, streets and alleys would discharge into the converted basement, and be allowed to infiltrate through the basement floor and into the ground (see Figure 2). As shown in Table 3, the estimated construction cost to provide groundwater recharge at the subject basement is $79,200, and the capital cost per gallon of water stored is $2.51. A detailed break-down of this cost estimate is shown in Table 4.

For the multi-purpose alternative, runoff from nearby rooftops would discharge first into a series of rain barrels, with overflow into the converted basement, and be allowed to infiltrate through the basement floor (see Figure 3). Since the property is in the combined sewer area, the existing floor drain and lateral can serve as an overflow point to slowly add water to the combined sewer. Since the runoff is coming from adjacent rooftops, the water is relatively clean and suitable for irrigation to support community gardens on the site, with overflow able to be safely infiltrated into the ground. As shown in Table 3, the estimated construction cost to provide rainwater harvesting and groundwater recharge at the subject basement is $62,500, and the capital cost per gallon of water stored is $1.98. A detailed break-down of this cost estimate is shown in Table 4.

The stormwater detention alternative would function the same as the multi-purpose alternative, except only minimal groundwater recharge would be provided. Most of the accumulated runoff would be discharged slowly to the existing sewer system to provide detention storage capacity for the next storm event (see Figure 4). As with the multi-purpose alternative, only roof runoff from nearby homes would discharge into the converted basement. As shown in Table 3, the estimated construction cost to provide rainwater harvesting and stormwater detention under this alternative is $34,200, and the capital cost per gallon of water stored is $0.77. A detailed break-down of this cost estimate is shown in Table 4.

CONCLUSION

As discussed above, converting the basement of an abandoned house to a stormwater management facility is technically feasible, both structurally and operationally. The converted basement can be used for rainwater harvesting, stormwater detention, groundwater recharge, or a combination thereof. The combination ultimately used would be based on several factors, including cost, the desired volume reduction, and site-specific constraints or limitations, all of which would be considered in detail during preliminary engineering. The storage capacity would range from 13,400 to 44,400 gallons, depending on the basement conversion option constructed, which is an equivalent capacity of 243 to 807 55-gallon rain barrels. As shown in Table 4, the total costs for the four re-purposing alternatives evaluated under this study range from $34,200 to $79,200, and from $0.77 per gallon to $2.91.

The MMSD is encouraging use of rain barrels and rain gardens to reduce overflows of their collection system. In 2012, a single rain barrel was estimated to cost about $2 per gallon of storage capacity, and a rain garden was estimated to cost about $1.60 per gallon of storage capacity. As shown in Table 1, the costs per gallon of storage capacity for the three basement conversion options are $1.17, $1.51 and $0.44 for the stone fill, stormwater harvesting cells, and green roof options, respectively. Therefore, each of the three basement conversion options appears to be a cost-effective approach to help reduce combined sewer overflows. Adding the components necessary for re-purposing the basement increases the cost per gallon of storage capacity to a range of $0.77 to $2.91. Although two of the basement re-purposing alternatives are more expensive than MMSD's cost for rain barrels and rain gardens, it is important to note that all the basement re-purposing options would serve as more reliable forms of storage as they would be owned and operated by the City. Additionally, this high-capacity approach provides dramatically more capacity for flood protection than individual rain barrels, which can fill up in a matter of minutes during heavy rains.

It is the goal of the MMSD to capture the first half-inch of rain from a storm event using green infrastructure. Based on the potential storage capacity of the converted basement evaluated under this study, the first half-inch of rain could be stored from up to about 4.4 acres of high density residential land in the combined sewer area.

Regarding the potential flood mitigation benefit from the basement runoff storage concept, an analysis was completed for the one-block area within which the subject abandoned home is located. For a 3-inch rainfall on a one-block area of five acres, assuming 75 percent runoff, approximately 302,000 gallons of stormwater would run off to the combined sewer system. Under the green roof conversion option, 44,400 gallons, or 15 percent of the runoff from a 3-inch rainfall could be stored in a single basement. Similarly, two converted basements located within a 5-acre block area could store 30 percent of the runoff from a 3-inch rainfall, or runoff from almost the first inch of rainfall.

Table 1 Evaluation of Basement Conversion Options

Alternative	Description	Void Space	Capacity (gallons)	Effect on Structural Loads	Structural Maintenance Requirements	Public Safety	System Durability	Estimated Cost		
								Construction	Annual O & M	Per Gallon Stored
Stone Fill	Fill basement with aggregate	33%	13,400	Stone fill carries vertical loads to the basement floor. Basement walls would see less load after the house is demolished.	None	No safety issues	Most durable. Stone fill is self-supporting so condition of existing basement is irrelevant after construction. Estimated useful life of 25 years.	$15,700	NA	$1.17
Stormwater Harvesting Cells	Modular tanks from recycled materials	95%	31,600	Cellular system carries vertical loads to the basement floor. Basement walls would see less load after the house is demolished.	None	No safety issues	Very durable. Modular tanks are 85% polypropylene which has high chemical resistance. Modular tanks are self-supporting so condition of existing basement is irrelevant after construction. Estimated useful life of 25 years.	$47,800	NA	$1.51
Green Roof	Convert existing floor to green roof	100%	44,400	Possible net increase of vertical load on the existing floor.	Annual inspection	Potential unauthorized access	Roof system will be very durable and long-lasting. Existing walls in good condition will be very durable. Estimated useful life of 20 years.	$19,500	$1,000	$0.44

Table 2 Estimated Construction Costs for Basement Conversion Options

Construction Item	Quantity	Units	MSRP Each	Unit Cost Installed	Installed Cost	Conversion Option		
						Stone Fill	Stormwater Harvesting Cells	Green Roof
Stone Fill	204	CY	--	$ 40.00	$ 8,148	X		
Geotextile Fabric	1200	SF	--	$ 0.50	$ 600	X	X	
Remove Basement Wall Tops	130.0	SF	--	$ 25.00	$ 3,250	X	X	
18" Topsoil	55.6	CY	--	$ 15.00	$ 833	X	X	
Side Slope Restoration	7.2	CY	--	$ 45.00	$ 325	X	X	
Stormwater Harvesting Cell	918	Each	$ 32.00	$ 35.00	$ 32,130		X	
Geogrid	1100	SF	$ 0.56	$ 1.12	$ 1,232		X	
12" Gravel Layer	37	CY	--	$ 40.00	$ 1,481		X	
Floor to Roof Conversion	1000.0	SF	--	$ 10.00	$ 10,000			X
Roof Waterproofing	1000.0	SF	--	$ 6.01	$ 6,010			X
6" Topsoil	18.5	CY	--	$ 15.00	$ 278			X
Subtotal						**$ 13,156**	**$ 39,852**	**$ 16,288**
Engineering & Contingency - 20%						**$ 2,631**	**$ 7,970**	**$ 3,258**
Basement Conversion Total						**$ 15,788**	**$ 47,822**	**$ 19,545**

Table 3 Evaluation of Basement Re-Purposing Alternatives

Alternative	Description	Basement Conversion Type	Capacity (gallons)	Maintenance Requirements	Estimated Cost		
					Construction	Annual O & M	Per Gallon Stored
Rainwater Harvesting	Capture rooftop runoff from adjacent houses for irrigation.	Stone Fill	13,400	Periodic inspection of plumbing and filter change.	$39,000	$500	$2.91
Groundwater Recharge	Capture and infiltrate runoff from adjacent street and/or alley.	Stormwater Harvesting Cells	31,600	Periodic inspection of plumbing, cleaning of treatment device and filter change.	$79,200	$1,000	$2.51
Multi-Purpose	Capture rooftop runoff from adjacent houses for irrigation & recharge with overflow to sewer	Stormwater Harvesting Cells	31,600	Periodic inspection of plumbing and filter change.	$62,500	$1,000	$1.98
Stormwater Detention	Capture rooftop runoff from adjacent houses for slow metering to sewer	Green Roof	44,400	Periodic inspection of plumbing and filter change.	$34,200	$1,000	$0.77

Table 4 Estimated Construction Costs for Basement Re-Purposing Alternatives

Construction Item	Quantity	Units	MSRP Each	Unit Cost Installed	Installed Cost	Re-Purposing Alternative: Rainwater Harvesting	Groundwater Recharge	Multi-Purpose	Stormwater Detention
Basement conversion - stone fill	1	Each	--	$13,156	$13,156	X			
Basement conversion - cellular fill	1	Each	--	$39,852	$39,852		X	X	
Basement conversion - roof	1	Each	--	$16,288	$16,288				X
Create sump in basement floor	1	Each	--	$1,500.00	$1,500	X			
Sump Pump	1	Each	$330.00	$660.00	$660	X			
Booster Pump	1	Each	$620.00	$1,240.00	$1,240	X			
Pump Access Tube	1	Each	$795.00	$1,590.00	$1,590	X			
Plumbing	1	Each	$1,113.00	$2,226.00	$2,226	X	X	X	X
Access Manhole	1	Each	--	$3,200.00	$3,200		X	X	X
Stormwater Treatment Device	1	Each	--	$6,000.00	$6,000		X		
Inflow Pipe	60	LF	--	$65.00	$3,900		X		
Inlet	2	Each	--	$2,000.00	$4,000		X		
Drilled holes in basement floor	40	Each	--	$8.00	$320		X	X	X
Soil Testing	1	Each	--	$1,000.00	$1,000		X	X	X
Waterproof Basement Floor	1100.00	SF	--	$6.01	$6,611	X			
Waterproof Basement Walls	786.00	SF	--	$6.01	$4,724	X	X	X	X
Downspout Filters	2	Each	$200.00	$400.00	$800	X	X	X	X
Subtotal						**$32,507**	**$66,022**	**$52,122**	**$28,558**
Engineering & Contingency - 20%						**$6,501**	**$13,204**	**$10,424**	**$5,712**
Total						**$39,008**	**$79,226**	**$62,546**	**$34,269**

Note: The costs of the Groundwater Recharge and Multi-Purpose Alternatives are based on filling the basement with rainwater harvesting cells. These two alternative functions could be matched with the green roof basement conversion option to reduce costs.

Figure 1 Rainwater Harvesting Alternative

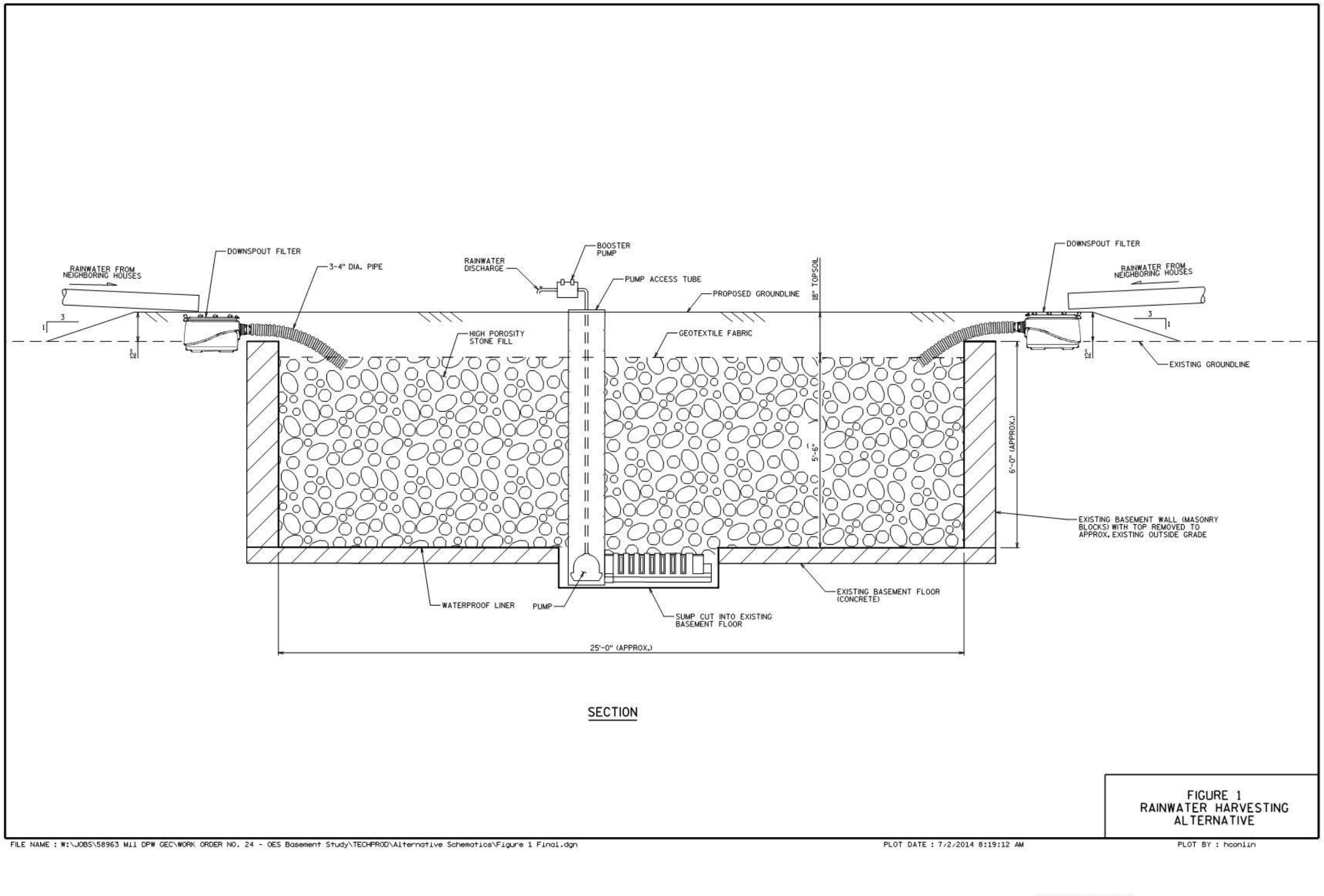


Figure 2 Groundwater Recharge Alternative

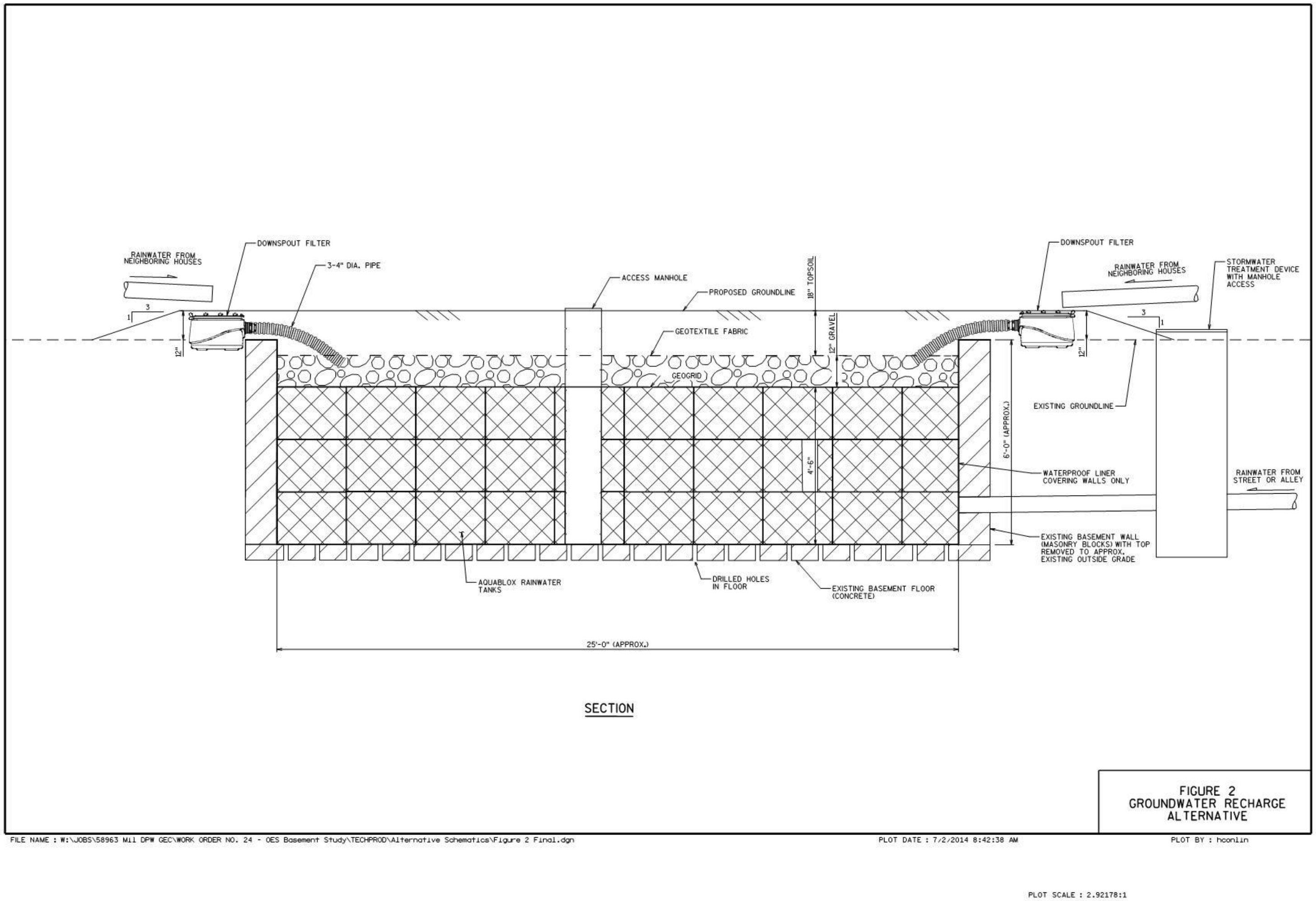


Figure 3 Multi-Purpose Alternative

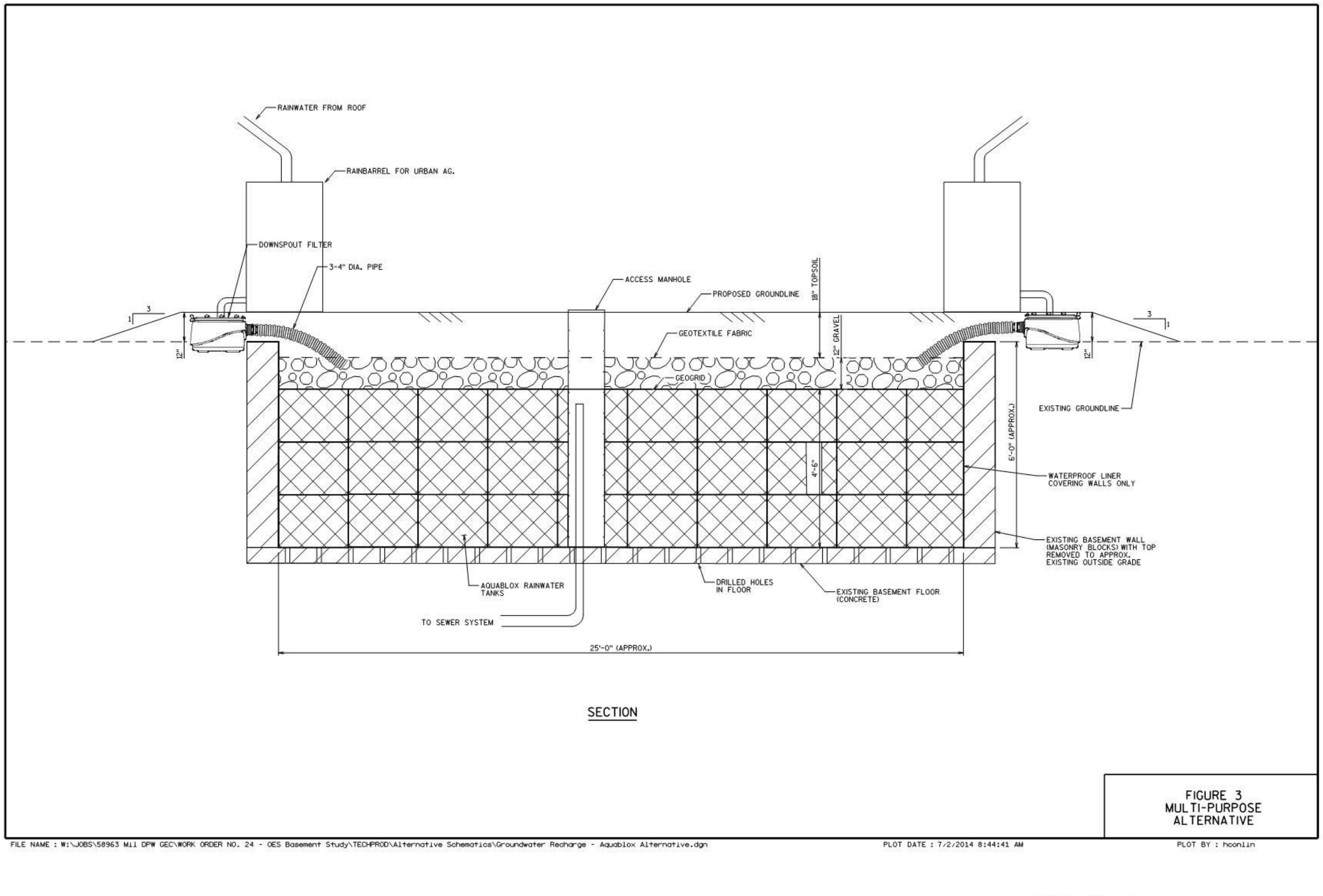
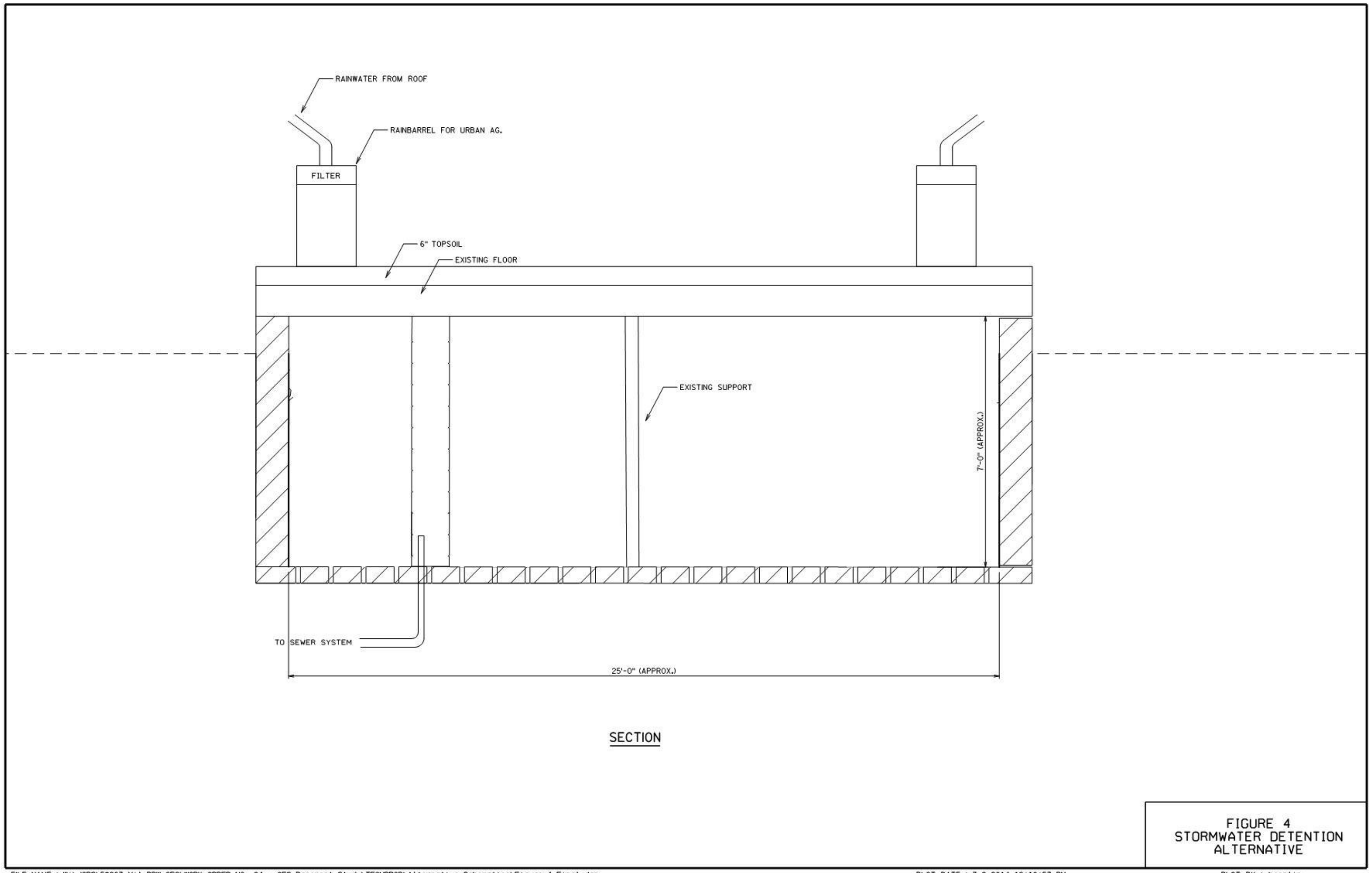


Figure 4 Stormwater Detention Alternative



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