"A New Norris House": Making Criteria for Sustainable Landscapes Visible

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ABSTRACT: *A New Norris House* is an award-winning, university-led design|build|evaluate project located in Norris, Tennessee. Norris is a model community constructed in 1933 by the Tennessee Valley Authority as part of the Norris Dam construction project. A key component of this New Deal village was the Norris House, a series of homes built for modern, efficient living.

A New Norris House commemorates the 75th anniversary of the Norris Project and seizes the opportunity to reconsider the shape of landscapes, communities and homes today. A LEED for Homes Platinum project, the *New Norris House* pursues complimentary performance and design intentions where water systems provide greater independence from the central grid. This paper focuses on the project as a case study for sustainable water systems and the designed landscapes of which they are a part. Design goals include: collecting, treating and re-using rainwater; infiltrating greywater on site; and managing 100% of run-off and stormwater on the project site.

An evaluation and residency program is ongoing. One year of collected water quality and quantity data prove we are able to collect, treat, and provide water that 01) is safe for human contact by EPA human health criteria, 02) meets drinking water standards, and 03) is sufficient in quantity to meet 30% of a two-person household's needs. Preliminary data indicates safe and effective greywater infiltration. This paper describes these and other results of the water monitoring program.

Underlying the town of Norris' picturesque vernacular landscape is a history of progressive planning and design. *A New Norris House* provides a unique case study for once again making visible the powerful union of environmental, technological and social forces.

KEYWORDS: Sustainable Landscape, Greywater, Rainwater, Stormwater Management, Water

Figure 1: NNH as seen from street (left); View of greywater and rainwater infiltration bed. Bags are planted with native grasses that will eventually grow to conceal the terrace structure (right). Source: Valerie Friedmann 2012

1.0 A NEW NORRIS HOUSE – A CASE STUDY

1.1 Project Team

A New Norris House (NNH) is an educational, research and outreach project by the University of Tennessee Knoxville (UTK). Initiated by the School of Architecture and Planning department, the project engages faculty and students from the College of Engineering and the Environmental Studies and Biosystems Engineering and Soil Science departments. The team designed and constructed the home and landscape, partnering with Clayton Homes, Inc. on the prefabricated shell. The LEED for Homes Platinum project received awards for design, pedagogy, and environmental performance, including the EPA P3 Award, the NCARB Prize for the Creative Integration of Research and Practice, the ACSA Design|Build Award, a RADA Merit Award, and an AIA Gulf States Award of Merit. An evaluation and residency phase is ongoing.

1.2 Project history

A NNH was inspired by the town of Norris and the 75th anniversary of the Tennessee Valley Authority (TVA).The TVA is a federal corporation formed to manage the region's development and resources during the Great Depression. The TVA was a technological and social experiment. President Roosevelt declared:

> *The work proceeds along two lines, both of which are intimately connected - the physical land and water and soil end of it, and the human side of it…* (Van West 2001, 212)

In 1930, few rural households in the valley had running water or electricity. Norris Dam, the first in a series of TVA hydroelectric dams, was built to generate electricity and prevent flooding and erosion. As part of the Norris Project, the TVA designed and built a model town, Norris, one of the nation's first planned communities. Municipal electricity, water and sanitary systems served the town, including all residences. A key feature of this New Deal village is the original "Norris House," a series of experimental cottages. The TVA program produced vernacular and traditional home designs that incorporated innovative building materials and equipment, as well as construction means and methods. Design, cost and performance were studied and recorded by the TVA with the goal of appropriate and broad adoption of in future housing.

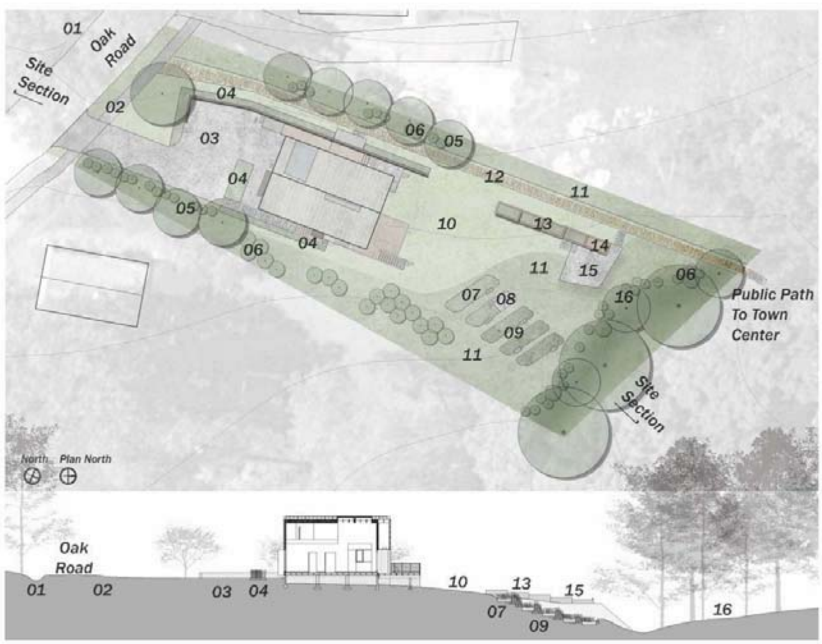

Figure 2: Site Plan and Section. 01 Existing Swale; 02 Sidewalk; 03 Parking Court/Site of Original Demolished Home; 04 Perennial Bed; 05 Small Native Trees; 06 Native Shrubs; 07 Greywater Treatment Bed; 08 Forebay/Rainwater Inlet; 09 Rainwater Infiltration Beds; 10 Drought Tolerant Turf; 11 Native Grass Meadow; 12 Crab Orchard Stone Community Path; 13 Raised Vegetable Beds; 14 Irrigation Cistern Enclosure/Hand Pump; 15 Gravel Patio and Fire Pit; 16 Existing Swale/Forest.

1.3 A New Norris House

A NNH is a single-family home (1,006ft^2) sited on a previously developed infill lot (.25 acre). As with the original Norris designs, the NNH is compact, carefully sited, and incorporates new building materials, techniques and technologies. The project goes beyond creation of a model home; realization required reforming perceptions and constraints that limit green development, such as home size and water regulations. The project emphasizes resource conservation and energy conscious design strategies. A gravel court marks the previous home's footprint and a public path leading to the town center was reconstituted on the site. Vegetable beds, a gravel plinth and fire pit, native grass meadow, and terraced infiltration beds are sited to fit the compact lot, prevent erosion, and provide outdoor living space.

1.4 Evaluation and residency phase

Projections of water and energy use are currently being evaluated against actual data collected during a two-year residency and post-occupancy evaluation. Residents support continuing education through blogs and tours, and their occupancy patterns are monitored using digital sensors. Collected data includes overall and specific energy use, temperatures and humidity, rainfall and water use, solar radiance, and water quality. This paper evaluates data collected during the first year of rainwater harvesting and treatment, greywater infiltration, and stormwater management.

2.0 RAINWATER HARVESTING AND TREATMENT

2.1 Objectives and outcomes: treated water quality

Water goals at the NNH begin with questions surrounding the appropriate balance between public and private services as they relate to safe, convenient, efficient and environmentally responsible water use. Rainwater from the roof is collected and treated for use in the house and landscape. Laboratory results show that rainwater stored and treated at NNH is safe for human contact under EPA Human Health Criteria.

Water quality of collected samples is tested at two laboratories - a state certified drinking water laboratory and a UTK laboratory. Samples are collected monthly for analysis in the UTK laboratory and quarterly for analysis in the certified laboratory. Two event-based sets of samples are tested by the certified laboratory to study summer/winter extremes. Samples are tested for 24 potential contaminants determined by the NNH team with guidance from the Tennessee Department of Environment and Conservation (TDEC) and results are compared with EPA Maximum Contaminant Levels (MCL) for drinking water (US EPA 2012).[1] To date, samples of treated rainwater collected from the NNH meet EPA regulated, secondary regulated, and non-regulated drinking water standards (Figure 3); however, TDEC restricts use of treated rainwater to non-human consumption uses. NNH permitted uses include clothes washing, toilet flushing, and landscape uses.

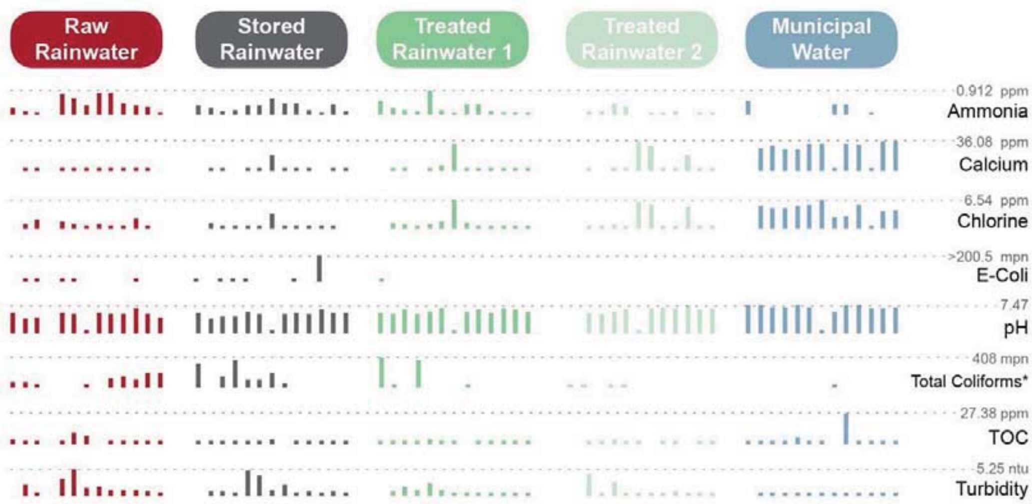

Figure 3: Results of 12 monthly UTK lab tests performed December 2011 – November 2012. Treated Rainwater 1 is sampled from a port in the cistern room installed February 2012. Treated Rainwater 2 is sampled from an exterior hose bibb. December 2011 positive result for e-coli in Treated Rainwater 1 is due to decomposing matter in exterior hose bibb. Four quarterly and one event-based state-certified water laboratory tests produced similar results. A full list of contaminants tested and associated EPA MCL is available at the conclusion of this paper.[1] *Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present.

2.2 Methodologies: treated rainwater quality

One "set" of water quality test samples is comprised of one sample taken from five locations: 1) raw rainwater collected from the gutter at the southwest corner of the house; 2) untreated rainwater collected from a port in the cistern 14" above the bottom; 3) treated rainwater collected from a port in the cistern room, just before the supply enters the house; 4) treated rainwater collected from the east hose bibb; and 5) city water sampled from the bathroom lavatory for comparison. A research assistant collects samples in vials (sterile vials for bacteriological tests) provided by each lab for testing. Care is taken to avoid contaminating water samples during collection, including the wearing of sterile gloves, removing faucet aerators, and allowing water to flow approximately five minutes before sampling. Water is allowed to flow into the vial at an angle to reduce aeration, per EPA-817-R-08-003 *Sampling Guidance for Unknown Contaminants in Drinking Water* (US EPA 2008). Collected samples are stored in a refrigerator or on ice in a cooler and delivered to the lab within 30 hours from the time of collection. Both the UTK lab and state certified water lab use the Enzyme Substrate Coliform Test (SM 9223, B.) to determine the presence of coliforms and/or E-coli. This test is approved by the U.S. EPA and is included in the EPA *Standard Methods for Examination of Water and Wastewater* (US EPA 2008).

Water quality tests are augmented by interviews with residents. The residents noted that treated rainwater did not look different than municipal water supply but did smell slightly different; the “earthy” smell did not bother them, however. Clothing washed in treated rainwater did not differ from their experience with clothing washed in city-supplied water. During one period, residents observed a further change in the smell of treated rainwater. The smell occurred when a filter in the treatment system was overdue for replacement. The residents received an operations manual but the team addressed most maintenance.

2.3 Objectives and outcomes: water quantity

The rainwater treatment system provides an average of approximately 800 gallons of treated rainwater every month for use in the home and hose bibbs. On average, 2,000 gallons of rainfall falls on the NNH roof ***each*** month; or, just over 25,000 gallons of total rainfall in year one. In year one, nearly 10,000 gallons of treated rainwater was used in the home.

A 0.5” rain event will fill the cistern, thus rainfall events regularly exceed cistern storage capacity. When the 400 gallons cistern reaches capacity, it overflows and diverts untreated rainwater to a 200 gallon cistern for vegetable garden irrigation. If capacity in the second cistern is exceeded, rainwater from this tank overflows to four terraced rain gardens for infiltration. (See section 4.0 Stormwater management.)

2.4 Methodologies: treated water quantity

Water-use volumes are digitally recorded at 15 minute intervals using a Campbell Scientific Datalogger system and digital flow-meters. Recorded water uses include: a) total volume of city water used; b) volume of city makeup water supplied to the cistern when emptied; c) total water volume pulled from the cistern; and d) total volume of hot water use. Other relevant measurements include calculated volumes based on measured values, total rainfall, and electricity used by the cistern pump and the clothes washer. (Figure 4)

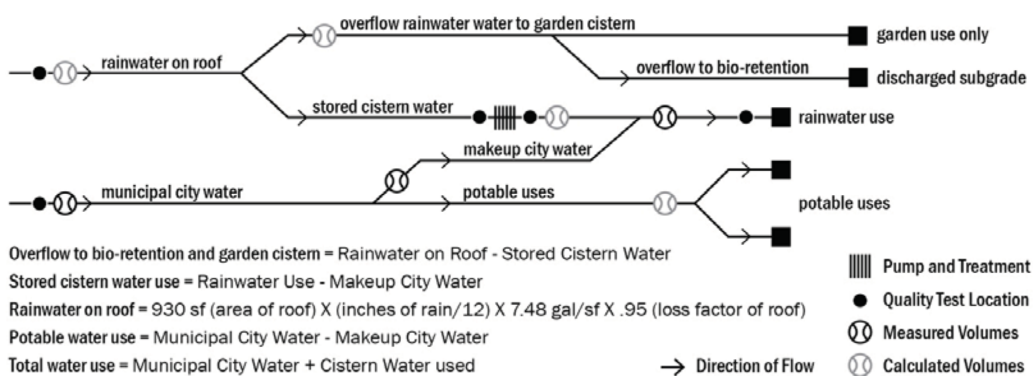

Figure 4: Schematic view of water supply system and categories for monitoring quantities.

Residents’ shared their consciousness of water use in blog posts on the project website, for example:

> *After being in the house for a few months, I found myself looking forward to rain, knowing it would keep the cistern full and provide water inside. Before living in the house, I hadn’t given any thought to repurposing rainwater; the firsthand experience of being able to reuse [rain]water has made me more mindful about how much fresh water I use daily.* (Leverance, 2012)

2.5 Design description and criteria: rainwater harvesting and treatment system

The team specified low-flow fixtures to reduce water consumption, then developed a water budget and researched codes. State and local codes currently prohibit treated rainwater use in the home; and the equipment supplier does not guarantee its system will produce potable water. The team thus obtained variances for use of treated rainwater solely for toilet flushing, clothes washing and exterior hose bibbs.

An insulated, at-grade equipment room accessed from the exterior houses the primary 400 gallon, plastic cistern. PVC piping concealed in a soffit connects gutters to the cistern. The first flush of rainwater containing loose contaminants from the roof is diverted before entering the cistern. A simple ball float allows subsequent rainwater to pass through a strainer box and enter the cistern. On demand, stored rainwater is pumped through the treatment assembly. In series, this includes: a 100 micron Y strainer; a 10 micron filter; 0.5 micron carbon block filter; and an ultraviolet lamp. Pressurized, treated rainwater (12 gallons) is stored in a hydro-pneumatic tank to minimize pump use. If the primary rainwater cistern is empty, make-up water from the city is automatically supplied. Make-up water supply avoids cross-connections with an air gap. The rainwater system can be turned off and residents can rely on solely city supply water to meet their needs.

2.6 Lessons learned

The team worked with the city manager and city water board on revising code ordinances to allow treated rainwater use. The process took 1 year and 6 months and resulted in a permit that expires at the end of the study (though results could extend the permit). The process, and length of time required - along with the the prestige of the university, the organization of the study program, and the study's limited scope (no human consumption) - developed trust and assurance that human health and liability concerns are addressed. The equipment supplier, BRAE / Watts Water Technologies, contributed pro-bono on-site commissioning (not a standard service) along with technical, regulatory, and maintenance experience. Even though it is meant to be 'plug and play,' local inexperience and unfamiliarity with rainwater treatment systems makes these important educational opportunities for contractors, government agencies, the design community and the academic team. The team's and residents' experience with maintenance and trouble-shooting, and their impacts on the user experience and data provide a valuable account that is documented for use by others.

3.0 GREYWATER ON SITE INFILTRATION BED

3.1 Objectives and outcomes

Similar to supply water goals, finding a balance between public and private services drove greywater goals. Greywater produced in the home is infiltrated on site, and existing sewer connections remove blackwater.[2] Primary benefits of on site greywater management include reductions of municipal energy used to transport and treat wastewater at a central facility, and re-charge of the local groundwater through infiltration.

Consultation with technical advisors revealed the importance of bed saturation - specifically, the assurance that greywater discharged below ground would not percolate to the surface. A broad study of gathered NNH greywater data was conducted to identify possible saturation events and causations (rainfall, high levels of discharge, etc). Focused studies were then conducted to evaluate individual greywater events as they were processed through the bed. Findings suggest average infiltration times based on discharge volume, discharge duration, and resulting bed saturation. Measurements show that the bed has yet to be fully saturated, with ample capacity to infiltrate all of the home's greywater discharge below grade.

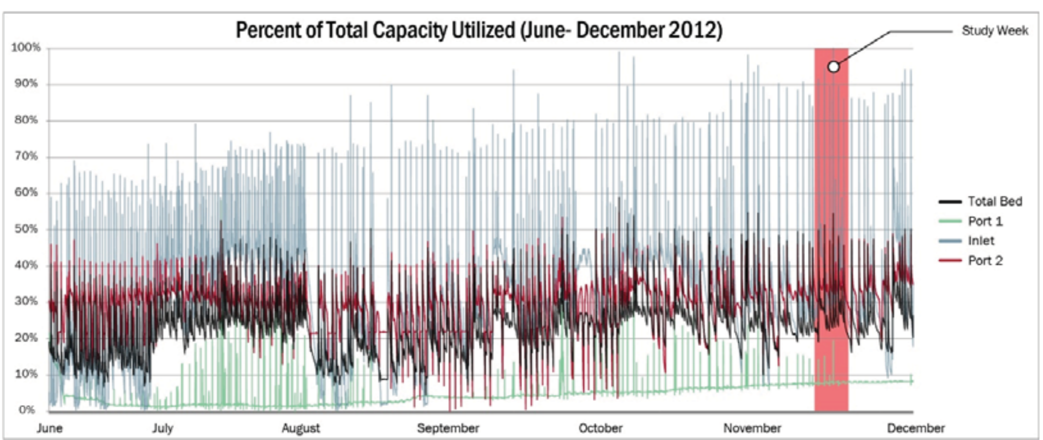

Figure 5: Saturation values within greywater bed during first six months of study. The area highlighted in red indicates the study week shown in Figure 6.

The spikes on the graph (Figure 5) show an increase in utilized capacity as recorded at each of three monitoring locations within the greywater infiltration bed. Though the total holding capacity of the bed (shown in black) rarely exceeds 50%, the greywater inlet (shown in blue) is routinely subjected to higher values. As the inlet for greywater collected from the entire house, this result is expected. Analysis of data recorded during the first 6 months of the study period indicates that capacity levels were observed above 90% only 0.035% of the time (the longest period lasting only 12 minutes). The inlet only reached full capacity once during the study period - a 3 minute inundation (Figure 6). Infrequent and short durations of high utilized capacity within the monitoring station suggest that complete saturation of the bed was unlikely and that discharge water stayed below the surface level. Initial results suggest it takes approximately 4 hours for a load of clothes washing water to infiltrate in the bed, and about 2 hours for a 15 minute shower to infiltrate.

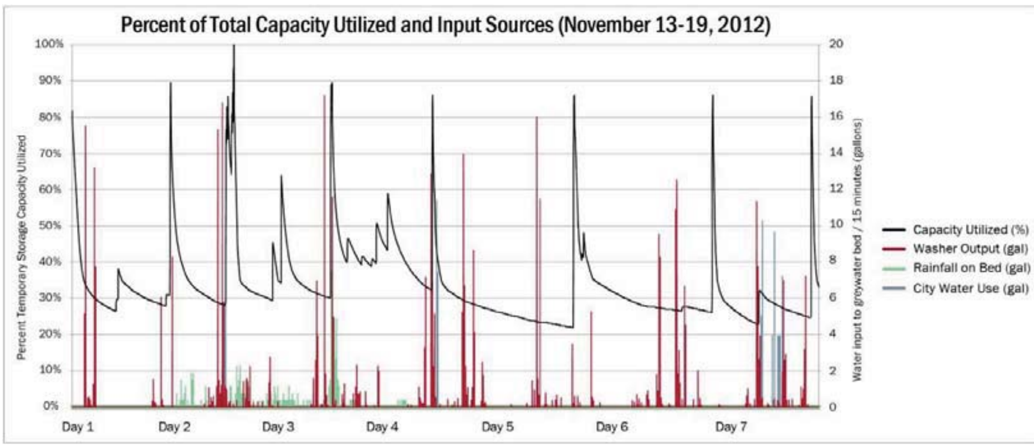

Figure 6: A seven day period of high saturation rates (including the highest level reach over the course of the initial six month study period). Heavy, red line indicates saturation percentage, which includes rainfall and greywater exiting the house and entering the bed.

3.2 Methodology

The team installed a simple monitoring system, three piezometers (monitoring wells) instrumented with atmospherically corrected pressure transducers, to collect data on water levels within the greywater bed. Data is used to determine the rate of water movement – either through infiltration and/or evapotranspiration. Values are recorded at 60 second intervals to a Campbell Scientific Datalogger, which is manually downloaded once per week. Observed measurements are returned in millivolts and converted to inches. Minimum millivolt values are first normalized using a static adjustment to establish a common bottom elevation to account for elevation differences between stations. A dimensional water level is determined by designating the minimum and maximum values of the inlet port station as 0” and 14”, respectfully, (derived from the dimensional height of a large-diameter, perforated piezometer, used as an inlet surge). A linear interpolation between the minimum (0”) and maximum value (14”) yields the height of sub-surface water within each piezometer.

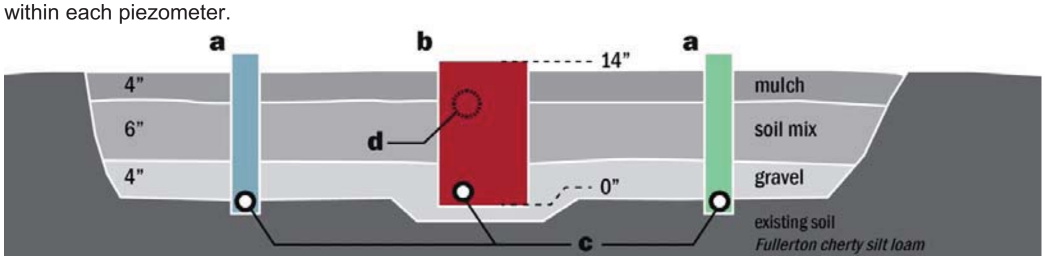

Figure 7: Diagrammatic section of greywater bed with monitoring piezometers (a) 4” piezometers; b) large diameter piezometer; c) pressure transducer; d) greywater inlet)

Holding capacity utilization is calculated [1] and allows analysis of the duration of potential saturations. These values are further informed by collected data measuring the volume of rainfall and estimated greywater discharge [4]. Observations and weekly logs note conditions such as the presence of standing water at the surface of the greywater bed, greywater seeping from the bed into adjacent landscape areas (neither condition has been observed to date), and the amount of organic matter in the large-diameter piezometer. Conditions are logged for submission to TDEC, per permit requirements.

Holding Capacity Utilization = Actual Greywater Held [2] / Potential Capacity [3] [1]
Actual Greywater Held (Volme) = Observerd water level in bed x bed area x porosity of each stratum [2]
Potential capacity (volume) = as-built dimensional volume of greywater bed x porosities of its strata [3]
Greywater (volume) = measured total water use - measured toilet use - estimated kitchen sink use[3] [4]

3.3 Design description and criteria

The design process began by testing the infiltration rate of the soil. The soil type on the project site is Fullerton cherty silt loam. The USDA classifies this soil type as “well drained” with a depth to a restrictive layer or the water table of more than 80.” An on-site infiltration test was performed by excavating a hole where the bio-retention bed was to be located. The hole was filled with water and an average infiltration rate of 0.2” per hour was observed. Though this rate is not considered “well drained” (in contrast to the site’s USDA soil survey), differing soil types are not uncommon. The bed is located away from existing surface water features, and in full sun.

Based on two residents and specification of low-flow fixtures, the team projected 40 gallons of the one-year return storm for this region ("Precipitation Frequency Data Server"). The greywater bed area was conservatively constructed at 7.5 (2.5 times larger accounting for an additional 83 gallons of rainfall from a 2.5” storm) times the required volume. Greywater is discharged to the bed via a 4” diameter PVC pipe that terminates into a perforated standard 5 gallon bucket that serves as a large diameter piezometer (see Figure 7). The 14’ long, 4.5’ wide, and 16” deep bed contains a 4” #57 gravel layer topped by an 8” layer of 20% sand 80% compost. The bed is top-dressed with an additional 4” layer of pine bark mulch. Greywater bed plants were chosen for their native status, ability to withstand frequent inundation, and support of microbes that aid in the decomposition of common greywater contaminants such as phosphates from soaps.[4] Resulting greywater bed holding capacity is projected at 300 gallons.

3.4 Lessons learned

Though greywater evaluation is ongoing, findings to date are promising. The system has operated without interruption, maintenance, or service for 1.5 years. Added difficulties arose by building into the steep slope of the site, but these concerns were mitigated using a permanent, vegetated retaining system and no adverse effects on performance have been shown (though cost did rise). The greywater system was easy to design and install, and operates largely independent of other water systems.

As with rainwater permits, the team worked with the Municipal Technical Advisory Service, the Norris Water Commission and city officials to revise city ordinances (written to be exclusive to the NNH research site). However, the main authority for greywater rested with the state (TDEC) Division of Water Pollution Control (WPC);a delegation visited the site and issued a State Operating Permit good for two years. The permit requires informational signage in the bed, an annual report summarizing the team’s inspection logs, suggested design revisions, and a maintenance manual. Future studies may include: exploration of shared systems that can process greywater from multiple homes; alternative methods for greywater delivery to and dispersal within the bed and the effects on saturation; and, refinement of regional plant recommendations.

4.0 STORMWATER MANAGEMENT

4.1 Objectives and achieved outcomes

Stormwater management objectives include utilizing treated rainwater for in-home use and hose bibb irrigation (see section 2.0), and on-site infiltration of untreated cistern-overflow rainwater. Combined, these practices manage 100 percent of stormwater generated from on-site impervious surfaces. Site stormwater management features are designed to integrate performance and aesthetic experience.

During the study period approximately 15,600 gallons of untreated cistern-overflow rainwater was infiltrated in four terraced infiltration beds—providing groundwater recharge and decreasing reliance on treated rainwater or city water for irrigation. A portion of the overflow rainwater was used to irrigate 105 ft^2 of raised vegetable beds, providing 100 percent of vegetable watering needs. Approximately 4,700 gallons of treated rainwater (66% of total irrigation water via hose bibbs) was used to establish 325ft^2 of drought tolerant native perennials and 2,070 ft^2 of native grass meadow (Figure 8).[5] Drought-tolerant plants and rainwater irrigation led to a 97 percent reduction from the average US home’s use of potable water for irrigation.[6]

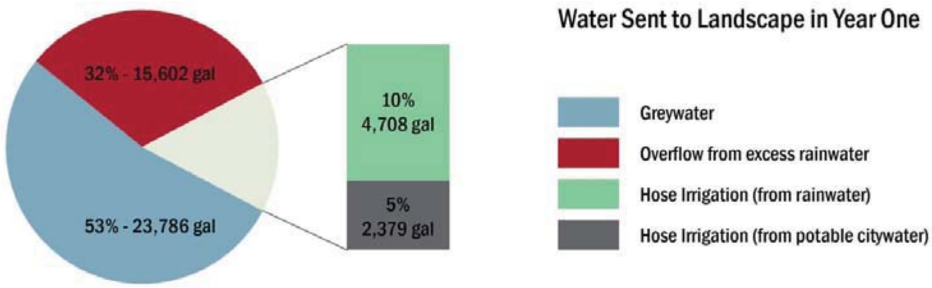

Figure 8: Water sent to landscape in year one. In the study period, a total of 39,388 gallons of greywater and cistern-overflow rainwater was infiltrated via the greywater treatment bed and 4 terraced infiltration beds. 7,087 gallons of water was drawn from hose bibbs for irrigation. 66 percent of water drawn for irrigation was provided from treated rainwater.

4.2 Methodology

Rainfall is measured with a Texas Electronics TR-5251 rain gauge and digitally recorded at 15-minute intervals with a Campbell Scientific Datalogger system. During the 12 month study period, 45.47" of rainwater fell on the site, resulting in approximately 25,000 gallons of rainwater harvested from the roof.[7] Of this, roughly 15,000 gallons overflowed as excess to terraced infiltration beds.

The resident records conditions during periods of both high intensity and high volume rain events. Observations included no overflow, seeping, or standing water in terraced infiltration beds during or after rain events, minimal on site sheet flow, and minimal sheet flow to adjacent properties. The terraced beds remain lush during drought periods and provide habitat for numerous birds and insect species.

4.3 Design description and criteria

The design of integrated on-site stormwater management features began with a pre-construction plan for the staging of construction equipment and materials. The previous/demolished home's footprint was used as a staging area, and later as the finished gravel parking court, reducing on-site soil compaction and maintaining undisturbed soil infiltration rates on the majority of the site. Excluding the roof area, the site is 99 percent pervious, which promotes quick on-site infiltration of stormwater.

Rain events generate excess water as 1) overflow rainwater from the cistern, and 2) as stormwater sheet flow from up-slope impervious surfaces. Overflow rainwater from the cistern is piped via an underground 4" diameter PVC pipe to a second 200 gallon sub-grade cistern located at the north end of the raised vegetable beds. Rainwater stored in this cistern is accessed with a hand pump for vegetable irrigation. Overflow from the second cistern is piped via an underground 4" diameter PVC pipe to a gravel forebay in the uppermost of four terraced infiltration beds. The forebay slows the velocity of the overflow rainwater before it enters the soil media; where it is evapotranspired by native plants or allowed to infiltrate. Infiltration bed plants were chosen for their drought tolerance, as well as their ability to thrive under frequent inundation.

The four lower beds (uppermost bed dedicated to greywater infiltration) provide level areas for infiltrating overflow rainwater on an existing 1:4 sloped site. Terraces are built from structural Geotextile bags filled with a sand/compost mixture and backfilled with an 80% mushroom compost and 20% sand soil mix. Each bed is approximately 14' long, 4.5' wide, and 16" deep. Water moves through the beds in a serpentine pattern following overflow channels and filling all beds for a combined holding capacity of approximately 930 gallons.[8] Stormwater sheet flow is intercepted by the perimeter native grass meadow—a "sponge" that slows the velocity of stormwater and provides deep root zones for infiltration. The meadow blend includes low-growing native grasses and perennials acting as the site's own greenbelt, a microcosm of the greenbelt that protects and recharges Norris's municipal water supply.[9]

4.4 Lessons learned

Due to the steeply sloped existing site, additional cost was incurred when terracing to create level infiltration beds. However, the beds are low maintenance, requiring little attention after establishment and no mowing. The beds are an ecological improvement over the pre-existing 1:4 sloped turf area and require less time and cost for general maintenance.

Rainwater irrigation and infiltration are permitted in TN, and the NNH practices could be implemented on other sites without additional regulatory oversight. Future studies may apply rainwater irrigation and infiltration at multiple single-family homes or multi-family units. Although Norris does not have a municipal stormwater sewer, rainwater infiltration practices such as those at NNH are particularly useful in areas with increasing demands on sewer and water treatment plants.

CONCLUSION

If one assumes the future of infrastructure (including water, energy, and food) will include decentralization and lower energy solutions pushed down to the level of the site, then society, at least in the US, has a long way to go toward implementation. Projects that combine education, research and community outreach, like the NNH, are effective vehicles for beginning those conversations. Such projects bring together crucial participation by all parties affected so that problems can be encountered, worked through, and resolved – and then disseminated. A NNH did not originate with the team its water goals required; rather, the process led the team to identify *who* needs to take part, *how* such a team can be assembled and organized, and *what* issues should be tackled first. While the NNH goals may be modest for parts of the US or world (the low hanging fruit") the reality in Tennessee demands demonstration projects that provide reliable data and that can lead to the regulatory changes that will make it not only permissible, but hopefully commonplace.

ACKNOWLEDGEMENTS

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ENDNOTES

[1] NNH Test List for EPA Primary, Secondary, and Non-Regulated Drinking Water Contaminants MCL*
Primary Contaminants: Ammonia (-),Cadmium (0.005 mg/L), Chlorine (4.0 mg/L), Copper (1.3 mg/L), E-Coli (0.05%**), Lead (0.015 mg/L), Glyphosate (0.7 mg/L), Nitrate (10.0 mg/L), Nitrite (.0 mg/L), Sodium (20.0 mg/L***), Total Coliform (0.05%**), Turbidity (5ntu)
Secondary Contaminants: Aluminum (0.05 - 0.2 mg/L), Iron (0.3 mg/L), pH (6.5 – 8.5), Sulfate (250 mg/L), Zinc (5 mg/L)
Non-Regulated Contaminants: Alkalinity, Calcium (Ca), Conductivity, Magnesium, (Mg), Potassium (K), Total Organic Carbon (TOC), Total Suspended Solids (TSS).
* The highest level of a contaminant that is allowed in drinking water.
** No more than 5.0% of samples positive in a month.
*** For individuals on a 500 mg/day restricted sodium diet

[2] For this study, greywater includes lightly used wastewater from the bathroom sink, shower, and washing machine, but excludes water from the kitchen sink and toilet (black water).

[3] An estimated value of 5.4 gal./capita/day was used as 50% of cited "Faucet" use per day. (Vickers 2001)

[4] Greywater bed plant list: *Iris virginica, Juncus effuses, Lobelia siphilitica, Saururus cernuus*
Infiltration bed plant list: *Baptisia australis, Conoclinium coelestinum, Helianthus angustifolia, Iris virginica, Liatris spicata, Monarda x media, Vernonia lettermanii* 'Iron Butterfly'.

[5] Native drought-tolerant perennial plants: *Amsonia hubrichtii, Baptisia australis, Coreopsis verticillata* 'Moonbeam'*, Echinacea pallida, Echinacea purpurea, Echinacea tennesseensis, Liatris microcephala, Liatris spicata, Porteranthus stipulates.*

Warm season grass and perennial meadow plants: *Andropogon ternarius, Andropogon virginicus, Aster laevis, Coreopsis verticillata* 'Moonbeam'*, Echinacea pallida, Echinacea tennesseensis, Elymus hystrix, Liatris spicata, Muhlenbergia capillaris, Panicum virgatum* 'Shenandoah'*, Rudbeckia fulgida* 'Goldsturm'*, Schizachyrium scoparium, Solidago rugosa* 'Fireworks'*, Sporobolus heterolepis.*
[6] The average US home's outdoor water use is defined as 100.8 gallons/capita/day. (Mayer 1999)
[7] Average yearly rainfall in the Tennessee Valley is 51" per year indicating that our study occurred in a relatively "dry" year. ("TVA: Rainfall in the Tennessee Valley")
[8] 930 gal. holding capacity is 64 percent of gal. generated by a 2.5" design storm including cistern overflow rainwater (1,375 gal.) and rainwater falling directly into beds (83 gal). A more common 1.5" rain event is held in the beds with 54 gallons to spare.
Equation used to generate gallons from rainfall inches: Area * (rain"/12) * 7.48 * .95 = gallons
[9] The Norris Town Plan incorporates elements of the Garden City Movement, including a greenbelt. (Ezzell 2010)