CIVIL&ENVIRONMENTALENGINEERING
COLORADO SCHOOL OF MINES

CEEN 471: Water Systems Analysis Design
Department of Environmental Engineering
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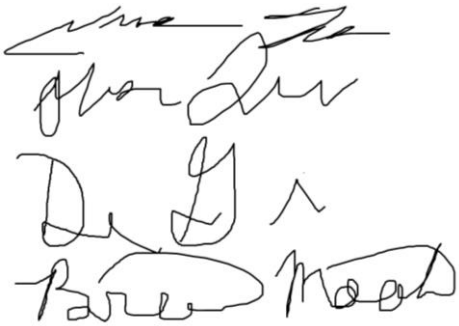
MEMORANDUM

Date: March 3, 2020
To: Dr. Christopher Bellona and Kate Newhart
From: Devon Gibson, Breanna Moak, Nicolas Tsao, Shea Zeman
Subject: City of Golden Graywater Reuse



Executive Summary:

Since meeting with Theresa Worsham, the team's scope of work has changed significantly to focus specifically on Laundry-to-Landscape graywater reuse in single family homes. The City of Golden hopes that starting here would provide a simple starting point for citizens to understand the importance of graywater reuse and what it is. Therefore, the team will be investigating the use of Laundry-to-Landscape graywater reuse for the City of Golden. This will include neighborhood mapping for the purposes of installation, water use, and water conservation. The team will utilize online resources from the City of Golden to quantify water use during both irrigation and non-irrigation seasons throughout the city's neighborhoods. This information will then be analyzed to determine the effectiveness of graywater reuse systems and how much water can be conserved. The city is also developing a resiliency plan to prepare for a time where Golden's climate may be substantially warmer and drier than it is today, and graywater reuse may be a part of that plan.

Introduction/ Background:

The team's goals and scope of work have changed, since meeting with the City of Golden. Now, instead of looking into various options when considering the implementation of graywater systems in a single-family household, the team will be focused specifically on Laundry-to-Landscape systems in single-family households. The goal of starting on Laundry-to-Landscape systems is to start simple. Starting simply makes it easier to convey complex information to the citizens of Golden before projects become more complex, expand to other graywater systems and larger, multi-family households.

Although these changes for the scope of work and goals for the team have occurred, the research done on Regulation 84 and 86 as well as the area of interest, are still relevant to the project. Since the scale has shifted to something smaller, the team will be focused on a small group of volunteers that have allowed the city to test Laundry-to-Landscape pilot systems on their property. With this, the team will now be able to understand how much money and water each household could possibly save by using a gray water system, as well as any potential problems that may occur when implementing gray water reuse.

A Laundry-to-Landscape system is a system that routes wastewater from laundry machines and laundry sinks to the landscape outside. It is the simplest, least expensive, and lowest effort way to get the most graywater out onto the home landscape most effectively [5]. It utilizes power directly from the laundry machines in order to minimize installation of additional pumps required to move the water larger distances or even vertically upwards. The system also requires little excavation of the landscape in order to install the system, as the piping just needs to route the water directly to the desired garden area or landscape.

According to Oasis Design, “the washer itself pumps water a large distance horizontally, or a short distance vertically” [1]. In addition, if the laundry machine is on an incline above the landscape, gravity can be utilized to further reduce energy usage. Without a pump, the system should be able to irrigate any distance downhill or pump up to an elevation 2 feet below the top of the washer 100 feet away. It is recommended by Oasis Design that a height differential of less than 6 feet should be used when using a Laundry-to-Landscape system and a pipe diameter of 1 inch or larger should be used to reduce resistance [1].

Installing this system is quite simple as well. Since the system can utilize power directly from the laundry machine itself, there can be a direct installation of a separate flow pipe from the laundry machine. The installation of piping throughout the landscape is also simple, as it requires little to no excavation of the lawn and can be easily routed around a garden or lawn.

Colorado Regulation 86 and the draft of the City of Golden’s graywater plans restrict the type of irrigation that can be used while a graywater reuse system is present [2,3]. Spray systems have the potential to spread unwanted pathogens and contaminate nearby rivers or lakes. Untreated graywater cannot be stored because pathogens can become more dangerous. System stagnation could cause the graywater to quickly degrade and become a health hazard [4]. In addition, root plants such as carrots, beets, and potatoes cannot be watered using this system as the water can contain harmful organic material. It is recommended that purple pipes be used to determine which pipes are flowing with graywater as well as the installation of a three-way diverter to divert laundry water to the landscape or sewer so that the system will not freeze in the winter [4].

With all this information, the City of Golden also requested that the team complete analysis using population data to predict potential economic and water savings if the entire city (just single-family homes to start) were to switch to this system. That way, the city could continue to gauge the system's effectiveness and determine if a long-term investment into this project would be worth the effort. As mentioned by the City of Golden, a group of three volunteers have lent the city their homes for pilot testing of Laundry-to-Landscape systems. As the project moves forward, these pilot systems should further solidify previous predictive analyses and confirm or deny the results.

Procedures:

1. Neighborhood Mapping - The City of Golden consists of a wide variety of different home developments. While some neighborhoods are historic or older developments, there are also newer developments with low flow fixtures and newer piping systems. Due to this, there is a large difference between water usage in different households. In order to account for this within water usage calculations, the team will divide the different city neighborhoods based on home size and characteristics. For example, neighborhoods with larger homes will tend to use more water than those with smaller homes. The irrigation requirements per neighborhood and per household will vary across the city.
2. Average Water Use- The city supplied data from their Water Conservation Website that included hot spots for water use in the City of Golden. The data will be applied to areas that are composed of single-family homes to determine the average water use per household. From this data the team will determine how much water can be saved through the implementation of laundry to landscape graywater systems. Summer and Winter seasons will be classified by irrigation amounts. This will also be considered when determining how effective gray water reuse is.

Results and Discussion:

The City of Golden maintains a Water Conservation and Efficiency website which contains an ArcGIS site map which detail Golden's water consumption. One of these maps includes seasonal water consumption breaking down the City of Golden into hexagonal grids and tracking consumption in irrigation and non-irrigation seasons [6]. The data for this can be found in Appendix A. While water consumption varies greatly between each gridded section, the average consumption during the irrigation season 383.3 gallons/day/unit (standard deviation of 139.1) while during non-irrigation season average water consumption is 130.7 gallons/day/unit (standard deviation of 24.6). The difference in water usage between irrigation and non-irrigation seasons can be seen in **Figure 1.** Data from this site indicates to the team that implementation of Laundry-to-Landscape irrigation will be particularly useful for reducing water consumption for homes whose water consumption increases significantly during irrigation season, such as grid area A-1 whose consumption increases 490.8 gallons/day/unit during irrigation season.

From the neighborhood mapping we were able to determine the areas in Golden that are mostly composed of single-family homes. From the data we were given from the City of Golden we were able to determine the average use in the different areas.

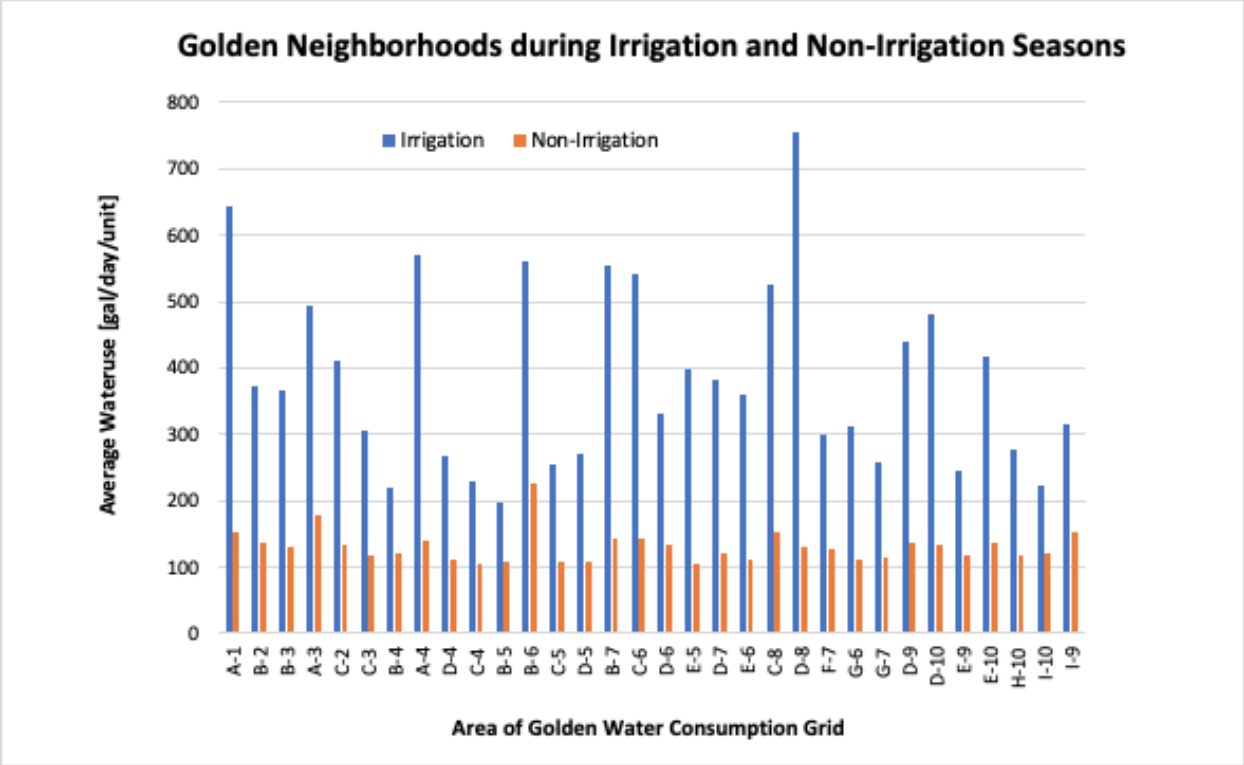


Figure 1: *Golden Neighborhoods' Average Water Use in gal/day/unit during different seasons*

Conclusions:

From the numbers provided by the City of Golden, a specified value of water savings could not be found due to lack of information on where the water comes from. The water data gave highly specific values on water usage without labels on which homes would be relevant for graywater reuse. From this, only a statistical analysis could be done using **Figure 1**. After analyzing the data from Golden's Water Conservation data by area, the average water use was determined. The data in Figure 1 compared peak irrigation season to non-irrigation season data showing significant changes in water use during each season. The Laundry-to-Landscape philosophy hopes to save more water during peak irrigation season in Golden, Colorado and therefore reduce water use and water strain on the city. However, during the non-irrigation season and low temperatures, the drip irrigation systems will have little to no functionality and will not allow for much reuse during that season.

Next Steps:

The team has a meeting scheduled with Theresa Worsham on March 11, 2020 to obtain more information and to decide the course of the project going forward. The team will then discuss

what they have done with the data that has been provided and what information they would like to obtain to continue to meet the goals of the project.

Until then, the team will continue analyzing the water use of the volunteer households that are interested in graywater reuse to determine the magnitude of water savings the average home in Golden could see with graywater implementation. This information will be essential in creating a comprehensive document for the future distribution of a Graywater Guide for the City of Golden.

References:

[1] "Greywater Reuse - Greywater Action", *Greywater Action*, 2020. [Online]. Available: https://greywateraction.org/greywater-reuse [Accessed: 22- Jan- 2020].

[2] "Water Conservation | City of Golden, Colorado", *Cityofgolden.net*, 2020. [Online]. Available: https://www.cityofgolden.net/live/sustainability-initiative/water-conservation/ [Accessed: 22- Jan- 2020].

[3] *GRAYWATER CONTROL REGULATION REGULATION #86*. COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT, 2020

[4] Barnes, D., "Greywater Guidelines," *Permaculture Reflections*, 18-Nov-2008. [Online]. Available: https://www.permaculturereflections.com/greywater-guidelines/. [Accessed: 21-Feb-2020].

[5] Ludwig, A., "Laundry to Landscape Grey Water System," *Laundry to Landscape Original Complete Information Hub*. [Online]. Available: http://oasisdesign.net/greywater/laundry. [Accessed: 28-Feb-2020].

[6] *cityofgolden.maps.arcgis.com*. [Online]. Available: https://cityofgolden.maps.arcgis.com/apps/Cascade/index.html?appid=21a50e388cba45b2b6571980867a89d4. [Accessed: 25-Feb-2020].

Appendix A: Irrigation and Non-Irrigation Water Consumption Data

Table 1: *Irrigation Season Water Consumption for the City of Golden*

ArcGIS Grid ID	Number of Homes	Average gal/day/unit
A-1	34	643.892
B-2	150	371.94
B-3	334	365.664
A-3	111	492.806
C-2	8	411.442
C-3	250	307.002
B-4	213	219.772
A-4	99	568.953
D-4	73	268.316
C-4	238	229.721
B-5	190	195.719
B-6	47	561.638
C-5	88	252.992
D-5	49	270.097
B-7	150	554.886
C-6	93	540.354
D-6	291	329.85
E-5	69	397.836
D-7	77	382.459
E-6	137	359.647
C-8	75	525.478
D-8	19	754.119
F-7	82	297.48
G-6	115	312.493
G-7	74	257.934
D-9	248	438.327
D-10	174	480.538

E-9	137	245.542
E-10	57	417.083
H-10	190	276.009
I-10	68	222.409
I-9	40	313.925

Table 2: *Non-Irrigation Season Water Consumption for the City of Golden*

ArcGIS Grid ID	Number of Homes	Average gal/day/unit
A-1	33	153.043
B-2	150	136.2
B-3	332	129.539
A-3	111	177.598
C-2	8	133.281
C-3	249	116.504
B-4	215	121.312
A-4	99	140.265
D-4	72	111.574
C-4	241	104.132
B-5	195	107.573
B-6	48	227.25
C-5	88	107.568
D-5	47	108.826
B-7	150	141.561
C-6	93	144.067
D-6	282	132.63
E-5	69	103.813
D-7	69	120.642
E-6	140	112.34
C-8	75	152.707
D-8	19	131.542

F-7	81	125.518
G-6	116	111.291
G-7	74	114.977
D-9	250	137.191
D-10	178	131.622
E-9	135	117.016
E-10	57	137.428
H-10	190	117.346
I-10	67	121.291
I-9	40	153.316