Final Grant Report
July 18, 2019
Colorado Water Plan Grant / Education and Innovation
The Greenway Foundation – Grantee
Grant Project Name: Clean River Design Challenge (2018-2019)
POGG1,PDAA,201900002072

Summary of project:

Overall, we are extremely pleased with this year's Clean River Design Challenge. It was a success from every angle. The competition, which represents Task 1 of this grant, has been completed in full. Task 2 will be addressed in the "challenges" section.

The Clean River Design Challenge (CRDC) develops innovative solutions to address trash in Denver's urban waterways. This two-part competition invites university students to design trash removal devices for placement in a Denver waterway. The 2018 – 2019 competition was focused on the South Platte River at its confluence with Cherry Creek, with a specific problematic location identified in front of the REI building at the former irrigation ditch (abandoned). This year's competition had 5 teams compete in Round 1, and 4 teams complete Round 2. Student teams represented three area universities: Metro State University, Colorado School of Mines, and University of Denver.

The CRDC is divided into two rounds, each culminating with design presentations to a panel of expert judges. In the first round, students created detailed plans for their trash removal device, and in the second round, scale models of the devices are built and tested on a flume. To aid in the design process, TGF connected the teams with professionals from engineering, public health, environmental, and regulatory agencies that were available for consultation throughout the competition.

Each of the five (5) student teams presented an innovative design/concept at the Round 1 Judging Presentation on December 6th, 2018 held at Industry, RiNo. Presenting were:

- Two (2) engineering teams from Colorado School of Mines
- Two (2) industrial design teams from Metropolitan State University of Denver
- One (1) engineering team from University of Denver.

We were pleased that we were able to renew our partnership with the US Bureau of Reclamation (BOR) for the Spring 2019 Round 2 testing. The BOR provided us with professional staff time and expertise, as well as use of the BOR Hydraulics lab for testing the student models. The opportunity to test models in this facility and interact with BOR staff was truly a tremendous experience for the students and provided an interesting story location for media.

At the time of the grant application, TGF intended to pursue the implementation of the winning trash removal device designed through this competition if it showed significant potential for real-world success. Due to a number of factors, we are not able to move forward with this Task, and have requested that the funding intended for this work be reallocated to cover staff time spent by TGF staff above the budgeted amount. A full explanation of these hurdles is provided later in this report.

PLEASE SEE this link to Google Drive Folder for all grant report attachments:
https://drive.google.com/open?id=1ntWT3VZoZ1hBpYMDDWOa1O-b8nGlxpBa

- ❒ **Number of students involved:** 5 teams, 37 students. A list of students and professionals who have and are participating in this competition is attached to this report. This list is 100% complete.
- ❒ **Number of professionals involved:** 14
- ❒ **Media:** See link to Channel 4 story . In addition, 8,000 metro residents reached through TGF communications (pdf attached). Social media posting pdf also attached.
- ❒ **Photos of events**: see Google Drive link to photo album
- ❒ **Designs and Models produced**: 5 concept designs; 4 working models.
- ❒ **Survey results:** Members of all teams were required to take a pre-knowledge survey. The task of mapping changing awareness and knowledge of the issue is 100% complete. Survey results are attached.
- ❒ **Design for implementable device:** Attached are winning design documents for the First Place winner. Other teams' design documents are available upon request.
- ❒ **Judging forms with criteria** (An example is included with this report. A full set of forms completed by the judges are available upon request.)
- ❒ **Invitations** to attend Round 1 and Round 2 judging of student designs – attached

A tally of staff time and expenses showing complete expenditure of grant and match funding is attached to this report.

Obstacles / Challenges

Obstacles encountered during this project fall into two categories: 1) Competition obstacle – BOR facility and 2) Implementation hurdles.

1) The US Bureau of Reclamation has been a tremendous partner for 2 years of this competition and we are grateful for their engagement, particularly the work of staff. We have discovered, however, that the process for obtaining approval for use of the facility and staff time is too difficult and is on a schedule that is not in line with the competition schedule, which is based on the academic year. We were not able to obtain a commitment from BOR for use of the facility for testing until January 2019, after a great deal of effort on our part, and we really

needed it months prior since the competition began in August. If the answer had been "no" at that time we would have been in a bind. Additionally, the BOR operates as a fee for service organization, and since we are not able to fund the required facility cost, the BOR needed to find community outreach or other funding for this event. Given the schedule and approval process complexities, we are not planning to use the BOR lab for future competitions.

2) As we created the CRDC, our full intent was to create a prototype of the winning design each year and test the prototype on a "pilot" basis. We have learned through the process that this is not possible within the City and County of Denver. We have been working since 2016 to build, install and test the winning design of the first CRDC competition. The design is called the Nautilus. We were able to obtain pro bono engineering work for that design, and the same engineer built a half-scale prototype. However, the process stalled at the installation phase, as we learned that we could not install anything in the waterway on a "pilot" basis. With a substantial amount of help from the Urban Drainage and Flood Control District, we are working our way through the Denver permit process for the installation and testing of the Nautilus. We hope to have it in Cherry Creek by August. Given the robust permitting hurdles for installing a device in a waterway, and given the fact that the engineer who helped with year one's design is not available for additional work at this time, and even if we proceeded with further design on a device we would not be able to test it in a feasible manner, we are not moving forward with the implementation of this year's winning design as originally envision at the outset of this grant and as articulated in Task 2.

   We ask that the funding provided for implementation of the winning design be reallocated to staff time for running the competition which has exceeded the hours funded through this grant funding plus the match.

Fulfillment of Matching

Running a competition with three universities, and coordinating with a federal agency, has required staff hours in excess of the budgeted amount of both the grant funding and match funding combined. Committed match money has been contributed and spent in full toward staff costs and competition expenses. A tally is included as an attachment.

Sincere thanks from The Water Connection / The Greenway Foundation for your support of this project. Please do not hesitate to contact us if you have any questions or need further information.

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Channel 4	Jeff Todd
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Channel 7 News	Sean McGarvy
Denver Post	John Wenzel
Denver Post	Dylan Owens
Colorado Public Television	Marci Cox
Colorado Public Televison	Szymon Kubica
Denver Business Journal	Cathy Proctor
Denver Business Journal	Kathleen Lavine
One World One Water Center	Nona Shipman
H2O Radio	Frani Halperin
FreshWater News (WECo)	Jerd Smith
MSU Metropolitain	Tim Carroll, Director of Media Relations
DU Sustainability Coordinator	Chad King, Ph. D
Colorado School of Mines	Emilie Rusch

MEDIA ADVISORY

For Immediate Release

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Clean River Design Challenge Device Testing Day

Students test innovative solutions to urban waterway trash problem.

(April 15, 2019)--Denver, CO--The Greenway Foundation (TGF) is excited to announce the testing day for the third iteration of the Clean River Design Challenge. This year, TGF has engaged undergraduate teams to design a device to remove trash from the section of the South Platte River just upstream of the Confluence with Cherry Creek.

Students from three local universities spent the first semester of the 2018-2019 school year developing preliminary designs. Now, their designs have come to life. The student teams will be testing scaled prototypes, built during their second semester, in a hydraulic lab flume that simulates waterway conditions. A winning design will be selected and a prototype of that design will be slated for future implementation.

WHAT: Clean River Design Challenge testing and judging. Lunch and coffee will be provided!
PARTICIPANTS: Student teams from Metropolitan State University of Denver, Colorado School of Mines, and University of Denver. A panel of judges from various relevant sectors will be present to give feedback, present challenges, and select the winner of the 2019 Clean River Design Challenge.
WHEN: April 18, 2019 9 am – 2 pm. Winners announced at 2:30 pm

LOCATION: Denver Federal Center Reclamation
U.S. Bureau of Reclamation Hydraulics Lab, Building 56
Denver, CO 80215
Visitor parking is available north of the building. People attending will need a valid US Government issued ID to enter the campus and the lab. We advise wearing closed toed shoes.

WHY: Despite the significant evolution in the health of the South Platte River, trash and other forms of pollution continue to be an ongoing challenge to the River. The Water Connection, TGF's water resources and policy arm, is working towards a comprehensive solution. The long term aim for this competition is to take the winning design and create a prototype to pilot in an urban waterway. This potential future device would be just one tool to achieve the goal of trash reduction in Denver urban waterways.

ABOUT THE GREENWAY FOUNDATION: The Greenway Foundation (TGF) is a local, environmental non-profit that has been dedicated to our urban waterways for the last 40+ years. TGF has been involved with the creation of new riverside parks and trails, has an extensive outdoor education program for kids and teens, and hosts community and volunteer events. The Water Connection, the water resources and policy arm of TGF, focuses on fostering civic action and technological innovation for resilient Colorado watersheds.

# # #

Professionals	Organization
Brian Murphy	Otak
James Hinds	Otak
Jordan Parman	South Metro Water Supply Authority
Barbara Biggs	Roxborough Water and Sanitation District
David Bennets	Flood Control District
Jason Stawski	Flood Control District
Steve Materkowski	Flood Control District
Jay Nanninga	United States Department of Commerce, National Institute of Standards and Technology
William Battaglin	U.S. Geological Survey
Jon Bridges	South Platte Renewal Partners
Ben Wade	Colorado Water Conservation Board
Christopher Shupe	U.S. Bureau of Reclamation
Kent Walker	U.S. Bureau of Reclamation
Devon Buckels	The Water Connection
Lauren Berent	The Greenway Foundation

2018-2019 Clean River Design Challenge Previous Knowledge Survey

Have you heard about The Greenway Foundation/The Water Connection before this competition?

__ Yes

__ No

Have you ever personally experienced trash in or around an urban waterway?

__ Yes

__ No

What do you think are the most common types of trash found in and around urban waterways Denver? (list as many types as you would like)

____

____

What do think the primary method for removing trash from in or around urban waterways in Denver?

____

Who do think is responsible for removing trash from in and around urban waterways in Denver?

____

What type of impact do you think trash has on the environmental health of urban waterways? (circle one number)

None		Minor Impact		Major Impact
1	2	3	4	5

What type of impact do you think trash has on the flow of urban waterways? (circle one number)

None		Minor Impact		Major Impact
1	2	3	4	5

2018-2019 Clean River Design Challenge Post Knowledge Survey

Q1: Did you/your team ever go down to the competition site?

__ Yes __ No

Q2: If you answered “Yes” to Q1, what types of trash did you see? (list as many types as you would like)

____

____

____

Q3: Have your thoughts changed about who is responsible for removing trash from in and around urban waterways in Denver? Briefly explain.

____

____

____

Q4: Now that you have been working on this project for two semesters, list/describe what you think the biggest barriers are to removing trash from our urban waterways? Continue on back if needed.

____

____

____

____

Q5: What type of impact do you think trash has on the environmental health of urban waterways? (circle one number)

None		Minor Impact		Major Impact
1	2	3	4	5

Q6: What type of impact do you think trash has on the flow of water in urban waterways? (circle one number)

None		Minor Impact		Major Impact
1	2	3	4	5

Team Black-Crowned Night Herons

The Water Connection and the Greenway Foundation

2019 Clean River Design Challenge

Metropolitan State University
Denver
School of industrial design

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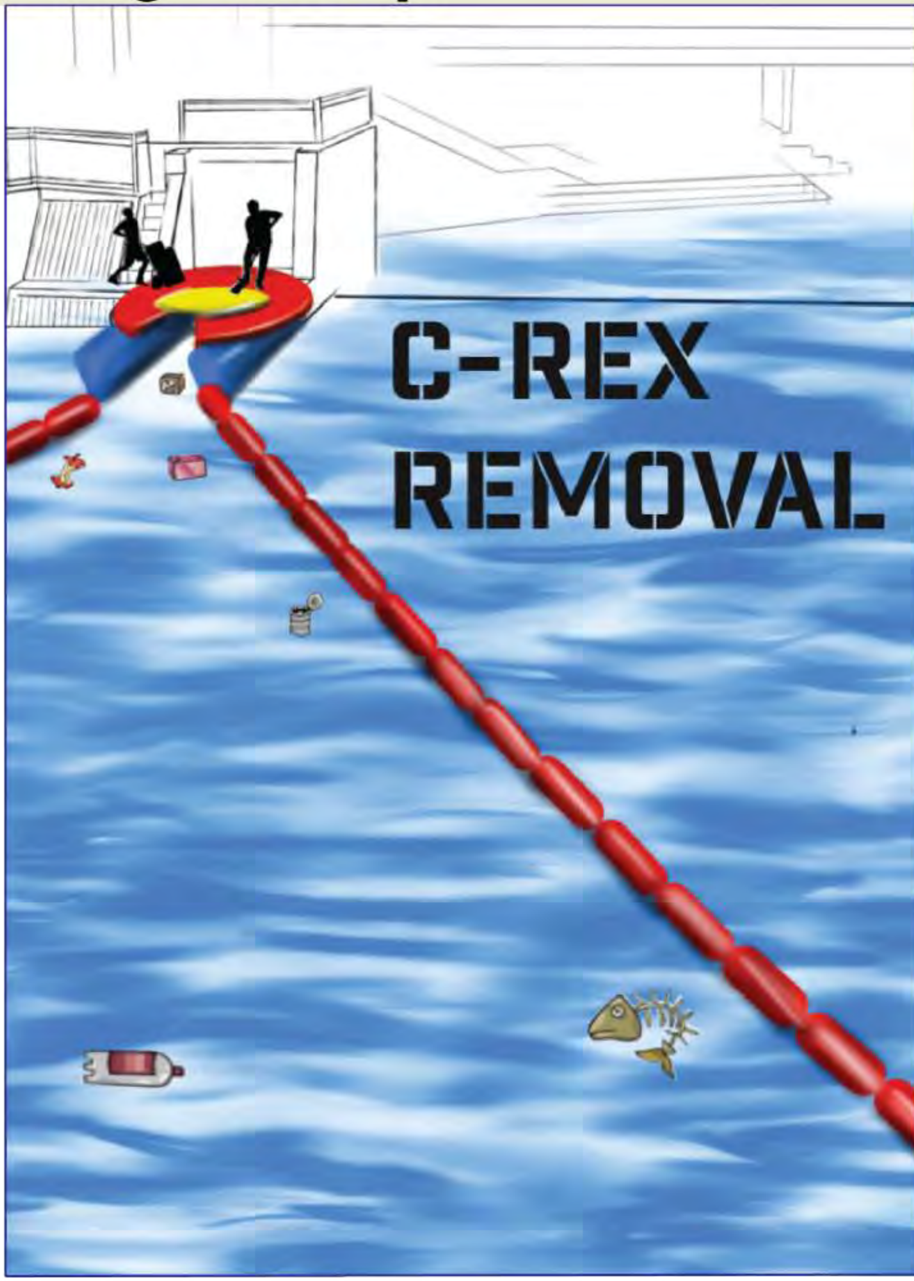
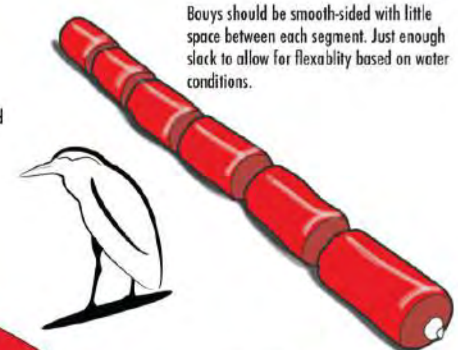
Design Concept

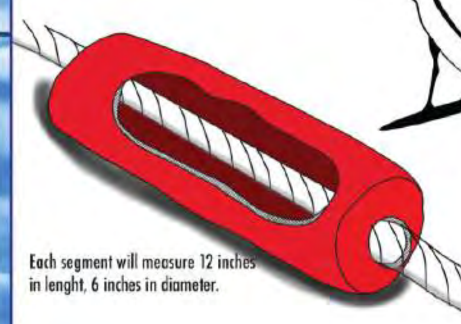


Diversion

Phase #1- Consists of two runs of roto-molded buoys that will run the length of the site. Held together with a heavy poly-nylon line, these lines are meant to float on the surface, and guide trash/debris to the "C-Rex". Durable and inexpensive.

Bouys should be smooth-sided with little space between each segment. Just enough slack to allow for flexablity based on water conditions.





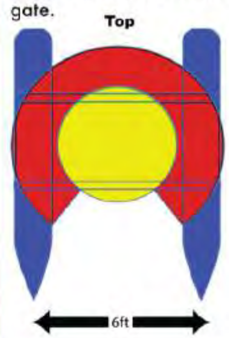
Each segment will measure 12 inches in lenght, 6 inches in diameter.

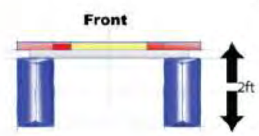
Collection

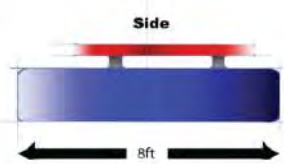
Phase #2- Once the trash/debris has been pushed inbetween the pontoons of the "C-REX", the high walls of each pontoon will keep trash/debris in place until there is enough water flow to push it over the threshhold of the lowered head-gate.

Made from roto-molded polyethylene plastic, the hollow body will float with very little maintenance.

The flag was a colorful and iconic choice, but the top surface can be used to market different messaging.







Alternate Tops

Form Development Buoys

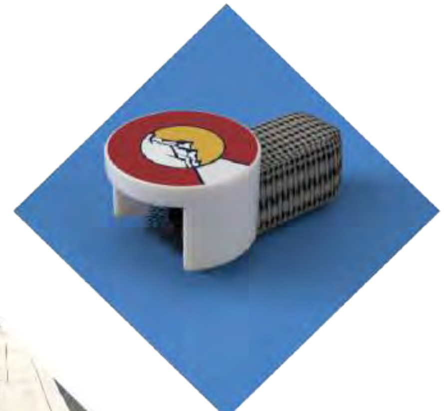
Tested all buoy ideations for diversion

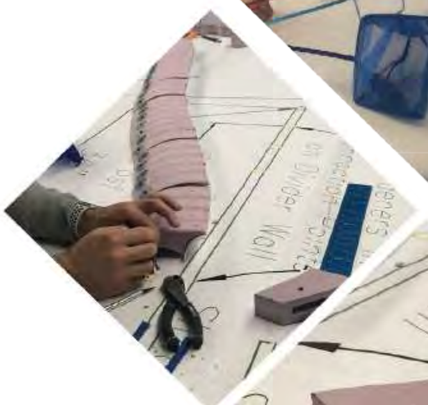
3D printed and lathed spiral buoys and round buoys

3D Printed and CNC Machined buoy form and tested for diversion

Form Development C-Rex

Tested collection net with multiple materials and sizes

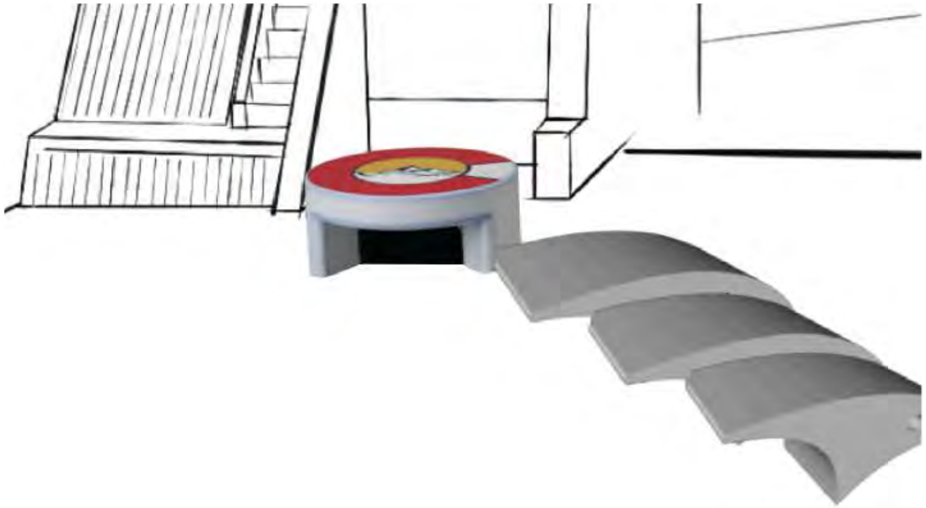


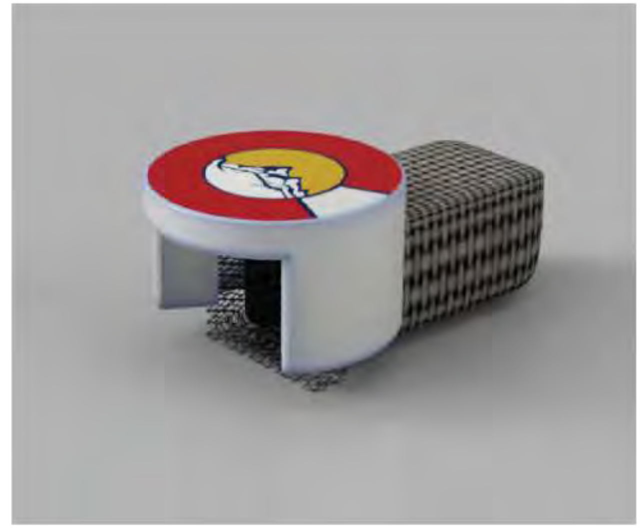


Printed the flume to real scale to solve buoy attachments

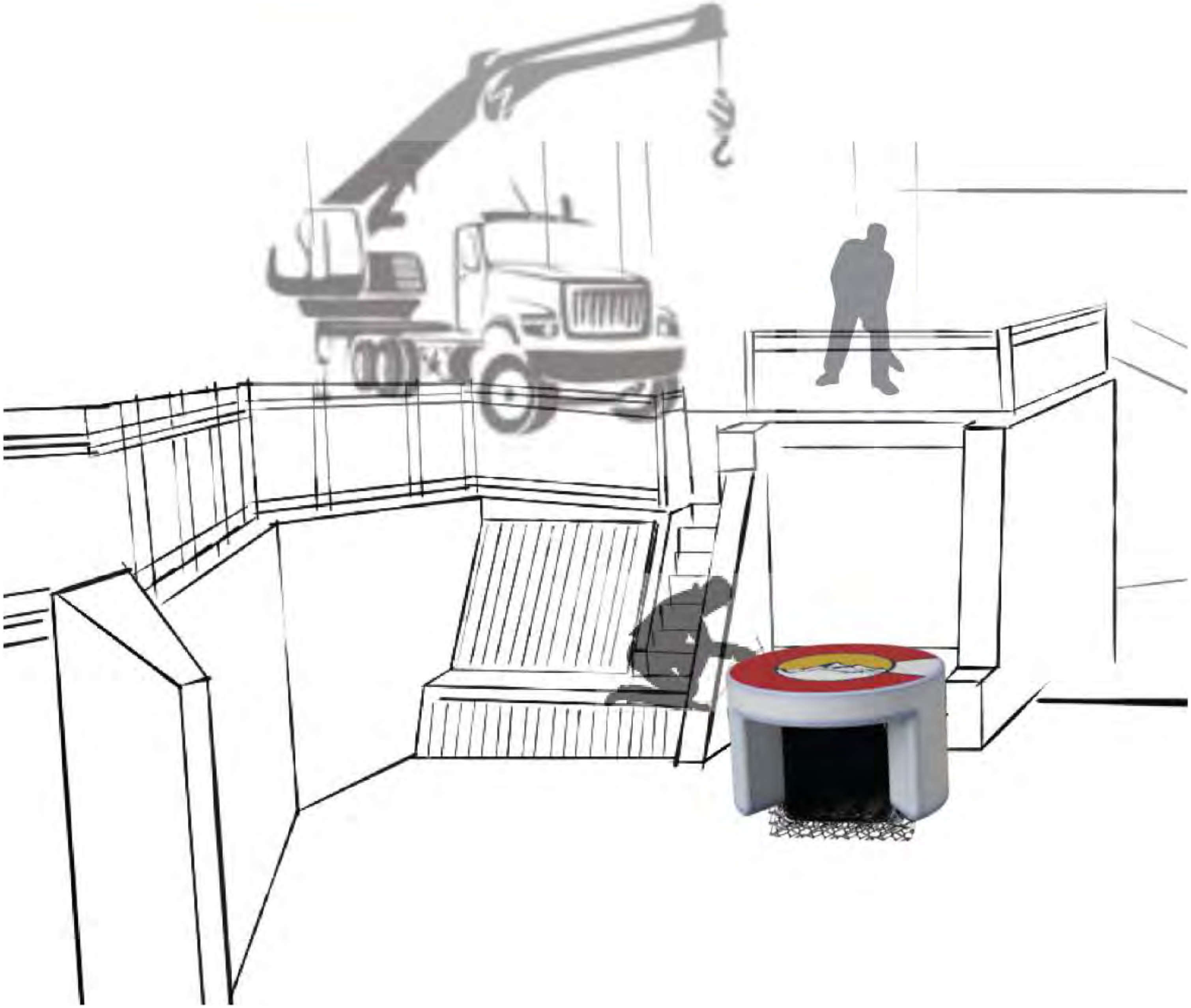
3D Printed internal catch for collection net. Molded form for C-Rex.

System Configuration

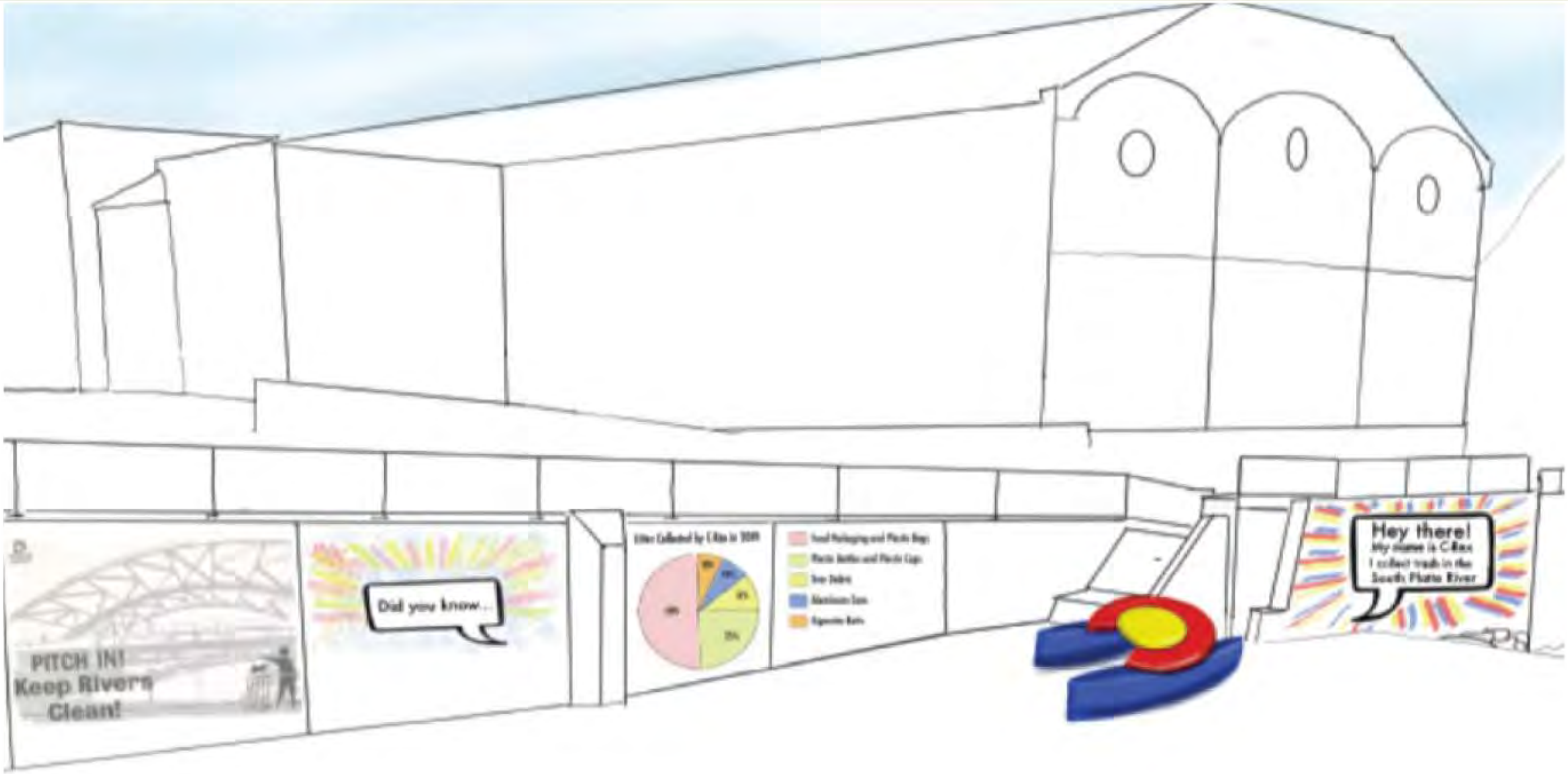




Trash Removal



Public Awareness



We wanted to use the available wall space to highlight current statistics about the pollution problems facing our river systems. We feel that any dollars spent on public education of this issues will result in the greatest improvement in this stretch of water.

Budget

C-REX REMOVAL SYSTEM for 1-10 units			
ITEM	Component	Quantity	Cost
C-REX			
	HDPE 80c/lb x 70		$56.00
	Addiditives: UV		$75.00
	Aluminum square tube frame 4" X 4"	1 set	$1,000.00
Cable			
	Braided Stainless Steel 1" Diameter $14/ ft	200 feet	$2,800.00
	Hardware and pulleys	tbd	$2,800.00
Buoys			
	HDPE 80c/lb x 70	32	$1,792.00
	Addiditives: UV	2	$75.00
	Hardware	tbd	$2,500.00
Crane/ Truck			
	Rental	1	
Installation			
	TBD	1	TBD
Total Cost			$11,098.00

BLAU

Vlad Keeper
Makinzie Vogel
Tucker McKinzie
Tyler Hallman
John Francis Nutter
Tom Witteveen
Chris Ng
Justin Smith
Ian Jakubiak

Confluence Park Trash Collection Project

Initial Observations

Debris gathering at fixed objects
Trash from storm drains
Natural debris
Variable sediment elevations
Use of existing structures

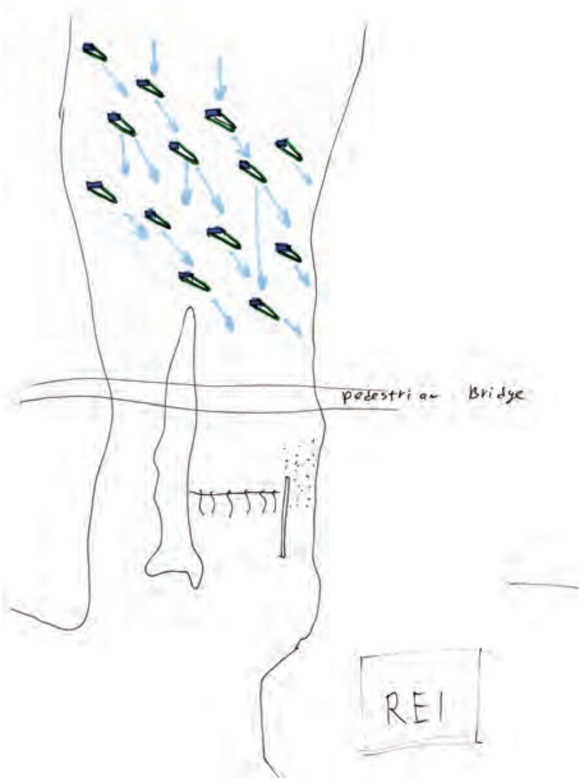
Challenges

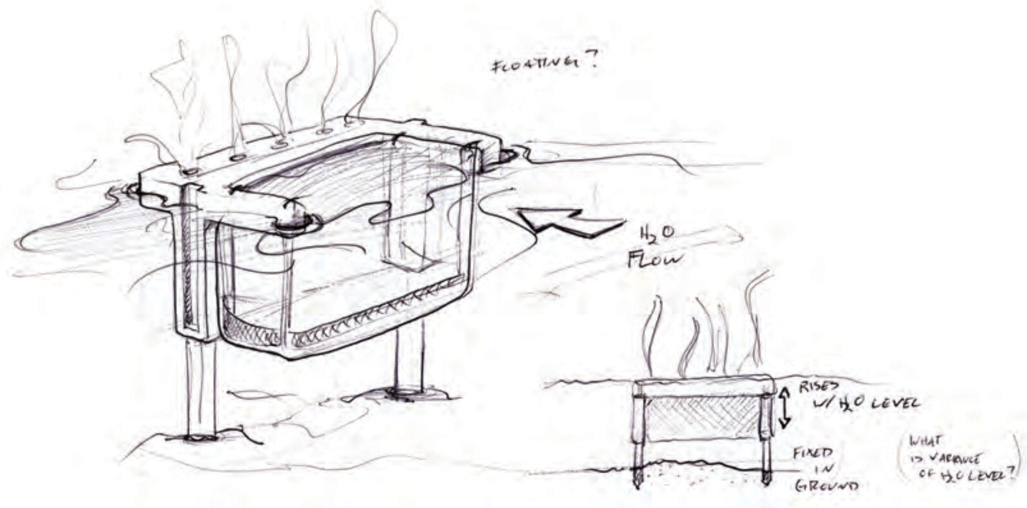
Limited power or none
Use of natural forces
High flow to low flow
Natural debris and trash
Trash Removable
Minimizing human labor

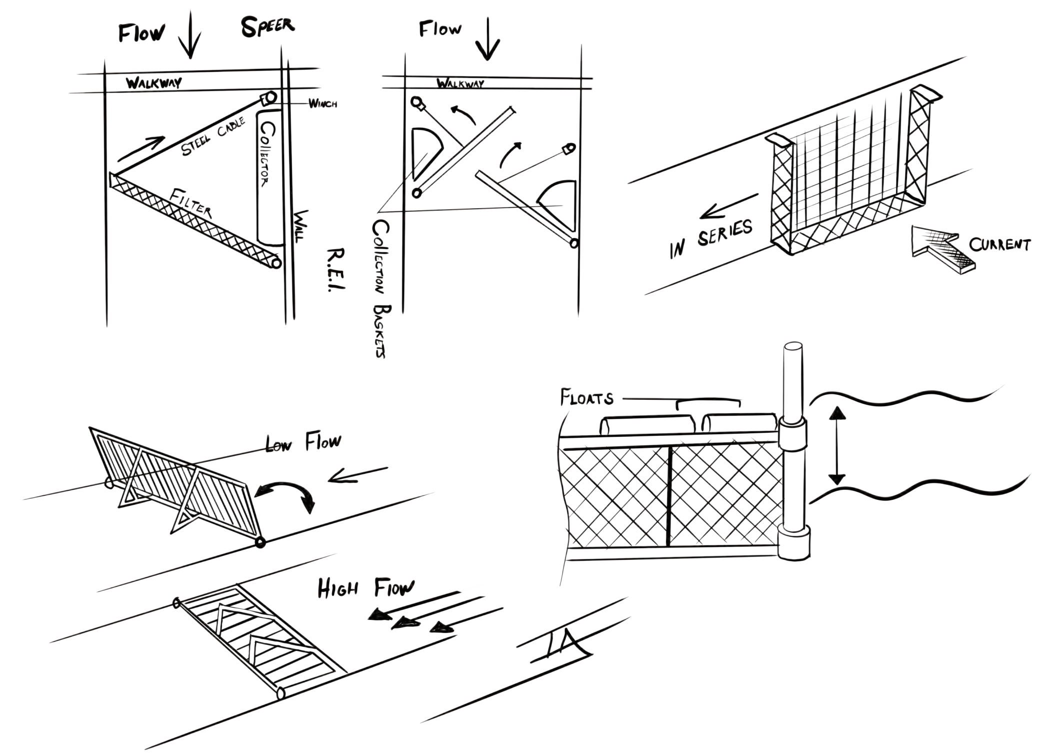
Design Direction

Raising Awareness
- Visually present
- A call to action

Versatility
Integrative
Inexpensive to high-end
Holistic system

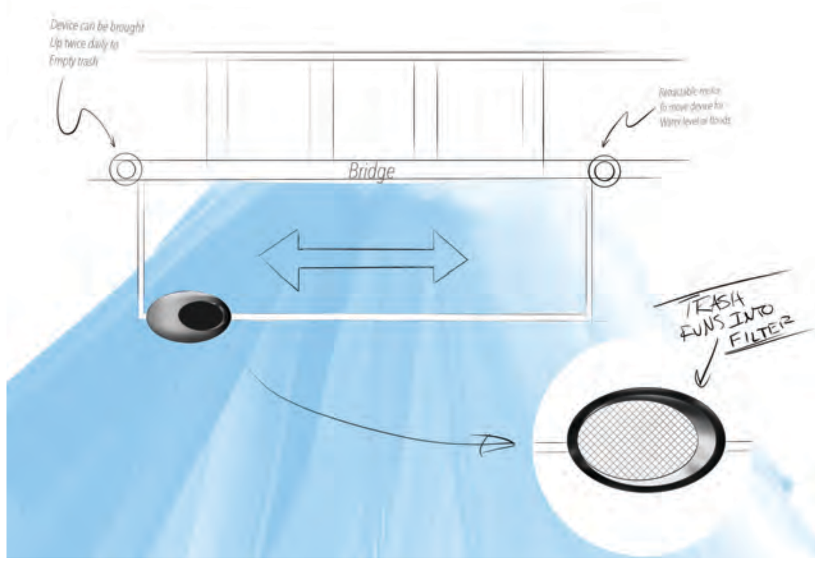


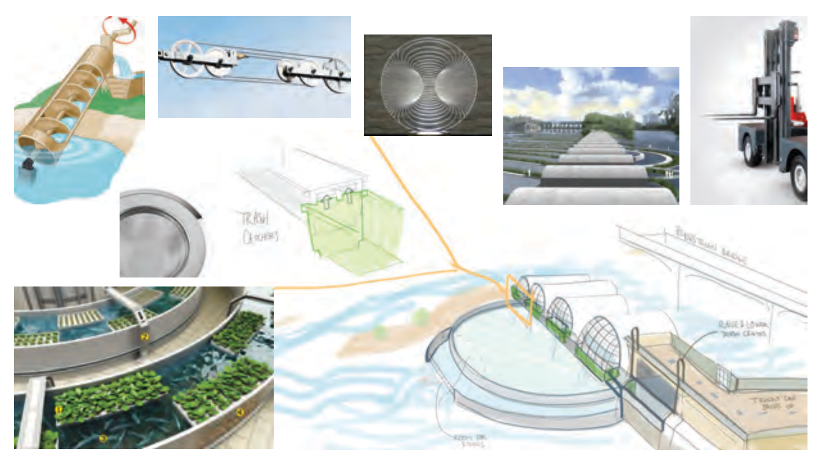


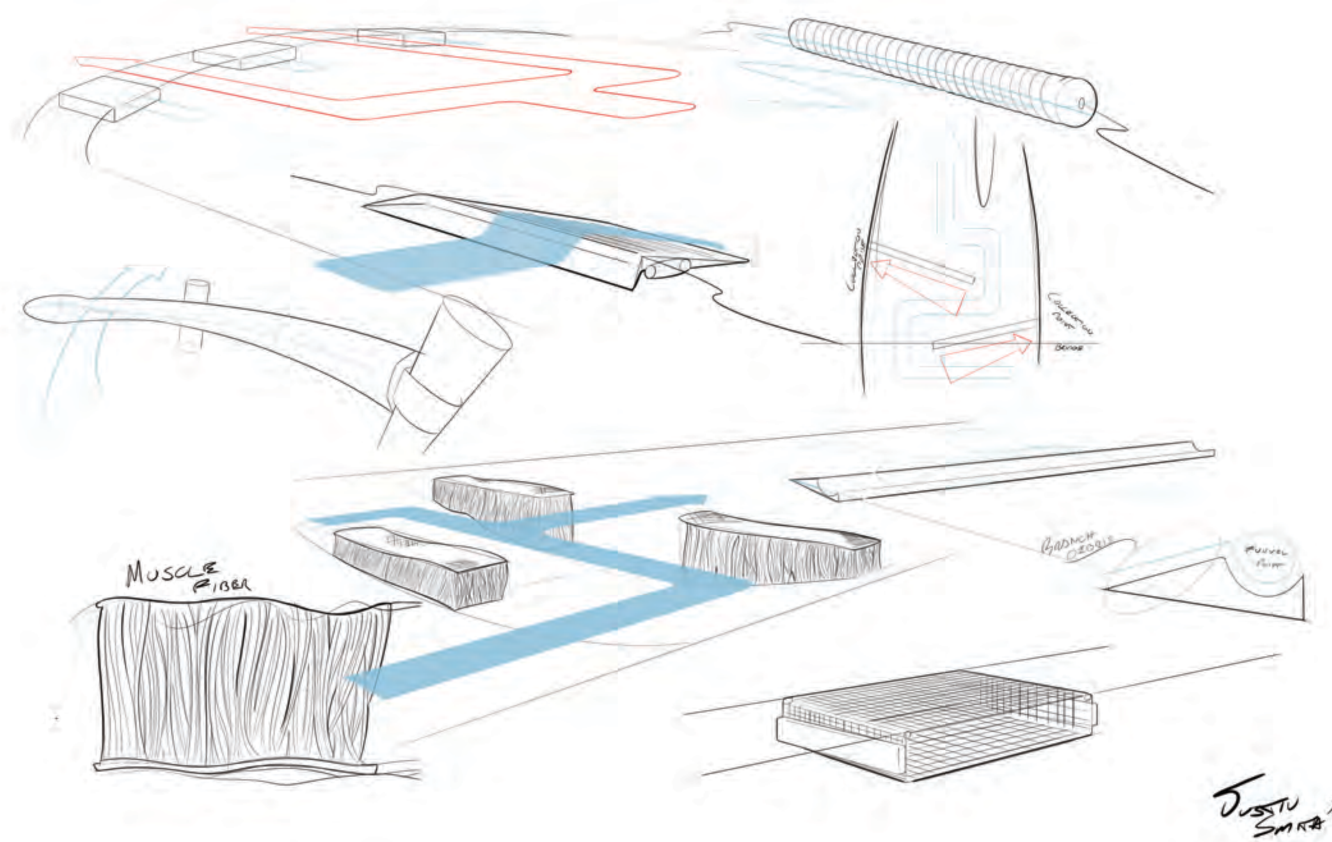


Ideation

+ Redirection of water and trash flow
+ Electrical pulley and collection
+ Floating baskets mounted in riverbed
+ Collapsible grates
+ Fibrous screens
+ Terra-forming existing environment

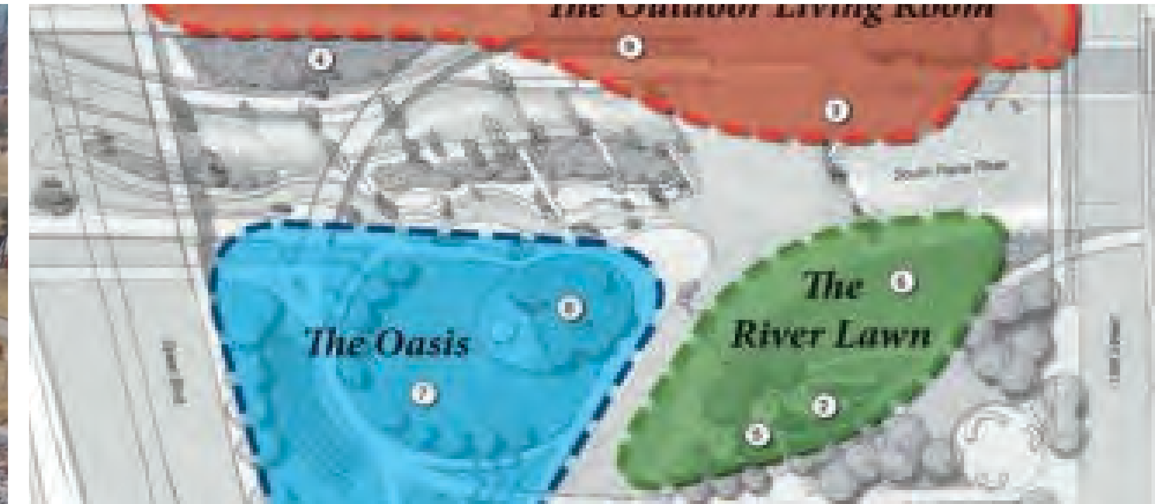


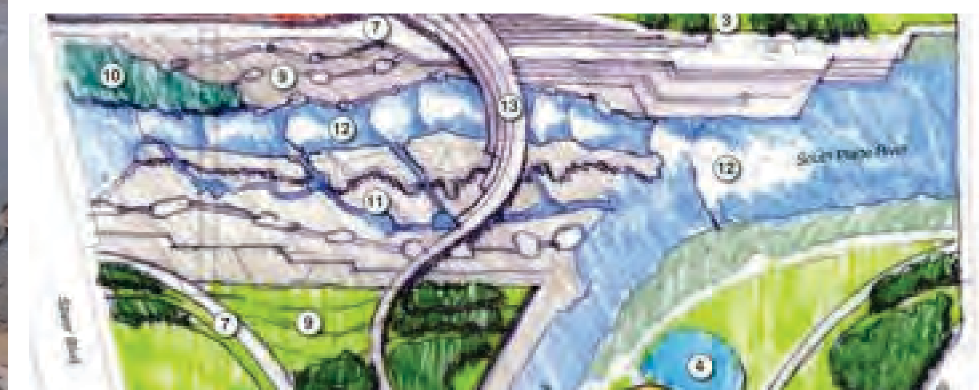


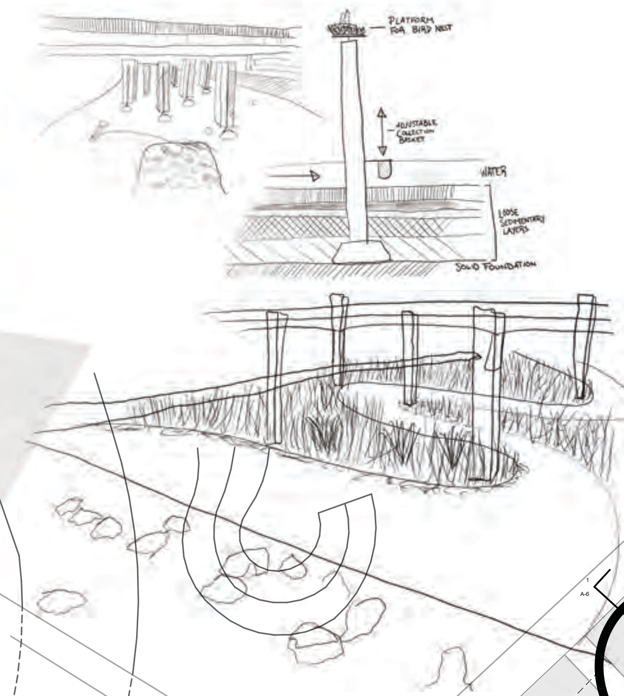


BLAU

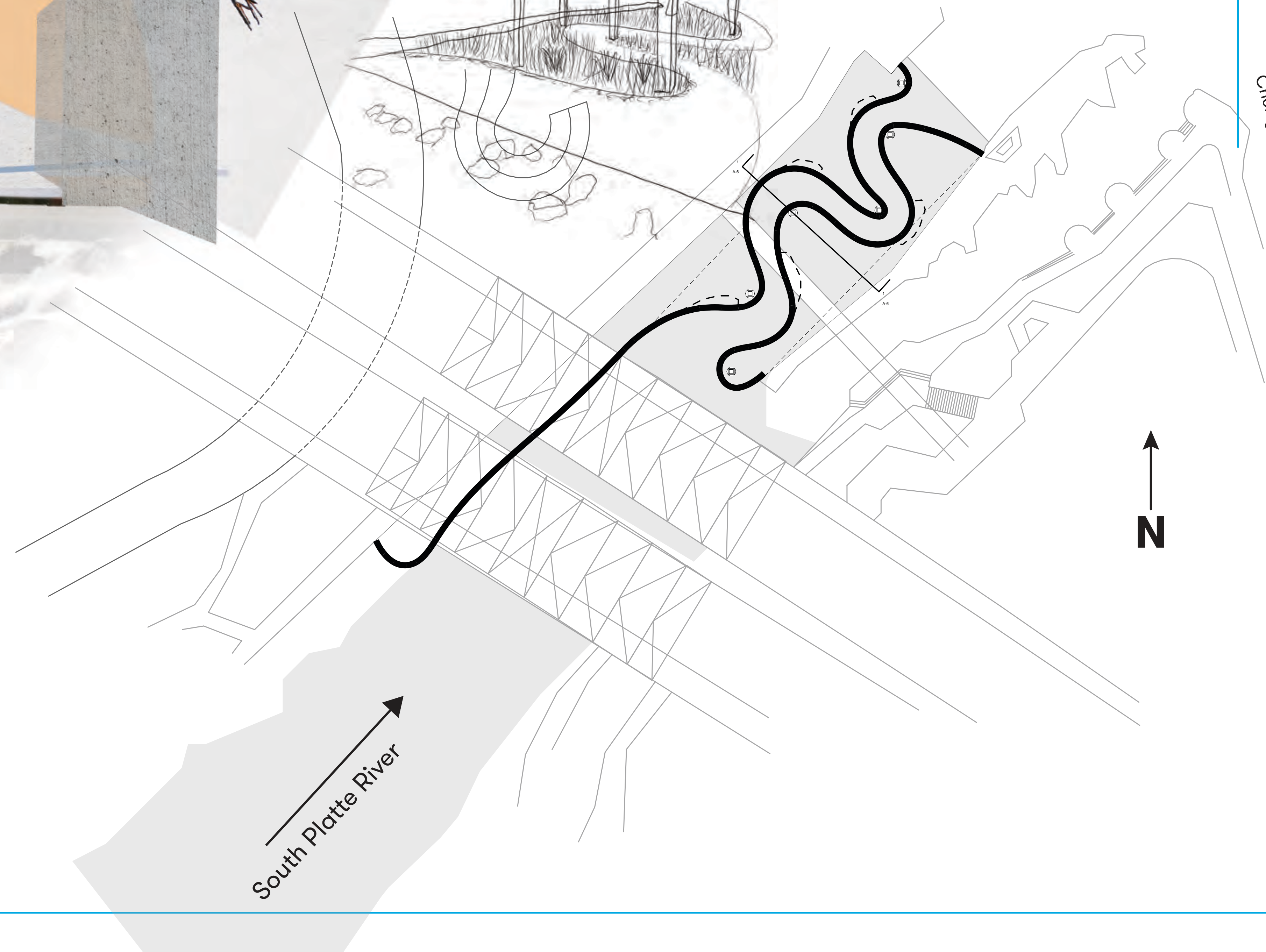
Future thoughts towards existing projects

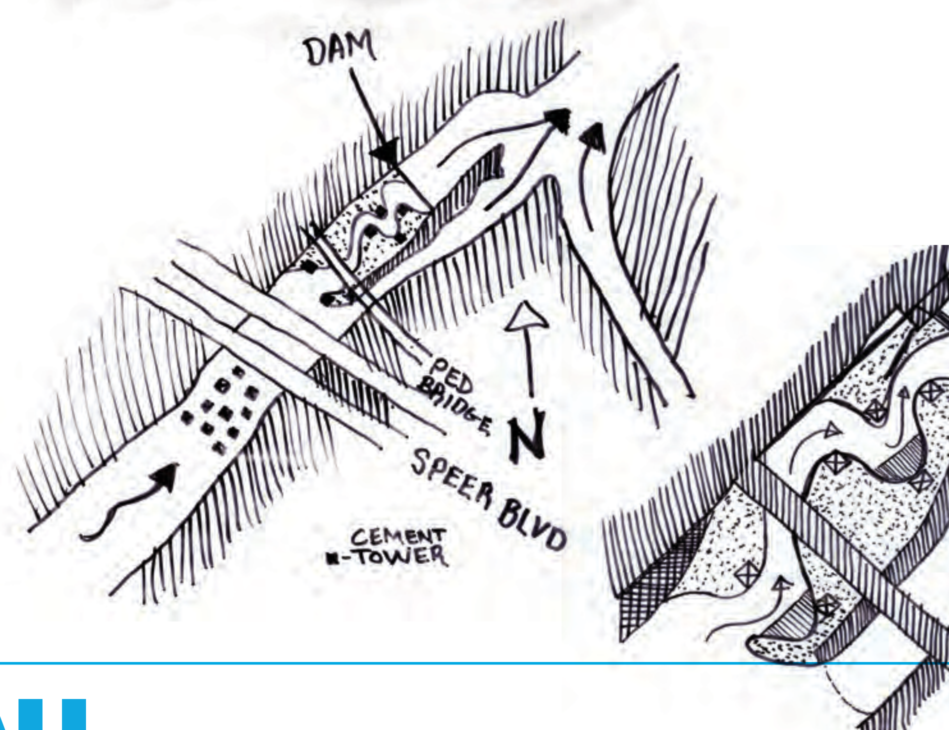






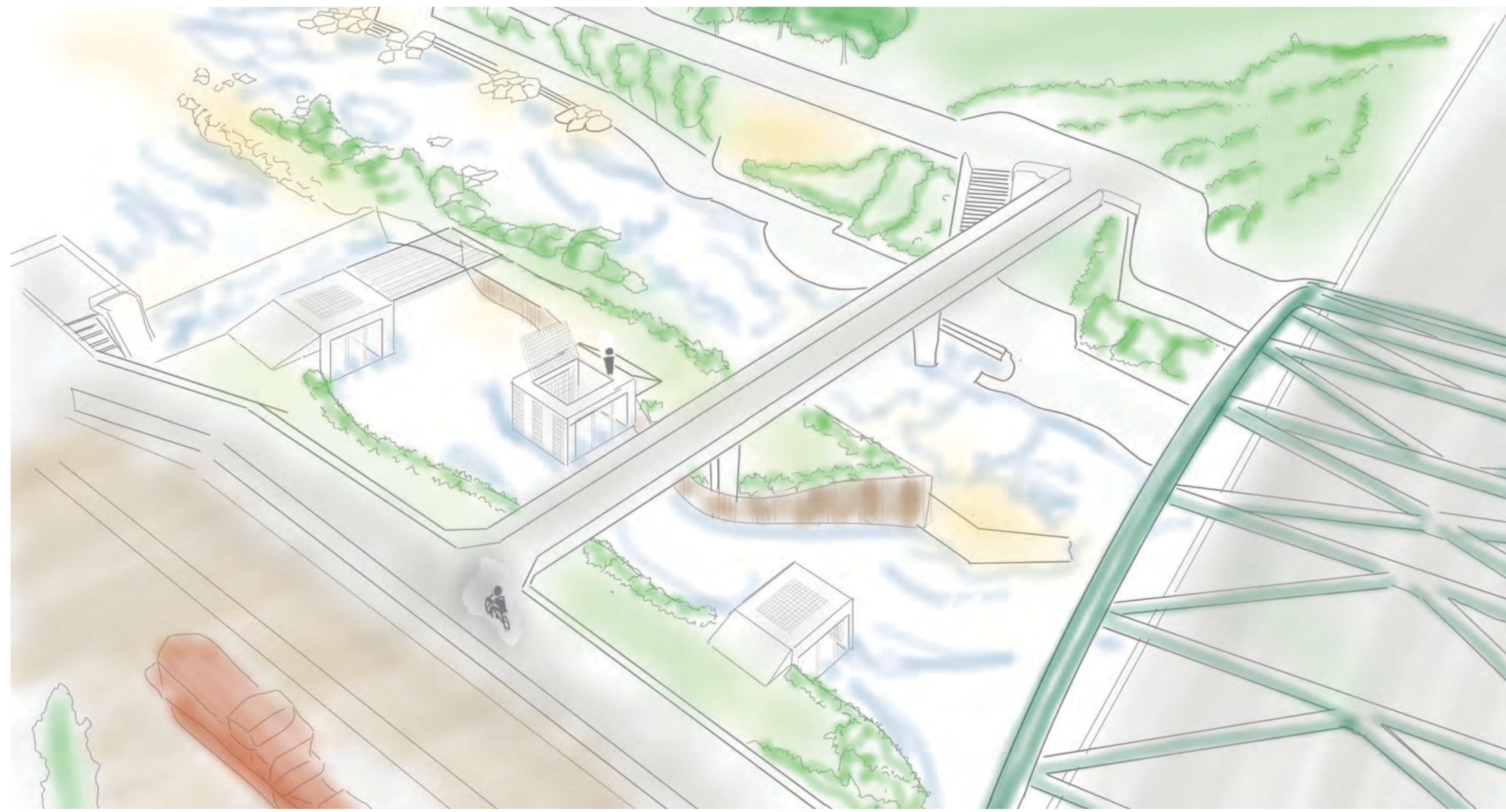
A Massive Undertaking





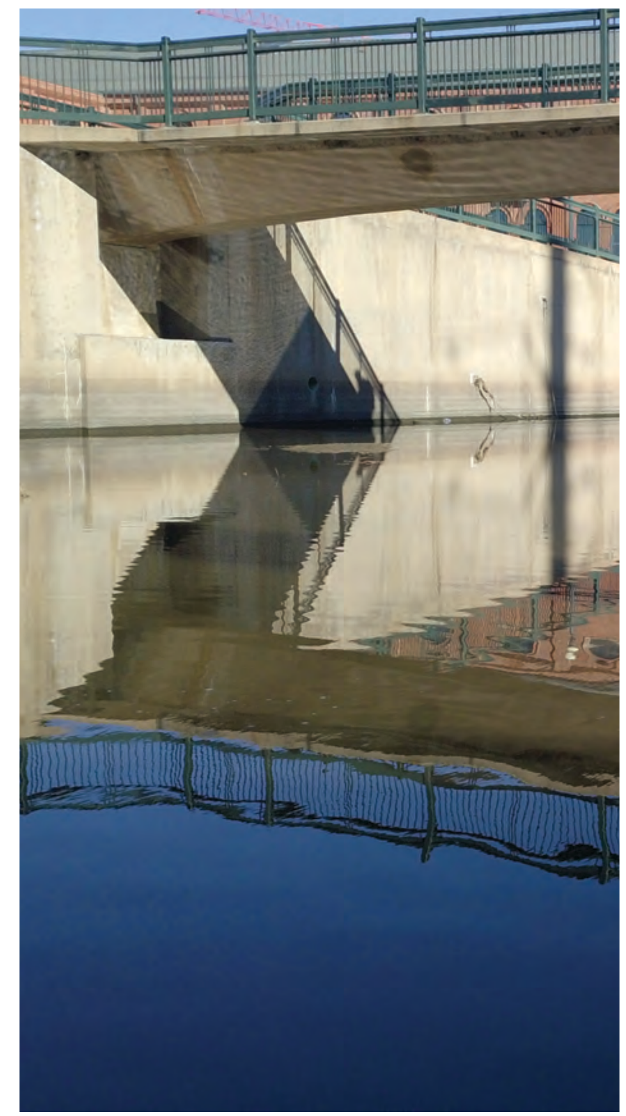
Redesign & Material

+ Adjustable steel sheet piling = $5 sq. ft.
+ Welded Aluminum grating = $150 / 2sq. ft.
+ Labor & Landscaping
+ $12 - $15k for local materials

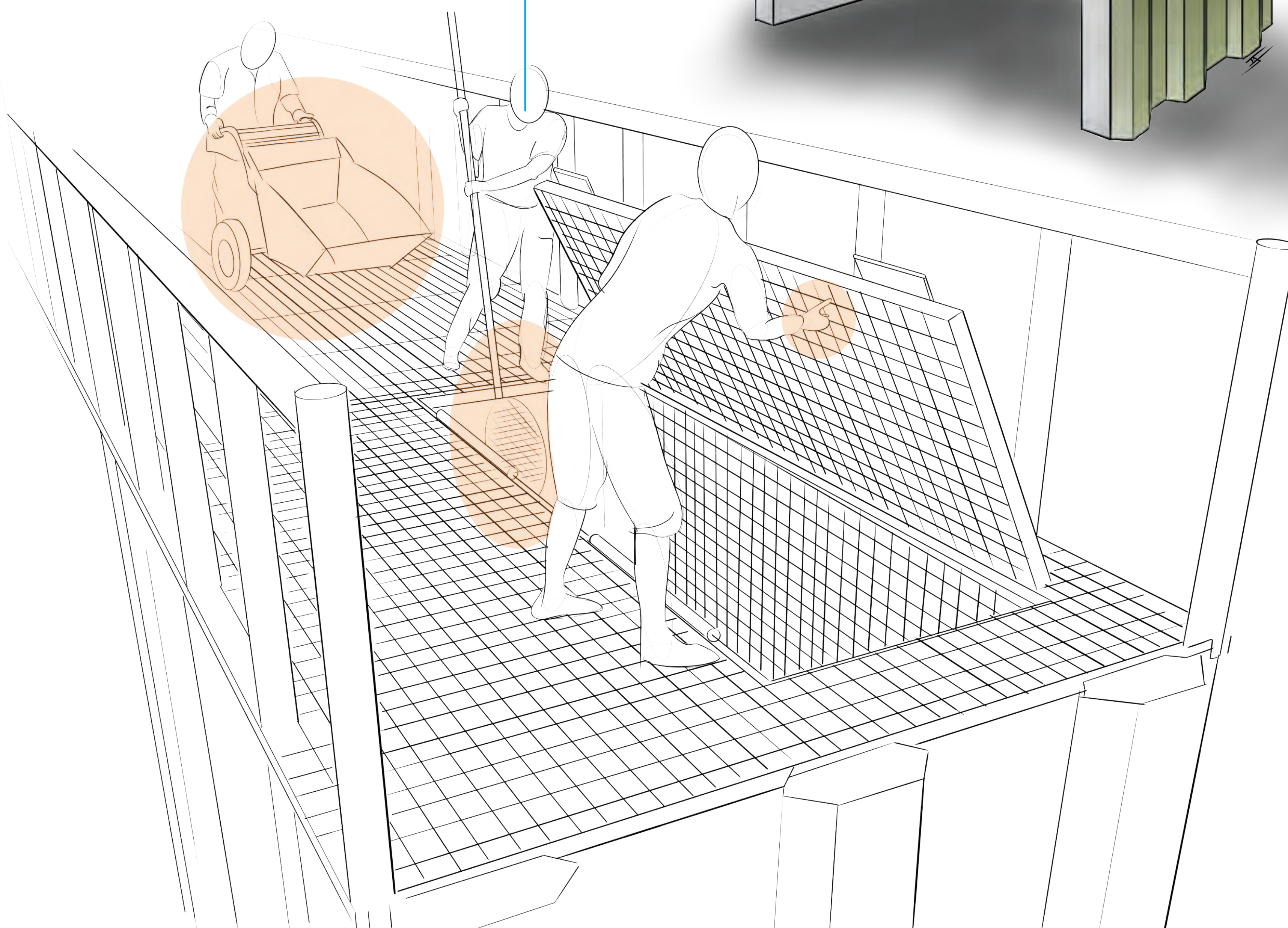


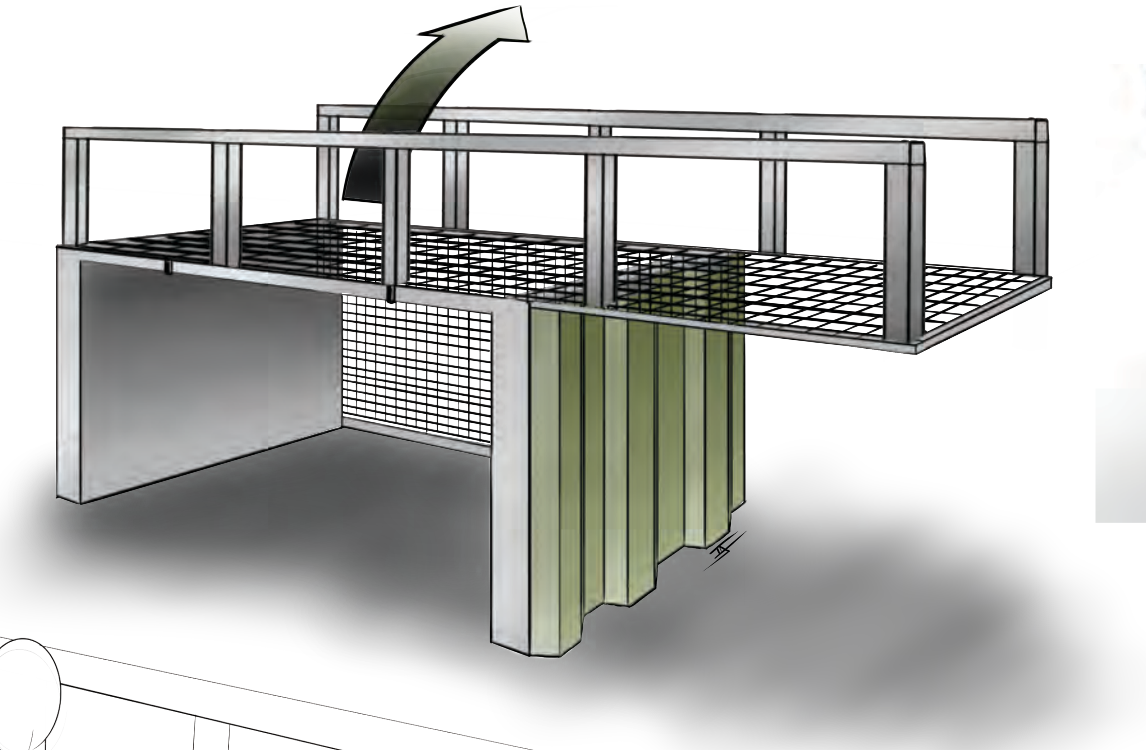
Aesthetics

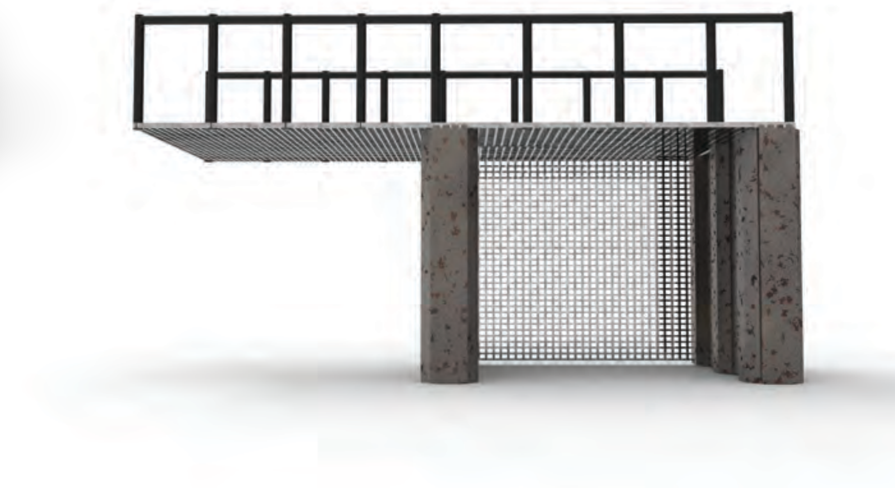
Terra-forming to match surrounding park areas
Allows wildlife passage through structure and provides additional sanctuary and habitat

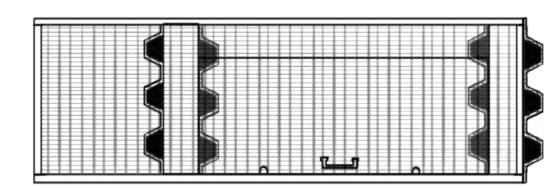


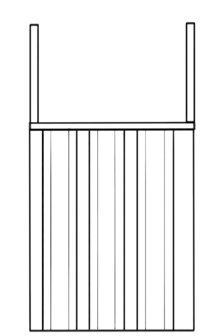
Collection

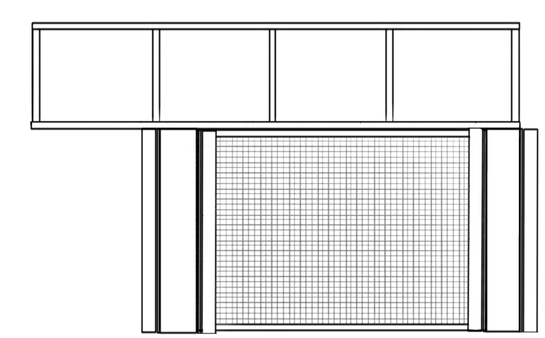




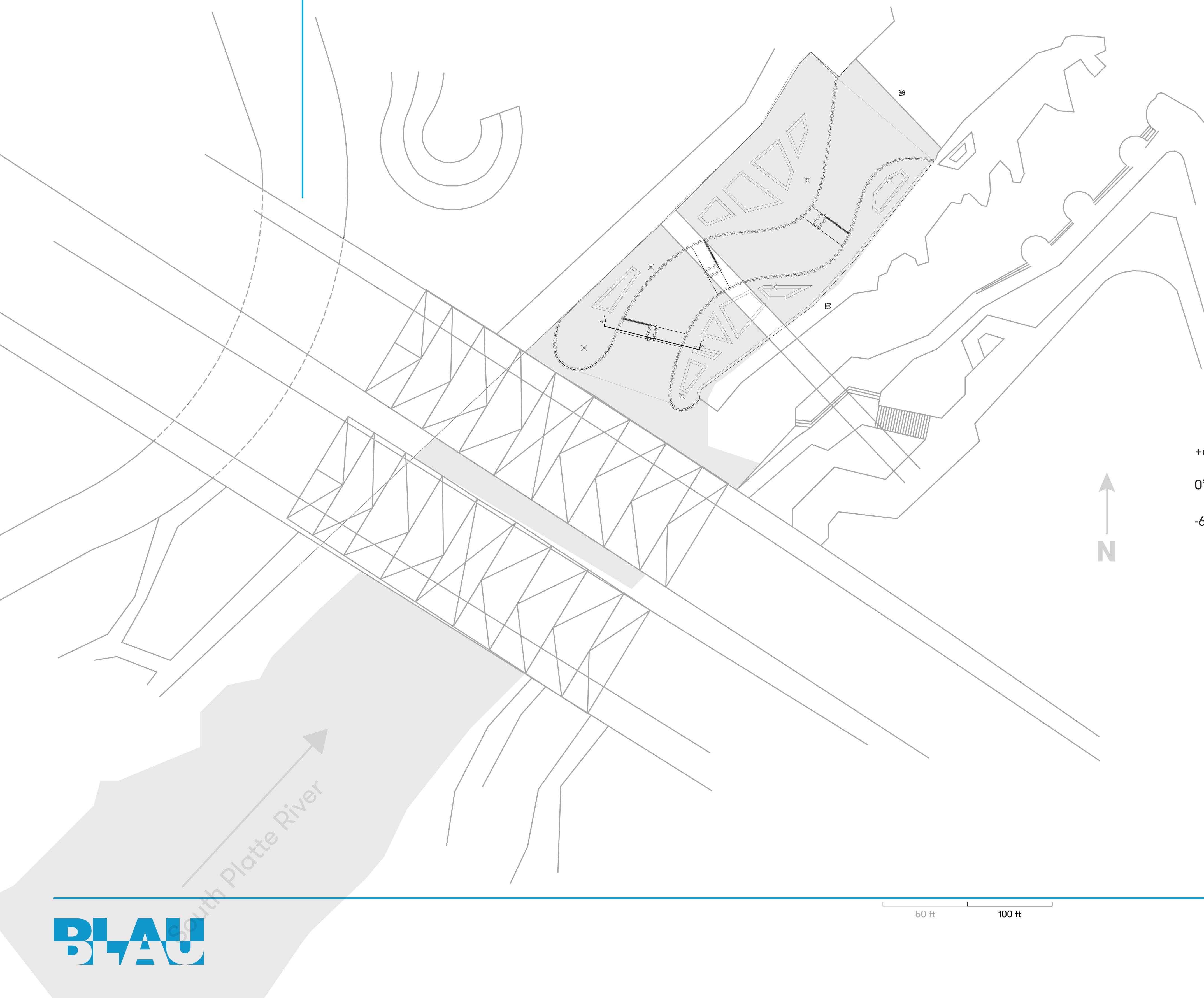


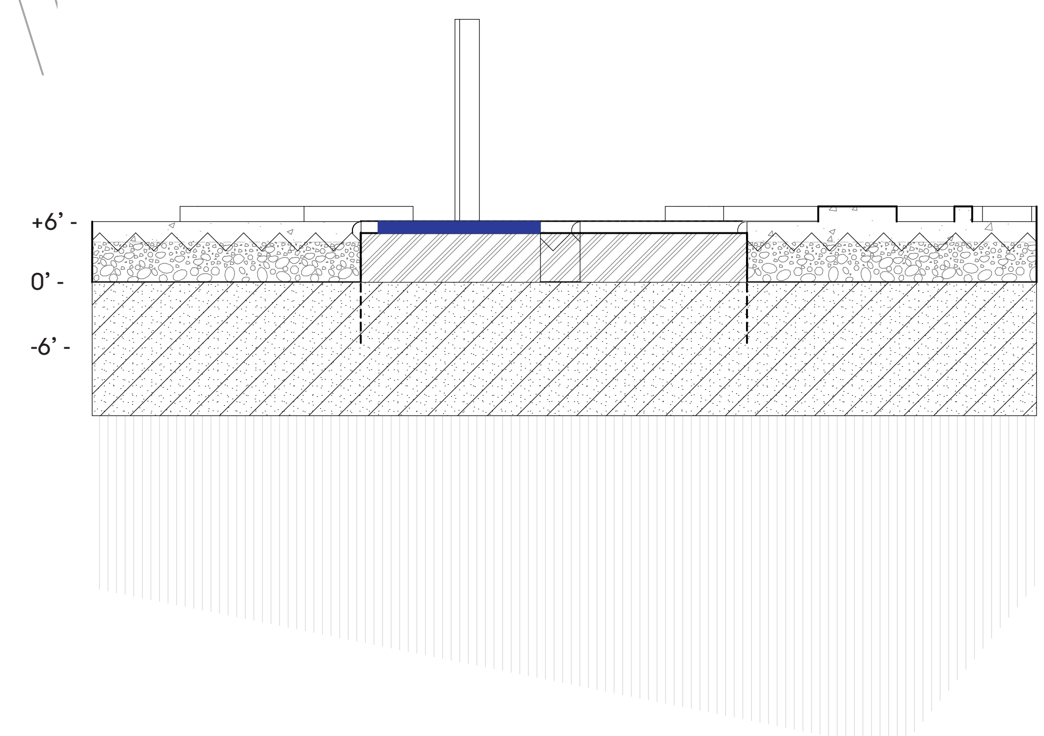




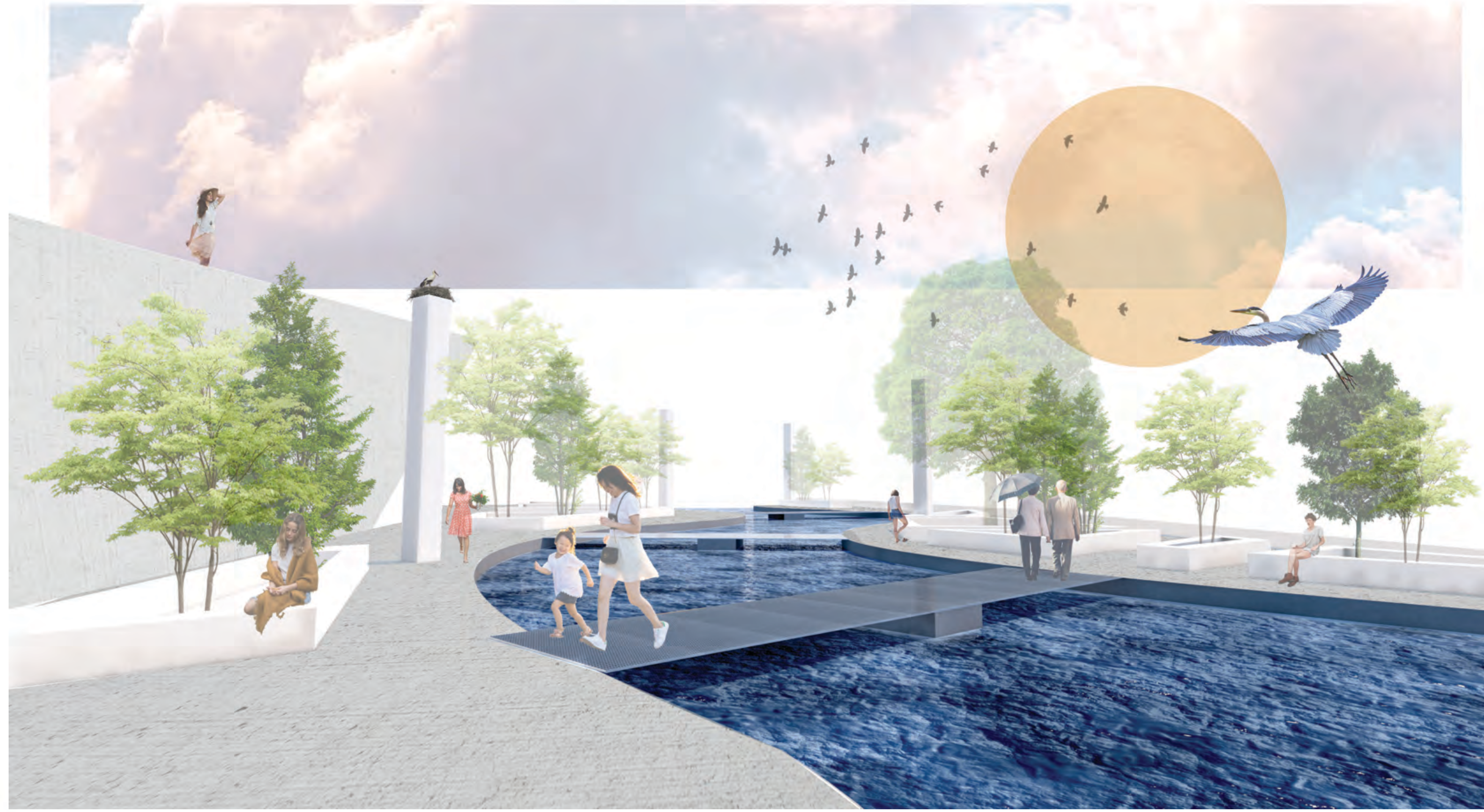


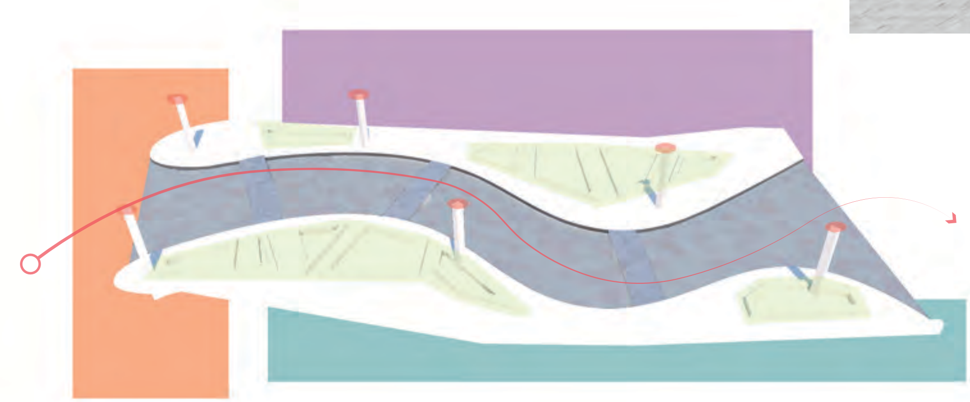
Redesign





50 ft 100 ft



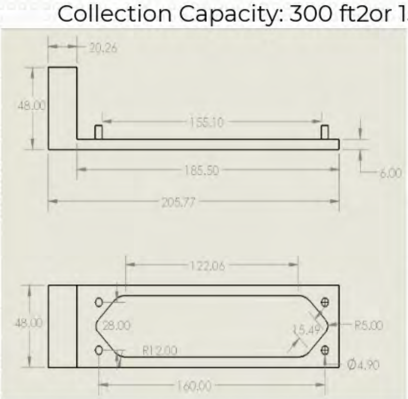


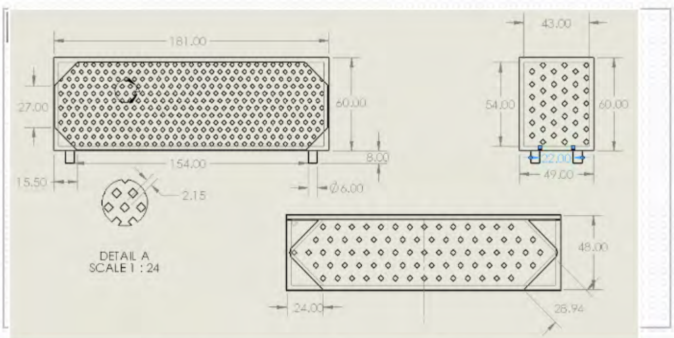
Denver Pioneers

University of Denver
George Andrulonis, Joe Burke, Edgar Del Real, Antonio Sermao, Madeline Nilan

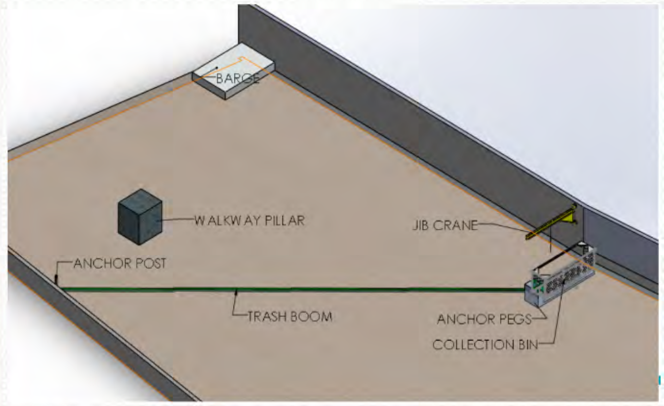
Trash bin and Anchor Design

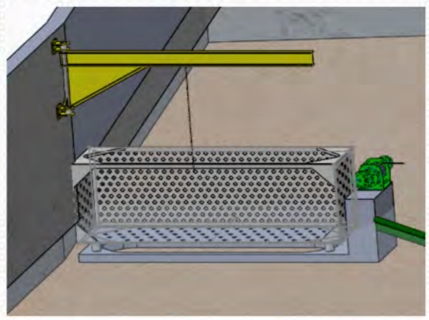
Collection Capacity: 300 ft2or 1500 lbs FS





CAD model of the system





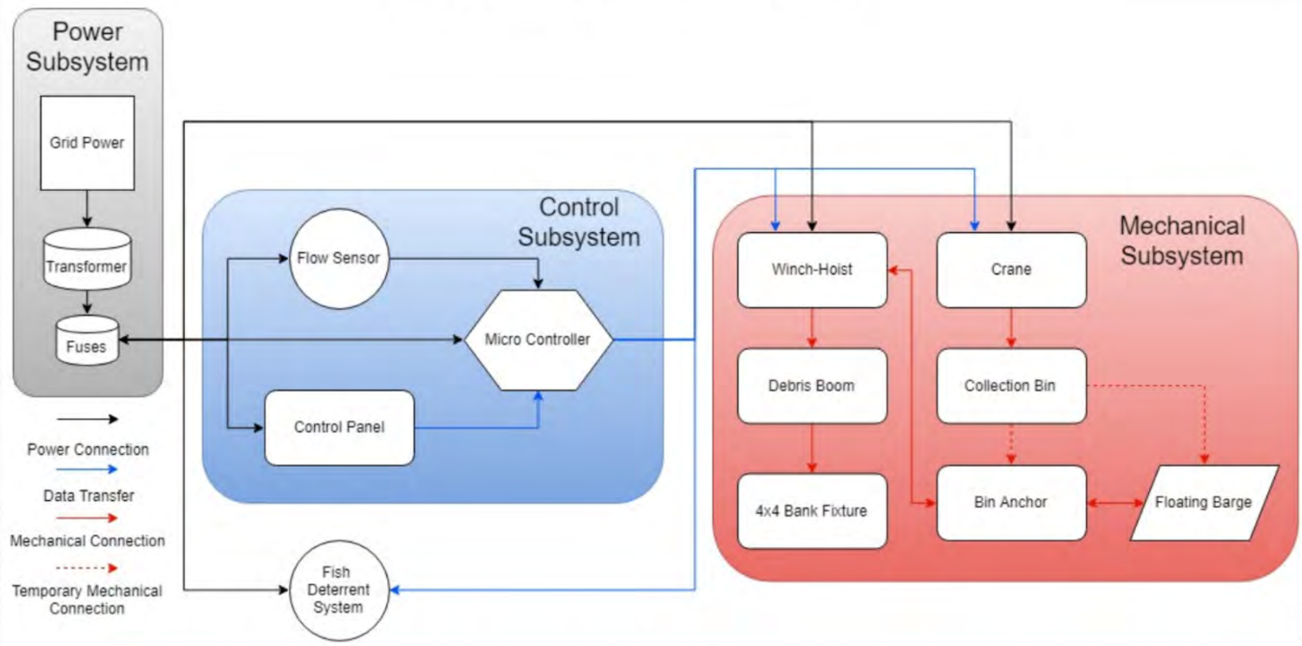
Bird's eye view of the system

Color	Function
Red	Trash collection bin
Blue	Floating barge
Green	Debris boom
Yellow	Awareness plaques

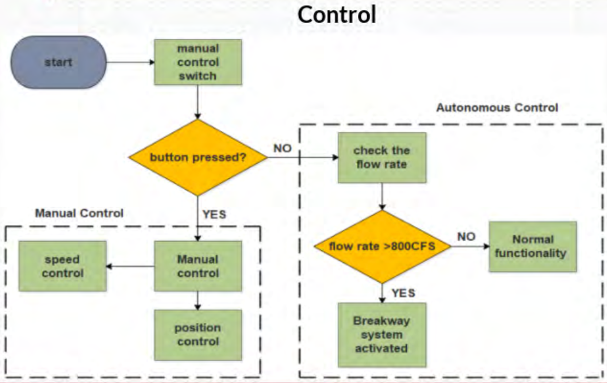
Materials and Components

Component	Price	Material
Trash Boom	$1,065	Impermeable PVC
Boom Winch	$2,656	Plated Aluminum
Trash Bin	$2,019	Aluminum 6061
Bin Anchor	$600	Concrete
Jib Crane	$2,111	Steel I Beams
Crane Hoist	$4,674	Plated Aluminum
Floating Platform	$1,500	Polyethylene
⅜" Steel Cable (200')	$160	Galvanized Steel
Flow Sensor	$910	PVC & Aluminum
Microcontroller	$25	Electronics
TOTAL COST	15,720	N/A

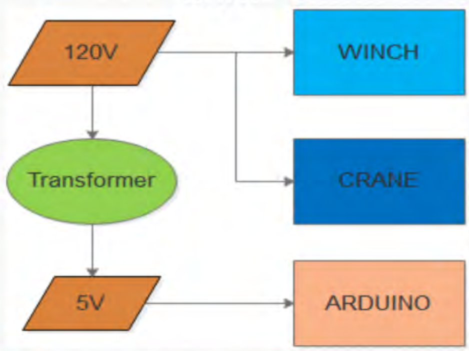
Subsystems



Control



Power



Operational Impacts

- The device will collect the trash floating through the targeted area of Confluence Park as the trash will be diverted in the collection bin
- This service will prevent trash build up as well as the aesthetic and pollution problems it causes.
- The target area of the park will become clean and safe for public use
- Plaques Placed in park and on bridge to promote public awareness to hazards of littered Waterways and promote social Responsibility.
- Plaque also highlights features of design Such as fish deterrence system, and Breakaway function.

Servicing Plan

The process of removing and cleaning out the trash container consist of 6 steps and the shall be serviced depending on river flow.

1.)The manual control switch must be activated

2.) The crane will lift up the trash container out of the water

3.) A floating barge is then sent out to float under trash bin

4.) Trash bin is the emptied onto the barge by workers

5.) Floating barge and trash are then retrieved and serviced

6.) The trash bin is then put back in the river to restart the cycle

Clean River Design Challenge

Submitted to:

The Greenway Foundation

ATTN: Lauren Berent

Submitted by:

F18-49
River Guardians
Engineering, Design, & Society
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Final Design Report

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April 30, 2019

Acknowledgments

Thank you to Lauren Berent, Devon Buckels, and The Greenway Foundation for allowing us to participate in this Design Challenge. Thank you to Bahman Rejai and Kristoph Kinzli for advising our team. Thank you to Christopher "Kit" Shupe and the Bureau of Reclamation for designing and building the testing space and making it available for practice runs.

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Final Design Report

Prepared by Emmanuel Almaras-Sandoval, Bryan Cazier, Jonathan Donehower, Marina Hansen, Alex Turner, Jessica Thompson

F18-49

River Guardians

Division of Engineering, Design and Society

Colorado School of Mines

Executive Summary

The Greenway Foundation requests that the River Guardians develop a trash removal device for the South Platte River in Confluence Park. Trash collects near the banks of the river and detracts from the natural beauty of the park. Current efforts to remove trash from rivers require manual systems that are labor intensive and costly. The accumulation of trash affects fishermen, kayakers, and other park visitors directly, while pollution may affect surrounding businesses indirectly if the pollution becomes too severe and reduces human activity in the area. This is a growing problem around the world and The River Guardians are grateful for an opportunity to remedy the issue.

The final design report covers all the steps our team took when developing The Trash Hopper. The team brainstormed ideas for trash collection devices, and then narrowed down the options using tools such as decision matrices. Our team decided that the final design would be modeled after a grain auger, and developed a final prototype. Next, we conducted an engineering analysis by utilizing equations and analysis tools to explore the technical considerations required to develop the device. Our team discovered we can verify concepts when doing calculations and assuming perfect conditions, however, when tested, many factors can cause failure. We conducted tests to optimize the final dimensions and other variables of the design. This included multiple tests in the Senior Design lab and one testing day at the Bureau of Reclamation in a 1/12 scale model flume before showcasing The Trash Hopper to a panel of judges at the final competition. The Trash Hopper was determined to be an effective design based on testing. Most of the surface trash was caught and brought to the waste bin when the motor was functioning in tests, and the waste bin was able to be lifted out of the water. At full scale, the Trash Hopper was anticipated to function with similar success, and catch most surface trash. The cost of full scale implementation is around $6000. Finally, the effects that the Trash Hopper will have on the Denver community and environment were assessed and reported on. This was important because one of the main focuses of the project is providing a device that impacts both of these factors in a positive way. Solving the problem of pollution will move beyond the intended outcomes.

Final Design Report

Prepared by Emmanuel Almaras-Sandoval, Bryan Cazier, Jonathan Donehower, Marina Hansen, Alex Turner, Jessica Thompson

F18-49

River Guardians

College of Engineering, Design and Society

Colorado School of Mines

1. Introduction

The Denver-metro area is known for its outdoor recreation, such as parks, rivers, and the surrounding mountains. Kayaking, fishing, and tubing are popular activities in the nearby rivers, and many people are active in local parks, as well. The dense population in Denver, as well as the frequency of outdoor activity, leads to trash accumulating in the rivers and parks, including the South Platte River and Confluence Park. The Greenway Foundation's mission is to clean up the rivers in the Denver area, and reduce the plethora of trash that finds its way into the waterways. Studies have shown that 90% of the plastic in the ocean stems from rivers [1]. It has also been determined that it is nearly impossible to clean up the trash that has already found its way into the ocean. However, concentrating efforts on rivers could prevent more trash from reaching the oceans. With this mission in mind, The Greenway Foundation started the Clean River Design Challenge, with the intention to design devices for specific sites on the rivers in Denver to collect and remove trash. Currently, volunteers remove trash so engineering students are focusing on designing devices to automate the process and make trash removal effective and efficient.

The River Guardians spent the past two semesters designing and building to achieve the Clean River Design Challenge goals. Constraints, that drove the design, were determined and used to brainstorm and narrow down the choices. The detailed steps completed during this semester are detailed in the following sections.

2. Design Selection

The basis of the design was developed after brainstorming multiple ideas, some practical, while others not possible given our resources. We conducted basic research on the concept of a trash collector to decide if any solutions exist about our given problem. Unsurprisingly, trash collectors exist in many forms, mostly in other countries with waste dumping issues and where the ocean trash can float hundreds or thousands of miles away from their source. The trash collectors ranged from simple devices that used long protruding arms and the water's current to catch trash in a bin, to more complex, mobile watercraft that were manually operated. Calculations were also completed to determine how the designs would hold up under the flow rate of the river [2]. These calculations are displayed in the appendix. Since the scope of the project is to collect trash in a moderately sized river, a more automated design that relies on the river's current would be the most effective. From here, a variety of concepts were illustrated around this finding and eventually settled on the corkscrew (auger) for its simplicity, effectiveness, and ease of manufacturing [4]. Table 1 below shows the design matrix we used to pinpoint the best design to prototype.

Table 1: Design Matrix for Initial Designs

	Criteria Ranked on Scale from 1-5							
Design	**Feasibility (Cost)**	**Effectiveness (In Capturing Trash)**	**Viability (Scalability)**	**Aesthetics**	**Impact on Wildlife/ Environment**	**Impact on Community**	**Ease of Installation/ Maintenance**	**Total Score**
Trash Hopper	2	4	3	4	4	4	3	24
Waste Wiper	3	3	2	3	3	3	2	20
Trash Sling	3	3	3	2	3	3	2	19

We determined specific constraints to devise the best solution to our problem. After multiple mockup designs and research on existing prototypes already released to the public, we finalized three designs and graded them based on our selected criteria. After much consideration, the Trash Hopper received the best score due to its superiority in effectiveness (ability to collect trash) and ease of manufacturing. While the Trash Sling (Figure 1) and Waste Wiper (Figure 2) designs were more cost-effective and nearly as effective in collecting trash based on tests, the large amount of parts and ability to generate a full-scale model would have been extremely difficult. With this, the Trash Hopper's simplistic design is ideal for the scope of the project's timeline and budget.

Figure 1: Trash Sling Design

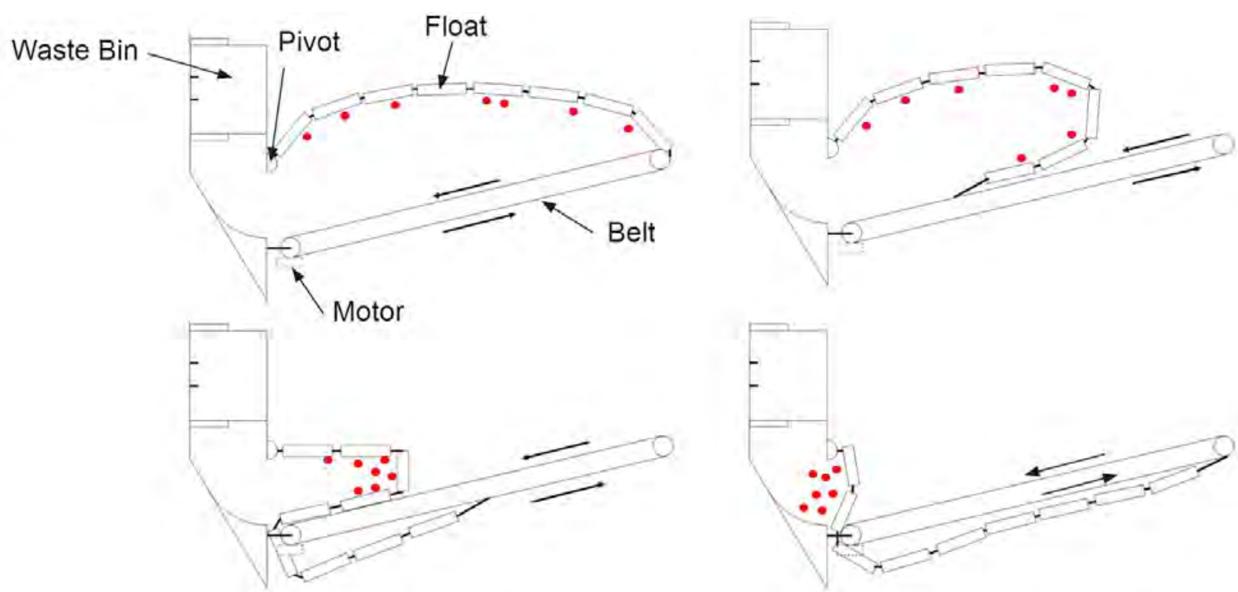


Figure 2: Waste Wiper Design

Upon deciding on the Trash Hopper, we conducted multiple tests on its important design choices. Our team tested key variables, such as thread pitch, thread height, and pipe diameter. Additionally, for the full-scale design, it was important that the corkscrew shaft floats on the surface to reduce interference with aquatic wildlife and the amount of trash that floats under it. Next, we performed a variety of calculations that varied material, volume, and weight, to make sure that the final design was the best possible. The material must be environmentally friendly (doesn't corrode in the sun or water), be lightweight enough to allow flotation, and support its own weight. Each combination of these variables demonstrated varying results that supplied the needed information for the final design.

3. Engineering Analysis

Optimization Test Results

To verify that the Trash Hopper's design met project requirements for trash removal, scalability, impacts of operation, hydraulics, installation, maintenance, and aesthetics, the team conducted a series of tests over the course of the semester: three in the Senior Design lab and one at the Bureau of Reclamation. In each test, iterations were made based on the findings of previous experiments.

The first test took place on January 21 in the Senior Design lab. The primary goal of this test was to equip multiple augers to an electric drill and investigate various diameters and thread sizes. The secondary goal was to assess the flume made from a plastic bin (1 foot wide by 3 feet long) and pump. The various augers used rope threads ranging from 0.5" to 1" thick and diameters ranging from 0.5" to 3".

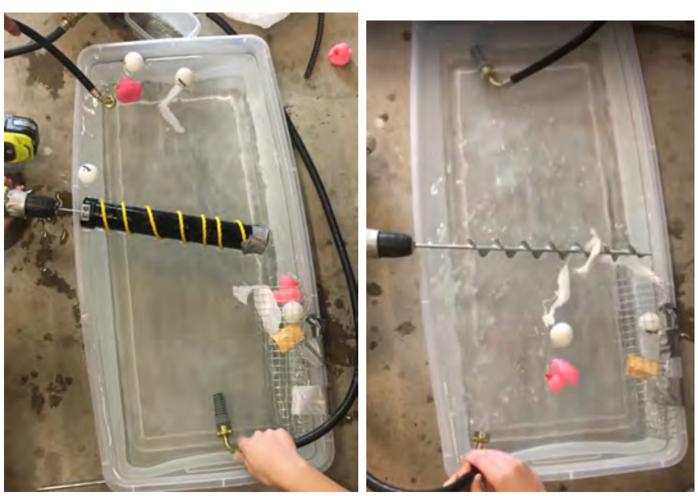
The core findings from the test were:

- Larger diameter pipe is better for trapping trash and preventing trash from flowing under;
- Loose pieces of trash get tangled in smaller diameter piping;
- Larger threads are better for grabbing and directing trash.

The larger design considerations were:

- Further testing would be done with larger diameter piping to decrease entanglement;
- More powerful and consistent flow is necessary to prevent swirling and better simulate natural flow conditions;
- Auger should be angled into the trash bin;
- 3D printed augers would facilitate faster production.

Overall, this test served to break ground from the conceptual to the experimental.



Figures 3 and 4: Images from the first test in the Senior Design Lab

The second test took place on January 31 in the Senior Design lab. The primary goals of this test were to gather additional data for the outer diameter of the auger and evaluate a new flume made from a larger wood bin (1.5 foot wide by 3.5 feet long) plus an improved pump attachment. The same auger diameters and thread sizes were used, but in more representative flow conditions.

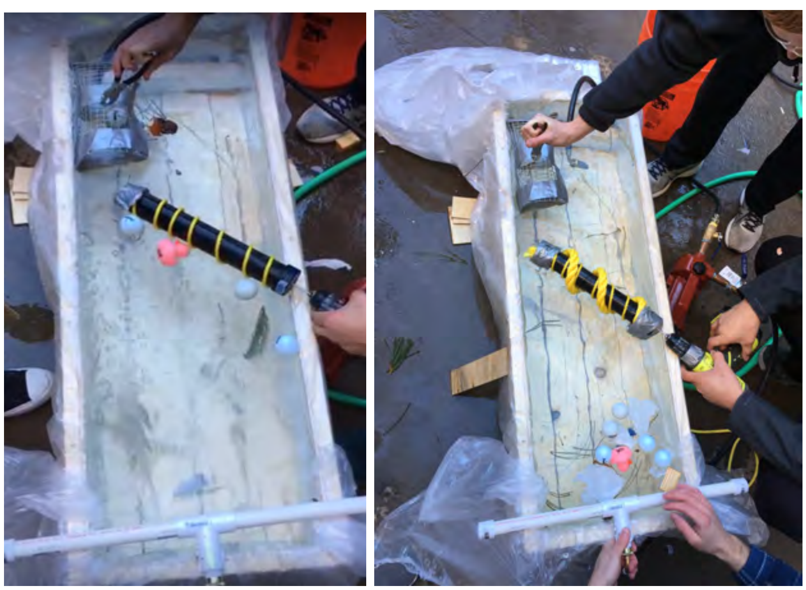
The core findings from the test were:

- Our notion that larger diameter pipe is better for preventing trash from flowing under was confirmed;
- Larger threads are better for grabbing and directing trash;
- Light and slightly submerged debris has a tendency to flow under the augers;
- The new pump attachment was successful at improving the flow conditions, but wasn't perfect.

The larger design considerations after this test were:

- A bigger flume is needed to prevent swirling and to fit larger augers;
- The augers need to sit deeper in the water to prevent trash from flowing under.

Again, this test served to familiarize the team with the critical variables involved in our design that needed refining.



Figures 5 and 6: Photos during our second test with improved flow and flume shape

The third test took place on February 15 in the Senior Design lab. The primary goal of this test was to experiment with the newly fabricated augers made from ABS with metal threads. The secondary goal was to assess a new, larger flume (2 feet wide by 5 feet long) equipped with the pump attachment. The auger diameters were 4", 3", and 2", the thread sizes were 0.5" and 1", and the pitch lengths were 6", 4" , and 2".

The core findings from the test were:

- The larger diameter piping once again proved to be most effective at guiding the trash towards the trash bin;
- The 1” threads were significantly more effective at grabbing the trash than the 0.5” threads;
- A smaller pitch length was better for ensuring trash moves “in line” towards the trash bin;
- The depth that the auger sits in the water can be modified by filling the tube with water;
- A stronger pump is required for using the full length of the flume.

The subsequent design considerations were:

- An auger with 4” diameter and 1” threads at 2” pitch will be the focus of further experimentation;
- The augers will sit approximately halfway in the water;
- Additional emphasis will be made toward the motor housing, waste bin, and support system;
- Abandon 3D printed prototypes.

This third test was a large step in the right direction. The team not only found an efficient fabrication method, but the size of the diameter, thread size, and pitch were made evident.

Figures 7 and 8: Test with first prototyped augers

The fourth test took place on March 11 at the Bureau of Reclamation, where the Platte River conditions were simulated at a 1/12 scale. The first goal of this test was to evaluate how well the design fit into the flume mount designed for the final competition. The second goal was to test both 3” and 4” augers at the competition flow rates (0.2 and 1.3 cfs). The third goal was to test the entire assembly complete with the waste bin, wall mount, motor configuration, and support system. The fourth goal was to assess thread direction. This was the team’s first look at the entire prototype complete with each component.

The core findings from the test were:

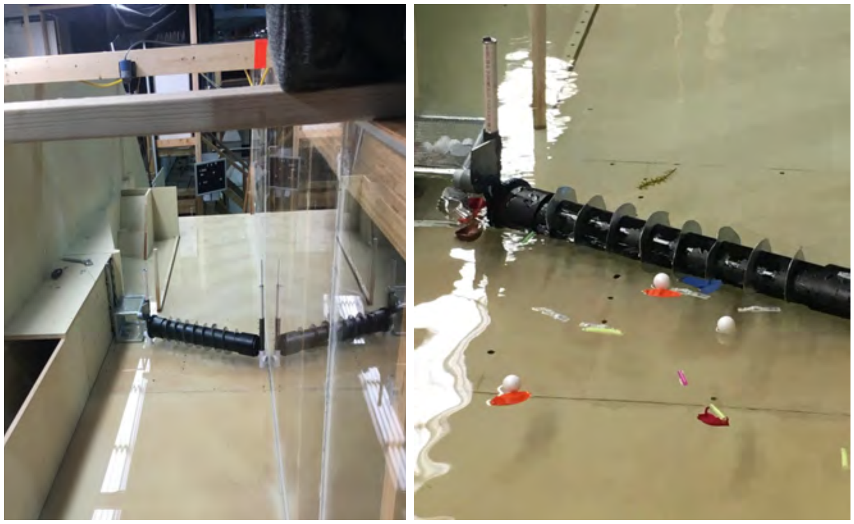
- Overall, the assembly fit well into the flume, both onto the floor mount and to the wall;
- However, a lubricant is necessary for ensuring the auger adjusts to the changing water depth without resisting the supports;

- The 3” auger directed more trash into the waste bin than the 4”;
- The motor mount fit well onto both augers. The gears didn’t skip and the motor had sufficient torque to rotate the augers at a satisfactory RPM;
- A downward thread rotation was more effective at catching smaller trash and directing it toward the waste bin;
- The threads should be extended to the edge of the caps to prevent congestion in front of the waste bin;
- Metal plates need to be attached to the bumpers on each support to close the gaps between the supports and the waste bin.
- Both augers performed as intended in the two flow rates;
- The waste bin was large enough to collect all of the trash flowing into it;

The subsequent design considerations were:

- The threads will be extended to the edge of the end caps on both sides of the auger;
- The augers will be better waterproofed;
- Additional emphasis will be made toward the pulley system for hoisting the waste bin up the wall mount;
- A second pair of gears should be 3D printed in the event that the threads chip or wear on the existing gears
- Metal plates will be attached to the bumpers on each support or to the motor mount in order to close the gaps between the supports and the waste bin.
- A spray or putty will be added to the auger and threads to improve adhesion as well as improve aesthetics

Overall, the testing at the Bureau of Reclamation was a resounding success. This was the team’s first look at the entire prototype complete with each component; the subsystem worked well together and the prototype left the test entirely intact. The team also identified the final iterations needed to optimize the final design and present a functioning prototype by the time of the final competition.



Figures 9 and 10: First test and setup at the Bureau of Reclamation

One final test was conducted at the Bureau of Reclamation. Unfortunately, the design did not function as successfully as anticipated. The motor fried and the auger did not float to the surface during the high flow test. However, the pulley system and waste bin functioned exactly as anticipated and moved up with the high flow. Trash caught in the auger threads but was not able to move towards the waste bin, since the motor was not rotating, and therefore most of the trash was not able to be collected.

4. Final Design

After several different tests of materials and applications, a final design was created that met the the project constraints and could be scaled up at a reasonable cost. This design consists of two different parts that work together to remove the trash from the river in a safe and efficient manner. They are both crucial components that must work in conjunction with each other to ensure the overall success of the project.

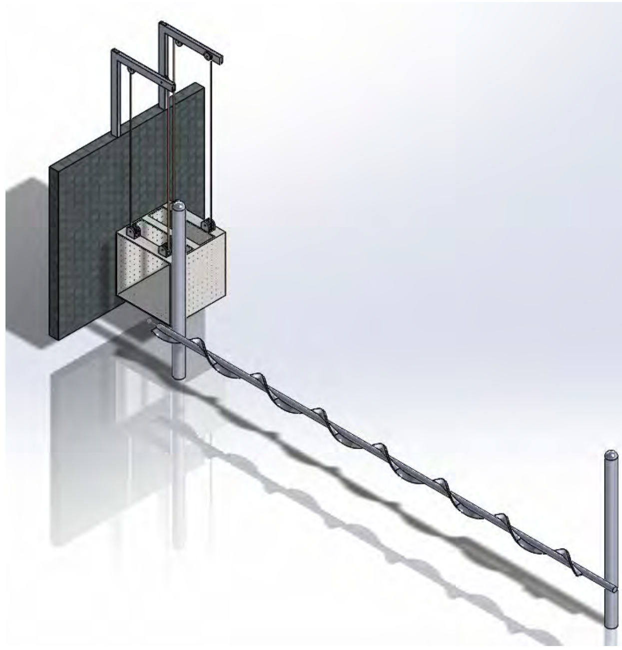


Figure 11: Solidworks Model of Final Design

The first piece is the trash hopper: a 3” diameter auger that spans across the river at an angle of 30 degrees and is supported on each end by vertically sliding supports that allow the device to be halfway submerged at any flow condition. An electric motor is mounted on the sliding support and rotates the auger at a speed of 10 revs/min. The rotating motion directs all the trash stopped by the auger to the concrete wall where it is collected by the second component, the waste bin.

The waste bin is supported by a pulley system that is fastened to the wall and is able to raise and lower the bin as needed, depending on the river conditions. Once full, the motor attached to the pulley system raises the bin to the elevation of the sidewalk and rotates it 90 degrees. This will allow the bin to lay safely on the sidewalk while an operator empties the captured debris. Figure 12 below shows a model of the waste bin.

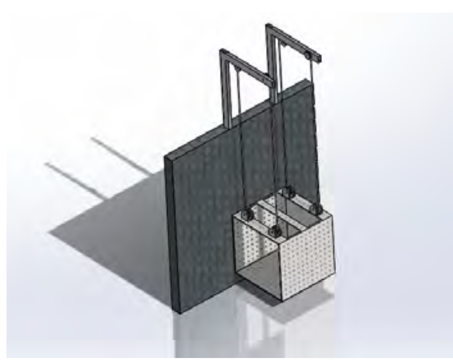


Figure 12: Solidworks Model of Waste Bin

A solar-powered battery will power the full-scale model. The power consumption will be minimal because of the low rotation of the auger and the small amount of power used by the pulley motor which is only activated when the water level changes or when an operator triggers it while removing trash.

The prototype auger was made of ABS pipe and with galvanized sheet metal threads, in the full scale model the auger would need to be made from 8” aluminum pipe with the threads made of aluminum and welded on to the pipe in a similar manner as the prototype. The buoyancy of the auger would need to be calculated in order to obtain the same submersion ratio. Figure 13 below shows the prototype in the flume at the Bureau of Reclamation.

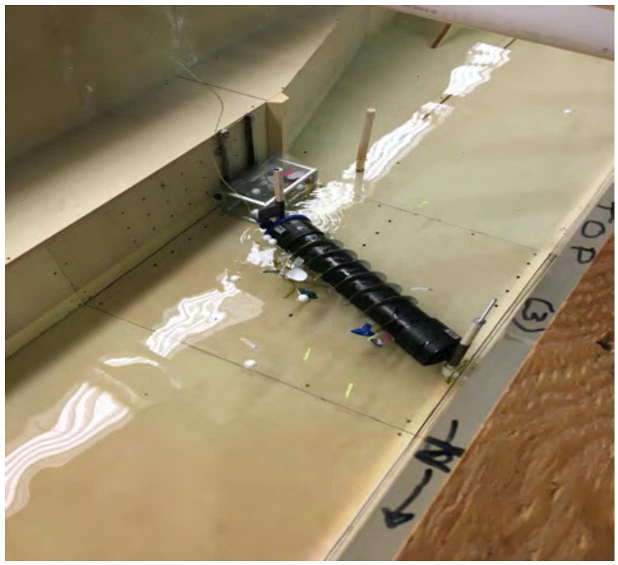


Figure 13: Prototype in Testing Flume

The waste bin cage is made of galvanized sheet metal angle that was cut to length and riveted together to create the frame that was then wrapped with ½” galvanized steel mesh. The waste bin is secured to the sliding frame by a steel bracket that wraps around the bin and secures it in place. This bracket is welded to sliding mechanism whose motion is restricted to vertical movement. In a full scale model a similar method would be used to build the bin and aluminum would be used to construct the frame for the 2” mesh. A bill of materials for the prototype is shown in Table 2 in the Appendix.

5. Broader Impacts and Safety

The goal of The Trash Hopper is to efficiently and effectively remove trash from the South Platte River while considering the interaction it will have with the surrounding area. In the South Platte River at the location of the install, there are various types of recreation, animal activity and shopping in the area. A few important stakeholders to note are kayakers or those involved in water sports, shoppers, families, fish, birds and other animals. It is crucial to the design of the device to consider the effect The Trash Hopper would have on these groups.

The South Platte River at this location diverges into two sections. The flow on the right side of the river is much higher than the flow on the left side of the river. The area with the lower flow rate is where the Trash Hopper will be installed while the higher flow rate attracts more water sports and other forms of recreation. Since the two areas do not interfere with one another (due to a barrier) the Trash Hopper should not disrupt any of the recreational activities. However, even though public interaction with the device may be slim, signs will be designed and posted around the site. These signs will be used to increase public awareness of the purpose of the device, how it works, and to maintain a safe distance away from the area of operation. The Trash Hopper will be rotating at a very slow speed in an area of slow moving water, so the potential for people to get pulled towards the device is unlikely. Although, contact with the device is slim it is important for people to maintain a safe distance away to ensure no harm comes to anyone or the device. The public's safety as well as the longevity of the Trash Hopper are extremely important. The signs will be useful in helping to increase public awareness of multiple different aspects such as personal safety around the area and how trash in waterways affects the planet.

The Trash Hopper will be spanning a large area of the South Platte so one consideration that was taken into account was how this device may affect wildlife. Fish in particular need to be able to pass under or through the device without getting stuck or harmed. The Trash Hopper floats on top of the water allowing fish to safely swim under it. As stated before, the device is rotating at a slow enough speed to not bring harm to anyone who comes into contact with it while being a fast enough speed to direct the trash into the waste bin. Noise is also an issue that could affect both wildlife and the public. Since the device will be powered by a motor, there is potential for the motor to disrupt the activity in the area by causing noise pollution. However, the slow rotation of the device in the water should ensure the noise level of the motor will not be disruptive to the surrounding area.

Safety is an important aspect to consider when designing a device to be placed in waterways. This device will interact or be around many forms of wildlife and people so it is crucial to produce a design that will be safe for those that may come into contact with it. Some design considerations used to protect others as well as the device are a textured adhesive sprayed on the exterior to ensure there are no sharp edges and signs to help with public awareness of the river clean-up system. The prototype is constructed with two different materials: abs piping and sheet metal. The ABS piping is the base of the auger while the sheet metal was used to create the corkscrew design. At the smaller scale the sheet metal is sharp and could potentially harm the user. However, at a larger scale the thickness of the corkscrew blades will be increased to a size that will allow for the edges to be dull instead of sharp. The purpose of this design is to direct the trash into a bin by influencing the flow of the water so it is unnecessary for the corkscrew to have sharp edges in the final design. For extra precaution, a spray on adhesive material was used on the prototype to ensure the fins were rounded and had a rubbery texture. The material used was Flex Seal. This solution adhered to the ABS and sheet metal giving the device a cleaner look while dulling and removing the sharp edges along the metal blades.

Many design considerations were taken into account when constructing the final prototype. Each one of these focused on the safety and potential impacts the Trash Hopper could have on the stakeholders in the South Platte River area. The area near Confluence Park consists of numerous types of recreation, animal activity, shoppers, and families. By taking these stakeholders into account the final prototype has minimal noise pollution, rotates slowly as to not harm anyone who comes into contact with it, and has no sharp edges. The area around the Trash Hopper will also have signs posted to increase public awareness of the trash removal process and to stay back a safe distance from the device. While the purpose of the device is to remove trash from the waterway it is also important for it to be safe for the public to be around which is why multiple design considerations were used to improve the safety aspect of the Trash Hopper.

6. Lessons Learned and Next Steps

After spending the past two semesters working on the project, several lessons were learned about the engineering design process and prototyping. Design matrices were effective for quick decision making and choosing between a few similar options. These tools were used when deciding between designs, materials, dimensions, and design parameters. The most useful decision tool was testing and iteration, however. It was easier to narrow down design parameters when there were clear testing results showing the functionality. Testing was conducted to optimize auger parameters such as diameter, pitch, thread height, and auger manufacturing method. Several prototypes and iterations were made to the design after testing was conducted and gave clear results about how effective certain parameters were. Originally 3D printing was thought to be the best manufacturing method for the auger component. However, after creating an auger using 3D printing and other augers using PVC and sheet metal, it was determined that the quality and size capabilities of the 3D printed augers did not meet requirements. The testing of these two augers allowed us to quickly eliminate one fabrication method.

Another valuable lesson learned was to always prepare for the worst when working in the field. Testing our prototype at the final competition can be considered field, as time and material were limited. Unfortunate hurdles came up during the final competition that the team was unable to fix in the allotted time. The motor fried during the test, and the auger did not float during the high flow test. The team learned to be prepared for failure in the field and bring backups in case of any potential problems. The changes that would have been made to the design included waterproofing the motor and adding casing. The prototype should have been streamlined for easy setup before entering the flume, as it took much longer than the allotted 10 minutes. More tests would have been conducted in hindsight to account for failures faster.

Many valuable lessons were learned throughout the semester through the design, prototyping, and testing process that will be applied to future projects and work. The final design was one that the team is proud of and felt solved this important issue.

References

[1] C. Schmidt, "Estimation of Global Plastic Loads Delivered by Rivers into the Sea," *Helmholtz*, 2012. [Online]. Available: http://www.ufz.de/export/data/2/149396_EGU_2017_Schmidt.pdf.

[2] R. G. Budynas and J. K. Nisbett, *Shigley's Mechanical Engineering Design*, 10th ed. New York, NY: McGraw Hill Education, 2015.

[3] The Greenway Foundation, "Clean River Design Challenge Student Handbook," *Clean River Design Challenge Student Handbook*. The Greenway Foundation, Denver, CO, 2018.

[4] YouTube. (2013). *Sweep auger*. [online] Available at: https://www.youtube.com/watch?v=SsJ29jQluQw [Accessed 15 Sep. 2018].

Appendix

Bill of Materials: Prototype and full scale

Table 2: Bill of Materials for Prototype

Final Prototype		
Component	**Material**	**Cost**
Auger	3"x10' ABS Pipe	$16.12
	1'x1' Sheet Metal	$5.98
	Roller Bearings x 2	$62.82
	3" to 1 1/2" ABS Bushing x 2	$11.58
	3" ABS Coupler x 2	$5.98
	3" ABS Cap x 2	$13.14
	1/2" Round Steel Tube	$7.62
Supports	1/2" x 2' PVC Pipe x 2	$2.62
	3/4" PVC Tee x 2	$1.22
	Threaded Rod 36"x1/4-20	$1.31
	5/16 Cut Washers x 4	$2.60
	Jam Zinc Nut x 2	$3.54
Motor Assembly	DC 12V Motor (30RPM)	$15.00
	Steel Plate	$5.98
	12"x3/8 Stainless Rod	$2.86
	12V Battery	$19.99
	Wiring	$6.00
Waste Bin/Pulley	Rivets	$3.54
	Steel Mesh	$10.48
	Pulley	$8.71
	Rope	$3.40
	Flat alum bar	$5.72
	ZINC SCREW	$1.18
Total	**$217.39**	

Table 3: Full Scale Prototype

Component	Material	Cost
Auger	8"x80' ABS Pipe	$600.00
	24"x4' Sheet Metal	$200.00
	Roller Bearings x 2	$160.00
	8" to 6" ABS Bushing x 2	$40.00
	8" ABS Coupler x 2	$20.00
	8" ABS Cap x 2	$26.00
	12" Round Steel Tube	$250.00
Supports	Steel Columns: 12" Diameter	$247.00
	Risers	$20.00
Motor Assembly	DC 12V Motor (30RPM)	$125.00
	Solar Panel	$216.00
	Steel Plate	$20.00
	Battery	$45.00
	Wiring	$25.00
Waste Bin/Pulley	Rivets	$20.00
	Steel Mesh	$120.00
	Pulley	$32.00
	Cable	$155.40
	Flat alum bar	$56.00
	ZINC SCREW	$13.00
Machining	Machining Cost	**$3,585.60**
Total	**$5,976.00**	

Properties of Water:

$k := 0.461 \qquad \rho_w := 0.036127 \, \frac{lb}{in^3} \qquad g := 9.81 \, \frac{m}{s^2}$

Initial Estimated South Platte Properties:

$z_o := 0.3 \, ft \qquad Q := 700 \, \frac{ft^3}{s} \qquad h := 6 \, ft \qquad A := 95 \, ft \cdot 4 \, ft = 380 \, ft^2 \qquad v := \frac{Q}{A} = 1.842 \, \frac{ft}{s}$

Waste Wiper Drag:

$A_w := 2 \, ft \cdot 1 \, ft = 2 \, ft^2 \qquad n_w := 20$ Number of waste-wiper segments

$$C_D := \frac{k^2}{\left[\ln\left(\frac{h}{z_o}\right) - 1\right]^2} = [0.053]$$

$$F_D := C_D \cdot 0.5 \cdot \rho_w \cdot v^2 \cdot A_w \cdot n_w = [7.026] \, lbf$$

Corkscrew Calculations:

$D_o := 2.5 \, ft \qquad D_i := 1 \, ft \qquad L := 48 \, ft \qquad A_c := 2 \cdot \pi \cdot \left(\frac{D_i}{2}\right) \cdot L = 150.796 \, ft^2$

$$F_D := C_D \cdot 0.5 \cdot \rho_w \cdot v^2 \cdot \frac{A_c}{2} = [13.244] \, lbf$$

Buoyancy

$$V_{half} := \frac{149860.9 \, in^3}{2} = \left(7.493 \cdot 10^4\right) in^3$$

$$F_b := \rho_w \cdot V_{half} \cdot g = \left(2.708 \cdot 10^3\right) lbf$$

Approximate weight from Solidworks comes out to 2615 lbf, so the corkscrew will float.

Figure 15: Finding the buoyancy and drag forces on the corkscrew

-Force of drag from trash is negligible, especially at surface
-Assume water as a point mass for simplicity

F = load
R = outer radius
r = inner radius
V = volume of water inbetween threads
L = length of corkscrew

$$R := \frac{D_o}{2} = 15\ in$$

$$r := \frac{D_i}{2} = 6\ in$$

$$V_w := (R^2 - r^2) \cdot \pi \cdot L \cdot \left(\frac{1}{2}\right) = (1.71 \cdot 10^5)\ in^3$$

$$F := V_w \cdot \rho_w \cdot g = (6.18 \cdot 10^3)\ lbf$$

Figure 16: Finding the total weight of the water being displaced by the corkscrew threads

Bending Moment Including Buoyancy Force

$F_c := 2615\ lbf$ $I := 1391.42\ in^4$ $c := 12\ in$ $\sigma_{yield} := 6526.7\ psi$

$$F_{net} := F_b - F_c = 92.937\ lbf$$

$$M_{max} := \frac{(F_{net} \cdot L)}{4} = (1.338 \cdot 10^4)\ lbf \cdot in$$

$$\sigma_{max} := \frac{(M_{max} \cdot c)}{I} = 115.418\ psi$$

$$FOS := \frac{\sigma_{yield}}{\sigma_{max}} = 56.548$$

Bending Moment Disregarding Buoyancy Force

$$F_{net} := F_c = (2.615 \cdot 10^3)\ lbf$$

$$M_{max} := \frac{(F_{net} \cdot L)}{4} = (3.766 \cdot 10^5)\ lbf \cdot in$$

$$\sigma_{max} := \frac{(M_{max} \cdot c)}{I} = (3.248 \cdot 10^3)\ psi \qquad FOS := \frac{\sigma_{yield}}{\sigma_{max}} = 2.01$$

Figure 17: Finding the bending moment applied by the weight of the corkscrew

Velocity Calculations using USGS South Platte River at Englewood, CO

Average Discharge, cfs (1983-2018)

Jan	Feb	Mar	Apr	May	Jun
76	82	125	329	734	690
Jul	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
468	331	136	129	113	81

High, Q_{high}: 3221 cfs (June 2015)

Low, Q_{low}: 21.4 cfs (February 2015)

Average, Q_{avg}: 274.5 cfs

Gage height

Average crest (1983-2018), h_{crest}: 7.85 ft

Average low (1983-2018), h_{low}: 1.2 ft

Average gage height, h_{avg}: 4.5 ft

Site width

High flow, b_{high}: 83 ft

Low flow, b_{low}: 54 ft

Peak Discharge

A = b_{high} x h_{crest} = 83 ft x 7.85 ft = 651.55 ft^2

Discharge = velocity x area => V = $\frac{Q_{high}}{A} = \frac{3221 \frac{ft^3}{s}}{651.55\ ft^2} = \mathbf{5.1}\ \frac{ft}{s}$

Average Discharge

High flow:

A = b_{high} x h_{avg} = 83 ft x 4.5 ft = 373.5 ft^2

V = $\frac{Q_{avg}}{A} = \frac{274.5 \frac{ft^3}{s}}{373.5\ ft^2} = \mathbf{0.73}\ \frac{ft}{s}$

Low flow:

A = b_{low} x h_{avg} = 54 ft x 4.5 ft = 243 ft^2

V = $\frac{Q_{avg}}{A} = \frac{274.5 \frac{ft^3}{s}}{243\ ft^2} = \mathbf{1.13}\ \frac{ft}{s}$

Minimum Discharge

A = b_{low} x h_{low} = 54 ft x 1.2 ft = 64.8 ft^2

V = $\frac{Q_{low}}{A} = \frac{21.4 \frac{ft^3}{s}}{64.8\ ft^2} = \mathbf{0.33}\ \frac{ft}{s}$

Figure 18: Velocity Calculations for South Platte

Appendix A: Judgeing Criteria for Round 1

Criteria for Judging of the Clean River Design Challenge -- Round 1 Design		
Team Name: ____ Judge Name:____	Possible Points	Judges Score
Design • Innovation • Captures trash on the water's surface and the water column • Cost of device: ____________ • Design is implementable and scalable • Operational energy needs (up to 5 bonus points if device does not need to be connected to the electrical grid)	**15**	
Aesthetics • Visual appearance serves a purpose • Has educational value (signage or artistic design) • Does it operate quietly? • Does it emit odors?	**15**	
Impacts of Operation • Allows passage for fish and other wildlife • Materials do not degrade surrounding air, water, and/or soil health • Safe for pedestrians and recreational users to be near	**15**	
Hydraulic Consideration • Ability to function in a variety of flow conditions (low, normal, bank full, flood) • Resistance to damage during flood events • Does it cause sediment accumulation and/or bank erosion? • Minimal head loss	**15**	

Installation, Maintenance, and Trash Removal • Ease of installation: Does it need additional structures/work to be installed? • Longevity of materials; how frequently will pieces need to be replaced? • Trash collection capacity: ____________ • Effectively gets the trash to a serviceable location • How is trash off loaded/how is the device reset to continue collecting trash	**25**	
Presentation, Design Handout, & PowerPoint • Did the level and quality of work reflect the number of students on the team? (especially applicable for large teams) • Professional PowerPoint File • Professionalism of presentation • Preparation level/confidence • Voice projection • Handout: 1 page (2 sided)— includes team name, student names, school, a design drawing, materials breakdown, potential operational impacts, trash servicing plan. • Writing skills: grammar, spelling, etc. • Ability to answer judges' questions with concisely and with expertise	**15**	
Any Deductions and Bonus Points (judges will list reasons)		
TOTAL	**100**	


SINCE 1974
CAUTION
SLIPPERY
VISITOR
DENVER


THE GREENWAY FOUNDATION
SINCE 1974
THE GREENWAY FOUNDATION
The Water Connection's
2018–19 Clean River Design Challenge
THE GREENWAY FOUNDATION
THE WATER CONNECTION
Clean River Design Challenge
COLORADO
Colorado Water Conservation Board
Department of Natural Resources
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
Otak
ROXBOROUGH WATER AND SANITATION DISTRICT
METRO WASTEWATER RECLAMATION DISTRICT
METROPOLITAN STATE UNIVERSITY OF DENVER
COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT
UNIVERSITY of DENVER
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CERTIFICATE


Team Black-Crowned Night Herons
The Water Connection and the Greenway Foundation
2018 Clean River Design Challenge
Metropolitan State University Denver
School of industrial design
The Water Connection's
2018–19 Clean River Design Challenge
Clean River Design Challenge
Otak
COLORADO SCHOOL OF MINES
UNIVERSITY of DENVER
THE GREENWAY FOUNDATION
THE WATER CONNECTION


Design
Autonomous & fully mechanical operation
Integrated, powered trash emptying system
Boom & submerged cage capture all floating trash
Final cost: $21,000.00
No grid connection
Scalable
Same design would work in many sizes
COLORADO SCHOOL OF MINES
The Water Connection's
2018–19 Clean River Design Challenge
Clean River Design Challenge
Otak
UNIVERSITY of DENVER
THE GREENWAY FOUNDATION
THE WATER CONNECTION
THE GREENWAY FOUNDATION

<u>Subject Line:</u> Round 1 Winners of the 2018-19 Clean River Design Challenge
<u>Date Sent:</u> 12/11/2018
<u>Number of Recipients:</u> 8,658

Design Presentations of the Clean River Design Challenge!

The Water Connection was happy to host the Round 1 presentations for the third annual Clean River Design Challenge (CRDC) last week at INDUSTRY RiNo Station. Thank you to INDUSTRY for donating your wonderful space for this competition!

CRDC is a two-semester competition where teams of undergraduate students are tasked with designing and building a trash removal device to be placed in an urban waterway. This year we have 5 teams from 3 universities-- Metropolitan State University of Denver, Colorado School of Mines, and University of Denver. In Round 1, each team presented their designs to a panel of judges, and the top 3 were selected! All teams are invited to participate in Round 2 of the competition, where teams build a model of their design.

First Place: Team Trash Trouts from Colorado School of Mines
Second Place: River Guardians from Colorado School of Mines
Third Place: Team Black-Crowned Night Herons from Metropolitan State University of Denver

To view photos from the presentations, check out our Facebook Album!

To learn more about this competition, please check out our website.

Ways to Save for the Holidays

Xcel Energy offers a selection of programs and energy-saving tips that can help customers conserve energy while saving money this holiday season. They are committed to giving customers ways to control energy use in their home by offering programs varying from renewable energy options to energy-efficiency rebates. There are many ways to save money ranging from small changes around the house, to larger whole-home upgrades. One of the top energy consumers in a home is heating equipment. Paired with cooling equipment, these appliances consume almost 50 percent of a customer's energy bill. To offset the cost of a new high efficiency appliance, Xcel Energy offers natural gas furnace rebates and financing options.

Xcel Energy also offers weatherization services, in partnership with Energy Outreach Colorado and weatherization agencies, for income-qualified customers in single-family homes, multifamily and nonprofit buildings to help lower energy costs for those who need it the most. Services include free energy assessments, rebates and behavior-change education. Over the years, Xcel Energy has put $18 million into programs directly benefiting the low-income community.

To learn more ways to save energy and money this season, visit xcelenergy.com/WaysToSave.

For more information or to donate, please visit
www.greenwayfoundation.org

The Greenway Foundation
1855 South Pearl St, Suite 40, Denver, CO 80210

Subject Line: Winners of the Clean River Design Challenge 2018-19

<u>Date Sent:</u> 4/24/2019
<u>Number of Recipients:</u> 8,290

2018-19 Clean River Design Challenge Results

After two semesters of hard work, the top three models from the third Clean River Design Challenge were chosen last week by a panel of judges! This year, teams were tasked with designing and building a scaled model of an in-stream trash removal device to be near the old head gate structure near the confluence of the South Platte River and the Cherry Creek. We're proud to announce this year's winners:

First Place: Black Crowned Night Herons from Metropolitan State University of Denver
Second Place: Team Trash Trouts from Colorado School of Mines
Third Place: River Guardians from Colorado School of Mines

View photos from the entire competition here!

Click here to watch the segment about the CRDC on Channel 4 CBS Denver.

City Nature Challenge is back!

Last year, with 4,811 species identified, Denver ranked 25th in observation of over 60 cities that participated in the global bio-blitz. Next weekend, it is happening again with over 120 cities participating globally!

Between April 26-29: We need you to get out and observe nature! Take pictures and post them to iNaturalist.

Between April 30- May 5: We need naturalists' help in identifying the observed species.

Denver- we need you to get out and observe... You may be surprised with the wilderness that our City offers!

National Western Center

The redevelopment of the National Western Center is underway with the development of a riverfront open space and a variety of world-class facilities designed to support agriculture, education, and research in the heart of Denver. New access to the South Platte riverfront in this area will provide six acres of vibrant, multi-use open space. Opportunities along the riverfront will include overlooks, educational spaces, and research opportunities in collaboration with Colorado State University's nearby Water Building.

Click on the image to experience a fly through video of the future campus!
Visit nationalwesterncenter.com to learn more.

For more information or to donate, please visit
www.greenwayfoundation.org

Privacy Policy | Unsubscribe

Team Trash Trouts	River Guardians	Denver Pioneers
Colorado School of Mines	**Colorado School of Mines**	**University of Denver**
Natalie Haber	Marina Hansen	Joseph Burke
Matthew Hansing	Jessica Thompson	George Andrulonis
Isaac Jimenez	Bryan Cazier	Edgar Del Real Garcia
John McNamara	Alexander Turner	Antonio Sermao
Kent Scott	Emmanuel Almaras-Sandoval	Madeline Nilan
Sean Kelly	Jonathan Donehower	
		Faculty Lead: Ann Deml
Faculty Lead: Lisa Woodward	Faculty Lead: Bahman Rejai	Faculty Lead: Adam York

Black Crowned Night Herons (Round 1)	Black Crowned Night Herons (Round 2)	Blau (Round 1 Only)
Metropolitan State University of Denver	**Metropolitan State University of Denver**	**Metropolitan State University of Denver**
Colin Scanlon	Samantha Donen	Vlad Keeper
Samantha Donen	Tyson Rasmussen	Tyler Hallman
Scott Duggan	Matthew Silva	Ian Jakublak
Curren Gaspar	Charlie Coil	Tucker McKinzie
Andrew Reardon		Tom Witteveen
Hiram Reyes		Chris Ng
Raul Varela Villegas		John Nutter
Luke Wheeler		Justin Smith
		Makinzie Vogel
Faculty Lead: Ted Shin	Faculty Lead: Ted Shin	
Faculty Lead: Gregg Harvey	Faculty Lead: Gregg Harvey	Faculty Lead: Gregg Harvey

Gmail by Google

Lauren Berent <lauren@greenwayfoundation.org>

CRDC Judging April 18th

3 messages

Lauren Berent <lauren@greenwayfoundation.org> Thu, Apr 11, 2019 at 11:09 AM
To: Ben Wade - DNR <ben.wade@state.co.us>

Hello Ben,

We would like to invite you to join us for the Round 2 Judging Day on April 18th, 9 am - 2:30 pm at the U.S. Bureau of Reclamation Hydraulics Lab! I realize this is again short notice, but I hope you are able to join us for at least part of the day!

Getting There:
The Federal Center campus is located south of 6th Ave and between Union and Kipling. The easiest way I've found to get there is to put **'Denver Federal Center Reclamation Denver, CO 80215'** into your map app.

Security:
Please remember that this competition is held in a federal campus/building, so you will need to present a US government issued ID at both the security gate and at the building. When you are at the security gate, please tell the guard that you are headed to the hydraulics lab in Building 56 for a student competition. Before you enter the building, please be sure you bring everything with you that you will need. Security frowns upon people leaving/reentering the building more than absolutely necessary. Check in at the security desk to receive a visitors badge.

Please let me know if you are able to attend and if you have any questions!
Lauren

Lauren Berent
Events & Volunteer Director
The Greenway Foundation
Phone: 303.743.9720 ext. 850
www.greenwayfoundation.org

Wade - DNR, Ben <ben.wade@state.co.us> Thu, Apr 11, 2019 at 12:59 PM
To: Lauren Berent <lauren@greenwayfoundation.org>

Well Lauren...dang it. There is another Water Plan grant I'm the PM on and they have scheduled a meeting the same day in Keystone. Sorry to miss this. Will you be filming any of the demonstrations? I would love to see those
[Quoted text hidden]
--
Ben Wade
Project Manager
Water Supply Planning
DNR CO COLORADO
Colorado Water Conservation Board
Department of Natural Resources
O 303-866-3441 x3238 | F 303-866-4474
1313 Sherman St., Rm. 721, Denver, CO 80203
ben.wade@state.co.us | cwcb.state.co.us

Lauren Berent <lauren@greenwayfoundation.org> Thu, Apr 11, 2019 at 1:09 PM
To: "Wade - DNR, Ben" <ben.wade@state.co.us>

Bummer! We will definitely taking photographs and there will be videos mounted in the flume, however we won't be filming the entire presentation/demonstration for any team. Whatever we do capture, we will of course be able to share that with you! If there is anyone else from you team who you think would be interested in attending, please let me know!

Enjoy Keystone!
Lauren
[Quoted text hidden]
[Quoted text hidden]

Link to Round 2 photos from the 2018-19 Clean River Design Challenge:
https://www.dropbox.com/sh/8v5td6lsuq55kyh/AAAJBJmgAANIuigD6Nj3t_aRa?dl=0

Additional photos from the Round 1 presentations of the 2018-2019 Clean River Design Challenge available upon request.

In-flume videos from the Round 2 model tests of the 2018-2019 Clean River Design Challenge available upon request.

Criteria for Judging of the Clean River Design Challenge -- Round 2 Model		
Team Name: ______________________________ Judge Name:______________________________	Points (Relative level of importance)	Judge's Score
Design (of both model and full-scale device) • Innovation and creativity • Captures trash on the water's surface and in the water column • Cost of scaled model: ____________ • Projected cost of full scale device: ____________ • Is design implementable and scalable? • Operational energy needs: Does it need power? Where is that power coming from?	**10**	
Aesthetics (of both model and full-scale device) • Visual appearance serves a purpose beyond function • Is there educational value (signage or artistic design)? • Fits in with the rest of the site	**10**	
Impacts of Operation (of full-scale device) • Allows passage for fish and other wildlife • Materials do not degrade surrounding air, water, and/or soil health • Safe for pedestrians and recreational users to be near	**10**	
Hydraulic Consideration (of both model and full-scale device) • Ability to function in a variety of flow conditions (low, high, flood) • Would it be able to withstand damage during flood events? • Would it cause sediment accumulation and/or bank erosion? • Minimal head loss; minimal impact on water level	**10**	

Installation, Maintenance, and Trash Removal (of both model and full-scale device) • Ease of installation: Does it need additional structures/work to be installed? • Approximate longevity of materials • Effectively/easily gets the trash to a serviceable location • Trash collection capacity/how often would full scale model need to be emptied?	**20**	
Model Test, Handout, and Presentation • Number of pieces of trash collected by model: ____________ • Handout: 4 total pages— includes team name, student names, school, a design drawing, materials breakdown, cost of model and cost estimate of full scale, highlights what make their design the best • Did the level and quality of work reflect the number of students on the team? (especially applicable for large teams; not all members of team are required to speak during presentation) • Did the teams create anything "extra": educational materials, art work, plan for other aesthetics to the site; etc. • Install and test model within allotted time • Prepared for the presentation and testing • Preparation level/confidence • Professionalism of presentation and model testing • Ability to answer judges' questions with concisely and with expertise	**40**	
Any Deductions and Bonus Points (judges please list reasons)		
TOTAL	**100**	

Notes:

First Place:
Black Crowned Night Herons
Metropolitan State University of Denver

Second Place:
Team Trash Trouts
Colorado School
of Mines

Third Place:
River Guardians
Colorado School of Mines


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Coleman

2018-19 Clean River Design Challenge Final Design Report

Submitted to:

The Greenway Foundation
1855 S Pearl St #40
Denver, CO 80210

ATTN: Lauren Berent

Submitted by:

F18-22
Team Trash Trouts
Engineering, Design, & Society
Colorado School of Mines
Golden, Colorado 80401

Capstone Design@Mines

Final Design Report

Team members:
Kent Scott: Project Manager
Natalie Haber: Communications Lead
Matthew Hansing: Resource Manager
Isaac Jimenez Jr.: Technical Specialist
Sean Kelly: Research Lead
John McNamara: Aesthetics Manager
Lisa Woodward: Project Advisor

April 30, 2019

Acknowledgments

Team Trash Trouts would like to express our deepest appreciation to the Greenway Foundation and The Water Connection for the opportunity to participate in the 2018-2019 Clean River Design Challenge. A special gratitude is given to competition coordinator Lauren Berent whose suggestions and design feedback helped the team perform successfully at both rounds of the competition. The Clean River Design Challenge allowed team members to collaborate and experience the ins and outs of a real-world engineering project.

Furthermore, Team Trash Trouts would like to acknowledge with much appreciation the crucial role of our Project Advisor Lisa Woodward whose project advice from her extensive real-world engineering experience helped the team to develop a successful project and to improve both our hard and soft technical skills.

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2018-19 Clean River Design Challenge Final Design Report

Prepared by:
Kent Scott, Natalie Haber, Matthew Hansing, Isaac Jimenez Jr., Sean Kelly, John McNamara
F18-22
Team Trash Trouts
College of Engineering and Computational Sciences
Colorado School of Mines

Executive Summary

In the Fall of 2018, Team Trash Trouts entered the Clean River Design Challenge, a competition put on by The Greenway Foundation and The Water Connection, that brings together groups of collegiate students around the Denver Metro area with a goal of designing and prototyping a device that removes trash from urban waterways. The existence of litter in public spaces is a common occurrence in many cities. Through natural forces or intentional means, trash finds its way into rivers and other bodies of water. Water-bound trash is not only an eye-sore for the general public but also has negative impacts on the surrounding environment. Small pieces of litter may be mistaken as a source of food by wildlife which may cause injury or death. Large items in rivers may cause a disruption to the natural flow or create unnatural blockages. Degradable trash can even release dangerous chemicals resulting in contaminated water sources.

Figure 1: Site Location

The Fall 2018 - Spring 2019 Clean River Design Challenge called for a trash removal device to be implemented on the west bank of the South Platte River, south of Shoemaker Plaza (see Figure 1). The Design Challenge was broken up into two phases. The first project phase included research of urban waterways, the contacting of stakeholders and the development of a conceptual design solution. The trash collection system was designed with consideration to stakeholders involved in installation, maintenance, environmental impact and aethstetics. A final design concept and presentation, including a powerpoint and a handout, was given to a panel of expert judges in December 2018. The second project phase (Spring 2019) required the construction of a scaled model to test the mechanisms and feasibility of the design. The second semester involved the creation, iteration, and implementation of a scaled prototype which competed in a design competition against four other teams in April 2019. The teams gathered at the Bureau of Reclamation to present and test their prototypes in the test flume. Team Trash Trouts finished second place and received a cash prize. The winning design from Metro State is scheduled to be implemented in the South Platte River.

2018-19 Clean River Design Challenge Final Design Report

Prepared by:
Kent Scott, Natalie Haber, Matthew Hansing, Isaac Jimenez Jr., Sean Kelly, John McNamara
F18-22
Team Trash Trouts
College of Engineering and Computational Sciences
Colorado School of Mines

1. Introduction

The presence of litter in our natural spaces creates unattractive visuals and can even make them unusable. The growth and seeding of plants can be disturbed and animals can ingest trash that may cause injury or death. Larger items can create major disruptions to water flow. There are many different ways for trash to end up in urban waterways. These bodies of water tend to extend along roads and public spaces which are prone to illegal dumping. Whether intentional or by accident, trash commonly ends up on sidewalks, streets, and other open spaces. During a rainstorm or as a result of melting snow, water flows through these open spaces picking up any trash in its path. This trash-filled water then enters storm drains and is directed into the nearby bodies of water. Litter in the South Platte River in downtown Denver is a major problem that needs to be addressed. The Fall 2018 - Spring 2019 Clean River Design Challenge called for a trash removal device to be implemented on the west bank of the South Platte River, south of Shoemaker Plaza. Team Trash Trouts entered the Clean River Design Challenge and set out to develop a solution to Denver's trash problem.

The Clean River Design Challenge is hosted by The Water Connection department of the Greenway Foundation. The Greenway Foundation (TGF) is a non-profit located in Denver, Colorado focused on revitalizing the South Platte River and the surrounding communities. The Water Connection serves as the primary source of water policy and water resources for the Greenway Foundation with a focus on the issue of urban waterway trash. Other stakeholders for this project include people who visit the part of the South Platte River where our design will be implemented: the City and County of Denver, Denver Parks and Recreation, Denver Urban Drainage and Flood Control District as well as water field experts and local engineering firms who may provide consulting services on the project. The importance of The Clean River Design Challenge is evident. As the human population continues to grow, the amount of litter and garbage found in urban areas will increase as well. This project aims to not only tackle the widespread issue of trash in urban waterways but to also raise awareness on the sources and migration of litter.

Team Trash Trouts fully participated in the Greenway Foundation's Clean River Design Challenge. As a team, we worked collaboratively to design and prototype a device that filters floating trash and debris from the South Platte River in order to make a positive impact on the natural environment. The conceptual design and prototype adhered to the standards outlined in the Clean River Design Challenge Student Handbook provided by the Greenway Foundation.

The design was considerate of stakeholders, of the natural environment, and aimed to be effective in reducing the amount of floating trash in the South Platte River. The first half of the project focused on the conceptual design of the device, and the second half was concerned with prototyping and testing.

Team Trash Trouts committed to designing and prototyping a trash collection device that will effectively remove trash from the river, while maintaining the aesthetic integrity of the site. The team followed the provided Senior Design schedule to ensure all deliverables were finished and provided to the client in a timely manner. Team Trash Trouts emphasized efficiency, sustainability, and stakeholders in order to design and prototype the most effective device to be implemented in the South Platte River.

2. Project Review

After receiving our individual assignments by the Colorado School of Mines Senior Design Department to the Clean River Design Challenge Team #1, several team meetings were dedicated to researching the competition and the drafting of a project charter. The first section of the charter provided an overview of the project by defining what the project involved, who the project was for, and the importance of the project. Below are excerpts from the project charter comprising the project overview:

The Clean River Design Project involves the development of a trash collection solution on the South Platte River and raising awareness for trash pollution in the city of Denver, Colorado. The Design Challenge will be broken up into two phases. The first project phase will include research of urban waterways and the development of conceptual design solution. The second project phase requires the construction of a scaled model to test the mechanisms and feasibility of the design. The trash collection system will be designed with consideration to stakeholders involved in installation, maintenance, environmental impact and aethstetics. A final design concept must be completed by December along with a presentation to a panel of expert judges. The following semester will involve the creation, iteration, and implementation of a scaled prototype to compete in the design competition by April.

The Clean River Design Challenge is hosted by The Water Connection department of the Greenway Foundation. The Greenway Foundation (TGF) is a non-profit located in Denver, Colorado focused on revitalizing the South Platte River and the surrounding communities. The Water Connection serves as the primary source of water policy and water resources for the Greenway Foundation with a focus on the issue of urban waterway trash. Other stakeholders for this project include people who visit the part of the South Platte River where our design will be implemented, the City and County of Denver, Denver Parks and Recreation, Denver Urban Drainage and Flood Control District as well as water field experts and local engineering firms who may provide consulting services on the project.

The team defined goals for the project in the form of a scope statement. Team Trash Trout's scope statement was stated as follows: 1) the goal of this project is to clean the South Platte River of floating trash by means of a easy to maintain, aesthetically pleasing device that would be designed and constructed by our team and 2) to construct a scaled model of the proposed design (with a detailed construction cost estimate) and provide a comprehensive final design report. The scope statement was accompanied with a list of all known restrictions, exclusions and assumptions known by the team to limit the range of design possibilities and a list of team deliverables that were provided to the project advisor and the client.

Project Restrictions, Exclusions, and Assumptions

- There is a maximum budget of $1000 supplied by the Greenway Foundation for the construction of the scaled prototype
- The project has many different stakeholders that must be taken into consideration:

    - The Water Connection of the Greenway Foundation
    - County and City of Denver
    - Local engineering firms
    - Experts in the water field
- The final design will be based on projected implementation into the South Platte River.
- The final prototype will compete in a 2' by 3' water channel with simulated trash consisting of packaging styrofoam and other small floating debris
- The final design will be judged on several criteria by expert panel of judges:
    - Innovation and functionality of design
    - Aethstetics
    - Impact of operation on surrounding environment
    - Hydraulic consideration
    - Installation, maintenance, and trash removal
    - Success of scaled model
- Final design must take into account the demands of the South Platte River
- The scaled prototype must fix and operate inside the testing rig

List of Deliverables
The following list of deliverables defined the targeted output of the project. The team delivered the following items to the client and project advisor as required throughout both semesters:

1. Letter of Intent
    a. Project Charter
    b. Project Schedule
    c. Preliminary Client Needs Table
2. Concept Portfolio
    a. Detailed Engineering Metrics/Constraints
3. Preliminary Project Drawing & Calculations Package
4. Final Design Report
    a. CAD Model of the trash collection system
    b. Complete Drawing Package
    c. Detailed Bill of Materials or Material Takeoff
    d. Construction Cost Estimate
5. Preliminary, Intermediate, and Final Design Review Presentations
6. A scaled prototype to be tested at the Colorado Bureau of Reclamation facility
    a. An analysis of river filtration trials.
    b. A working Prototype of the river filtration device.

In addition to the scope statement and the project restrictions, the team utilized the judging criteria provided in the CRDC Student Handbook to further drive the creation of the conceptual design and functional prototype. Each judging category presented new criteria that the final design aimed to meet. The competition featured a panel of expert judges who evaluated each team's conceptual design during Round 1 and the physical model prototype of the design during Round 2. The judging panel scored each design according to a variety of different categories. Descriptions of the criteria for Round 1 and Round 2 are provided below:

1) **Design (Round 1 and 2)**
    - Level of innovation
    - Cost of trash removal device
    - Captures floating trash and trash in water column
    - Scalability and implementability
    - Operational energy requirements
2) **Aesthetics (Round 1 and 2)**
    - Visual appearance with purpose
    - Educational value
    - Noise of operation
    - Associated smell with trash collection
3) **Impacts of Operation (Round 1 and 2)**
    - Allows passage for fish and other wildlife
    - Materials do not harm health of surrounding environment of air, water, and soil
    - No issues with safety of surrounding pedestrians or recreational water users
4) **Hydraulic Consideration (Round 1 and 2)**
    - Functions in variety of flow conditions (low, normal, bank full, flood)
    - Damage resistant during flood or high flow events
    - Potential for sediment accumulation and/or bank erosion
    - Minimal head loss
5) **Installation, Maintenance, and Trash Removal (Round 1 and 2)**
    - Ease of installation: does it require additional structures or work to be installed?
    - Longevity of materials: will pieces need to be replaced and how often?
    - Trash collection capacity
    - Efficiently moves trash to a serviceable location
    - Process of unloading trash and resetting device to collect more trash
6) **Presentation, Design Handout, and PowerPoint (Round 1)**
    - Does quality and level of work reflect the number of students on the team?
    - Professional PowerPoint File
    - Professionalism of presentation
    - Preparation and level of confidence
    - Voice Projection
    - Handout: 1 page (2-sided) includes team names, student names, school, a design drawing, materials breakdown, potential operational impacts, trash servicing plan
    - Writing skills: grammar, spelling, etc.
    - Ability to answer judges' questions concisely and with expertise
7) **Testing, Design Board (Round 2)**
    - Did the level and quality of work reflect the number of students on the team?
    - Install and test model within allotted time

- ○ Can withstand both low and high flow test rates
- ○ Minimal head loss
- ○ Prepared for the presentation and testing
- ○ Preparation and level of confidence
- ○ Professionalism of presentation and model testing
- ○ Handout: 1 page (2-sided) includes team names, student names, school, a design drawing, materials breakdown, potential operational impacts, trash servicing plan
- ○ Ability to answer judges' questions concisely and with expertise

Team Trash Trouts analyzed the problem by establishing the required project goals and applying all project restrictions. Each team member's engineering knowledge and experience contributed to the development of the most applicable solution for the project site in the South Platte River. Through brainstorming, iteration, and design analysis, the team decided to pursue the "Trash Trap" shown in Figures 2 and 3.

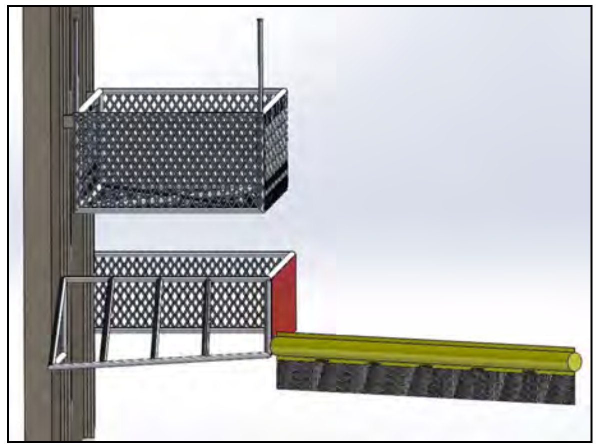


Figure 2: Trash Trap SolidWorks Model with lifted inner cage

Team Trash Trouts faced many challenges during the building of our prototype. The first difficulty was the scaling of the design. The rail system was modified from garage rollers to a curved sliding rail due to the compactness of the available area. In addition, the full flotation system for the outer cage could not be implemented as it would lift the cage above the water level during the low flow conditions. Another challenge was the design of the floating boom to direct trash into our cage system. The boom surface needed to be smooth to prevent trash from sticking. The boom also needed to adjust with the water level and required an appropriate tightness so the force of the water did not change its angle in the water.

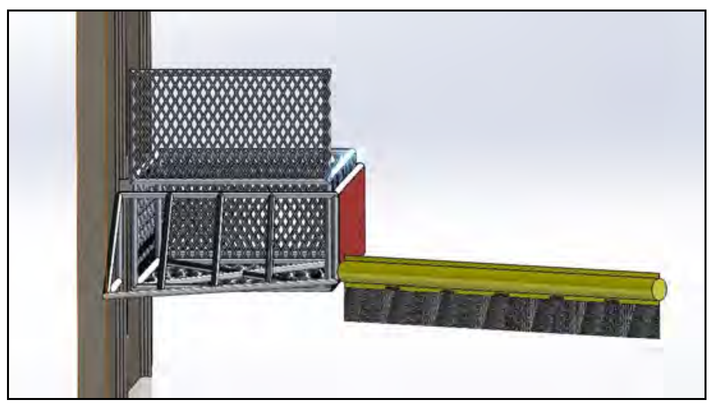


Figure 3: Trash Trap SolidWorks Model

3. Application of Design Methodology

The first semester consisted of the development of a conceptual design for the trash removal system. Background information was gathered from a variety of sources, including information from the Mines competition team from the 2017-2018, stakeholder interaction, and independent research. From analysis of last year's team and previous winners, Team Trash Trouts was able to examine past designs and prototypes for successful characteristics. These previous projects influenced our design and demonstrated that simplicity and aesthetics were just as important as overall function. Stakeholder interaction answered many of our questions, which helped us focus our design on important specifications. By reaching out and making connections, the team was able to better understand multiple perspectives to cater to the needs of the end-users. Independent research filled in the other gaps, and provided us with information about similar projects outside of the Clean River Design Challenge. Technical information, such as average flow rates, was gathered to supplement our engineering knowledge. The knowledge accumulated throughout the semester helped drive the concept selection and final design selection. Our final conceptual design was presented to a judging panel comprised of engineers and water experts. The judges rated our proposal on several criteria. Constructive advice from the panel was taken into consideration during the building of our prototype.

In September, Team Trash Trouts participated in the Fall South Platte Stewardship Day presented by The DaVita Village, The Nature Conservancy, and Jacobs. This event was held near the project site in the South Platte River in downtown Denver. The team utilized this opportunity to give back to the Denver community, to make connections with stakeholders, and to make observations about the river and its trash problem. Several observations were made about the project location:

Observations

- Wide variety of types and sizes of trash
    - Plastic bottles (12 oz to 5 gal), plastic bags, scraps of paper, aluminum cans, tires, couch cushions, shopping carts, etc.
- Trash already collects in one corner of the river as seen in Figure 4
- River also have a lot of natural debris such as tree branches and leaves
- Project location is in a highly visible area and must be aesthetically pleasing

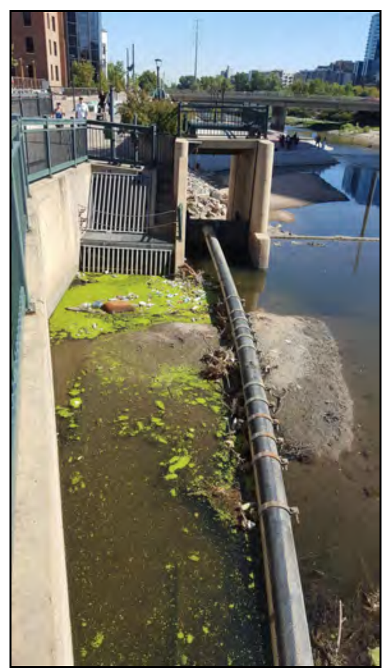


Figure 4 : Project Site Photo

The site visit was instrumental to the team in the generation of initial design ideas. Our preliminary observations were combined with the given project constraints to begin design development. One impression of the existing river infrastructure was to take advantage of the natural collection of trash by the old dam and lock system. A design that redirects trash further upstream or creates a natural flow toward our design would simplify collection by preventing our design from spanning the entire river. After observing large pieces of trash with the ability to damage any design in high flows, the team stipulated that any design would require a system to separate trash collection into two categories of small floating trash and large heavy trash.

To supplement the beginning of the brainstorming process, research was conducted on designs from past years of the Clean River Design Challenge as well as on current trash collection devices to identify successful design characteristics. These devices included the Bandalong Litter Trap in Washington DC (Figure 5) and the Mr. Trash Wheel in Baltimore, Maryland (Figure 6). Each design had distinct advantages and disadvantages to its design, operation, and maintenance. Our team aimed to pull the best aspects of each design in order to create the best possible design for the South Platte River.

Figure 5 : Bandalong Litter Trap in Washington DC

Figure 6 : Mr. Trash Wheel in Baltimore, MD

Concept Exploration

Concept 1: Trash Trap

Our first concept was inspired by the television show "Deadliest Catch" and the fishermen's use of crab traps. The fishermen use a simple, efficient pulley system to retrieve a heavy load of crabs from the bottom of the ocean. Our design team attempted to replicate a version of this process with our Trash Trap design.

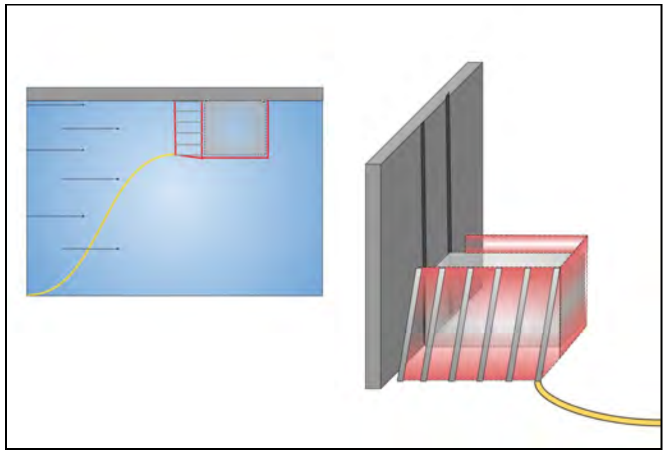


Figure 7: Drawing of Trash Trap

The Trash Trap, as seen in Figure 7, design consists of a floating boom and a system of cages and rails designed to make collection and disposal of trash both simple and efficient. The floating boom spans the full width of the river and includes a nylon skirt extending beneath the water surface to guide floating trash carried by the river current into our cage system. The boom sits at a steep angle to prevent trash from catching on the boom surface. Once the trash has reached the cage system, it first passes through an outer cage designed to deflect large debris that could damage our inner cage. This outer cage, called the "cattle guard', will have evenly spaced bars creating slots sized for common trash items. After bypassing the debris filter, the trash reaches the inner cage which is held in place by a rail system attached to the concrete wall at the collection site in the South Platte River. The inner cage will be buoyant (using a flotation device) to move up and down the rails with water level variation due to weather or seasonal changes. It will also be dimensioned with a length exceeding its width, allowing ample space for trash to pile up before reaching the inner cage entrance. After the cage reaches its maximum capacity, a pulley system will raise the inner cage up the rails to the sidewalk allowing the trash to be emptied and collected by park employees. This will be a cheaper and more simple design than our second concept as shown in Table 1 exploring the advantages and disadvantages of this design.

Table 1: Pros and Cons Table of Trash Trap Design

Pros	**Cons**
Fewer moving parts	Less functional in various flow rates
Lower construction cost	Less aesthetically pleasing
Lower maintenance cost	Greater flow disruption*
Greater protection against large debris	Wildlife may become trapped
Incorporated trash removal system	
No power required	

*flow disruption is unlikely to be a problem in either design

This concept was designed to be simple and inexpensive. The greatest obstacles we will have to overcome if we move forward with this design are improving its aesthetics and filling the cage with trash in an efficient manner. Preventing the trash from building up along the boom will also need to be addressed with proper angles and frictionless surfaces.

Concept 2: Trash Wheel

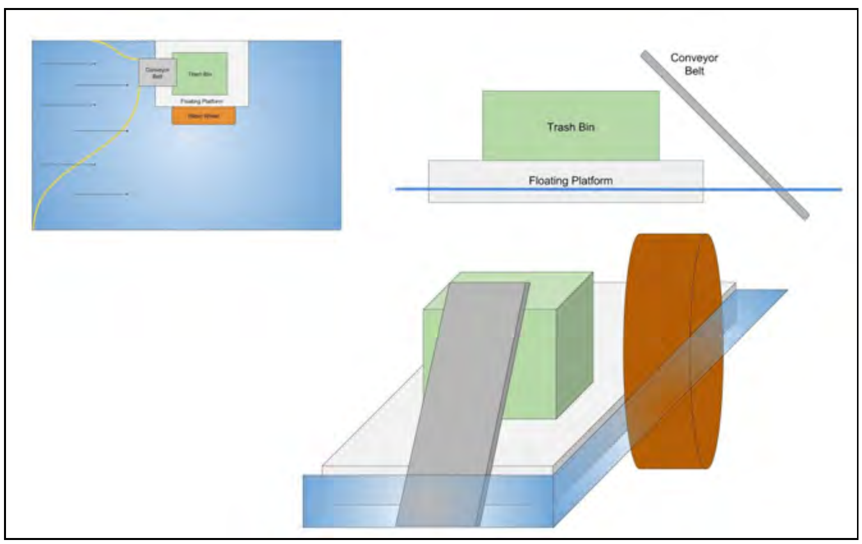


Figure 8: Drawing of Trash Wheel

Our second concept was inspired by a trash removal design already operating in the Baltimore Harbor. Affectionately named Mr. Trash Wheel, the design uses a water wheel powered conveyor belt which dips into the water and lifts trash into a garbage bin on a floating platform. This design has proven to have been successful but required over $720,000 for construction and installation.

The Trash Wheel, as seen in Figure 8, uses a conveyor belt to lift trash out of the water and into a garbage bin on a floating platform. The conveyor belt will be powered by a water wheel also mounted on the floating platform. When river flow is not sufficient to turn the water wheel, a solar powered pump will be used to pump water to the top of the wheel to provide a turning force. Long buoys or a continuous floating boom will be used to direct trash in front of the conveyor belt. The belt, partially submerged in the river, will pull the trash up the ramp and deposit it into the garbage bin. The bin will be covered by an aesthetic housing that can be removed to allow access to the trash bin for removal by crane. Since it will be located out of the water, our design would allow use of a large trash bin to maximize time between each bin emptying . In addition to carrying the trash out of the water, the conveyor belt could be designed so that it would create water flow, drawing trash to itself during operation at low flow rates. As shown in Table 2 this will be a more complex and expensive design than our first concept.

Table 2: Pros and Cons of Trash Wheel Design

Pros	**Cons**
Greater functionality in various flow rates	More moving parts
More aesthetically pleasing	Higher construction cost
Less flow disruption*	Higher maintenance cost
Less frequent trash removal	Vulnerable to large debris
	Requires a crane for trash removal

*flow disruption is unlikely to be a problem in either design

This concept was designed to be as functional as possible in all environments. The greatest challenges we will face if we move forward with this design are a simple power transfer system that will be minimize construction and maintenance costs, and a trash bin emptying system that does not require the use of a crane.

Concept Selection

After presenting our two concepts to The Greenway Foundation and receiving additional input from our stakeholders, we decided to move forward with our first concept, the Trash Trap, as seen in Figure 9. This design was less complex than our second concept, the Trash Wheel, and as a result was easier and less expensive to design, construct, implement, and maintain.

The Greenway Foundation's strong emphasis on ease of maintenance was the main proponent behind our selection of the Trash Trap. The lack of moving parts involved with trash collection, such as a conveyor belt, and the integrated trash emptying system, as opposed to using a crane, were the Trash Trap's greatest selling points. This design will require minimal maintenance and has the potential to be outfitted with a control system that would automatically send the cage up the rail system to be emptied.

The Trash Trap concept requires a number of improvements if it were to be installed in the South Platte River. First, its functionality at low flows needs to be addressed. It is anticipated that the boom used to direct trash into the mouth of the cage will tend to build up trash on itself, especially during low flows on this section of the South Platte. Several ways to correct this flaw include increasing the angle of the boom upstream, changing the boom material to minimize friction or having the boom move in a loop bringing built up trash towards the mouth of the cage. An additional concern will be the potential of large river debris to dislodge the boom and block

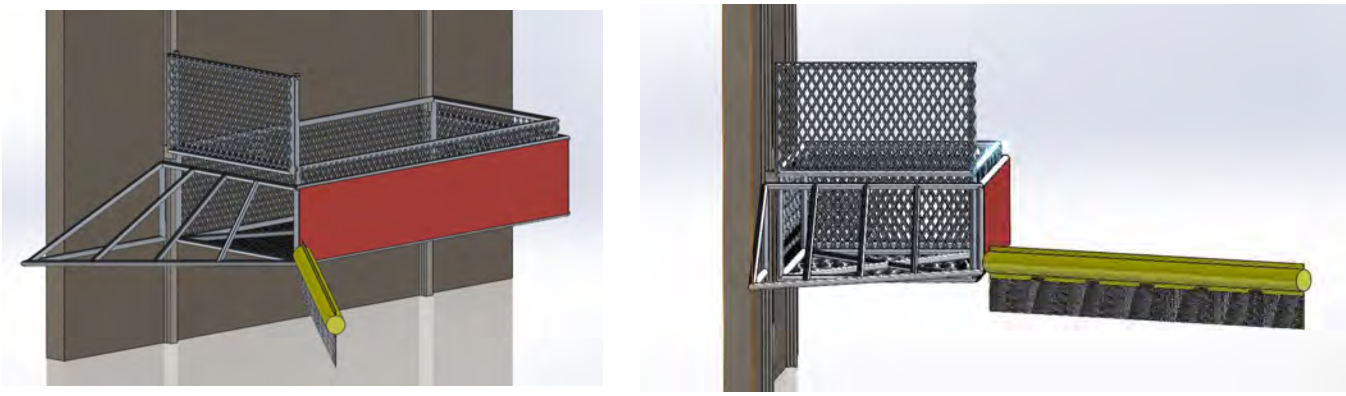


Figure 9: Concept of Trash Trap

the trash from entering the cage system. Although our interior cage will be protected by a sloped exterior cage designed to deflect large debris, our boom currently has no protection.

The next improvements will address functionality at high flows. Since the cages will be partially submerged, the rear, bottom, and river facing sides of the cage will need to allow water to easily pass through while preserving collected trash. The inner cage also requires adequate sturdiness to hold its form against the forces of the river and when it is lifted by the rail system shown in Figure 10. The interior cage will likely be constructed from a combination of sheet metal with drilled holes, woven metal rods, and a precisely sized metal mesh to capture a wide variety of trash sizes.

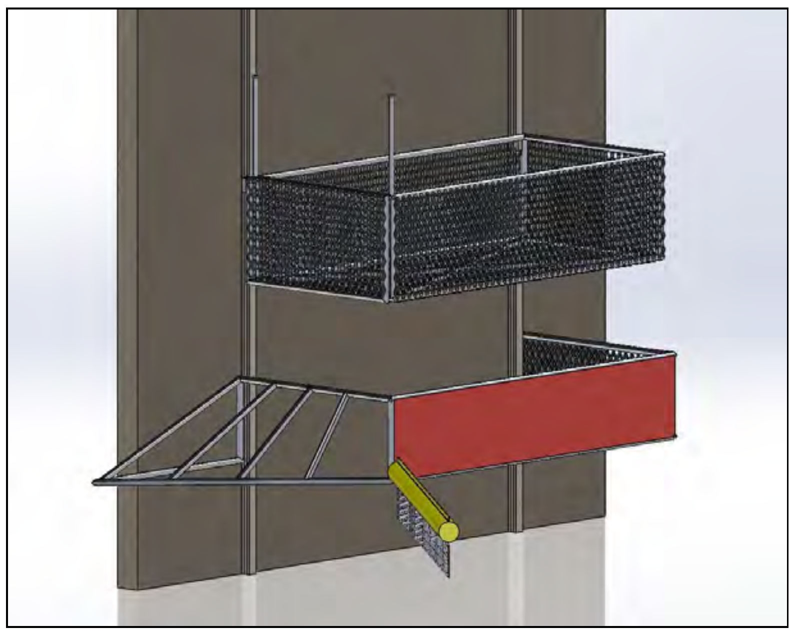


Figure 10: Illustration of rail system

Additionally, the team would have to ensure the rail system has the strength to raise the interior cage without deforming. Depending on the width of the cage and its trash carrying capacity, the weight could put a substantial moment on the rails. The total volume of the inner cage that fills with trash is another concern. Since it will be partially submerged, floating trash will remain on the top of the water leaving a large portion of the cage filled with air and water respectively. The team would need to investigate uses of a simulation software to model different cage designs before fully committing to cage construction.

The final design concern to be addressed will be the mouth of the interior cage. The front side will need to remain open during trash collection and covered to secure the trash during the emptying process. The team has researched several possibilities including sliding and swinging front door designs that will be triggered by the initial upward motion of the inner cage.

Concept Critique

To assist in the development of our design, Team Trash Trouts utilized several engineering standard tools. In the fall semester, our Clean River Design Challenge project was scored with the Engineering for Social Justice Checklist (ESJC). The ESJC is a great tool to identify social impact from our project. The checklist was designed around humanitarian engineering projects and encompases our project very well. The ESJC considers influenced parties, structural, political, self assessment, community risk, and human capability factors.

The are limitations with this form of analysis. Every category included in the checklist is not applicable to our project. In addition, the ESJC is not the most in-depth analysis available. The ESJC was still a very useful and relevant tool for our project. The limitations only changed the scale at which our design scored in the checklist. For example the ESJC can produce scores ranging from -48 to 48 but a positive score regardless of its distance from zero is still positively impacting the community.

The results of the checklist are located in Appendix A-1. Our project scored high in stakeholder engagement. The site visits that our team attended allowed our team to engage with the people who maintain and coordinate events in the area. Some of the stakeholders that communicated concerns and recommendations include Denver Parks and Recreation maintenance teams, nonprofits who organize clean up days, kayakers that use the area for recreational use, engineering groups that design projects influencing the waterways, and community members that utilize the parks and river. Our team scored average in categories like Structural Conditions and Increase Opportunities and Available Resources. This average score can be attributed to the project not having a large impact when compared to a major construction project such as a building. Instead, our project is a low impact run-of-river design that has minimal structural components. The project will increase the quality of the water which is a resource that many people like kayakers and swimmers use during the summer months. This allows us to score above average on reducing risk to users and community by providing cleaner river systems.

The outcomes of the analysis provided insight into what our team was doing well and the areas in which our team had room for improvement. Although some of the criteria did not directly relate to our project, the team continued our process with all criteria in mind. Our positive score of 15 indicated that our team’s efforts were making and will continue to make a positive impact in the community.

Based on the analysis, we modified our design process to include more of the Social Justice criteria. Many of the subcategories had scores of 0, so these areas were incorporated into our design process. Another applicable area of the ESJC was in the category of Identify Structural Conditions, especially in the subcategory of mapping resource flows. As we used resources for Phase II of the competition as well as the potential for resource use with the full-scale model, it was important to understand the life cycles of the resources we intended to use and to understand where these materials are coming from and how this may impact the sustainability of our design. By introducing these categories into further consideration, we were able to better design for sustainability and positive community growth.

The process and results of the ESJC analysis identified small issue we may have overlooked, but did not identify any major issues with our project. Our analysis had no negative scores, which suggested are design will do minimal harm to the community. Though there were no negatives, there were many scores of 0, which are indicators of room for improvement. Overall, our team's thoughtful consideration of the community and sustainability greatly improved our project.

Clean River Design Challenge Round 1

Figure 11: Clean River Design Challenge Round 1

In early December of 2018, Team Trash Trouts presented the "Trash Trap" to a panel of expert judges as part of the first round of competition in the Clean River Design Challenge. Round 1 consisted of a digital PowerPoint presentation along with a printed handout. The handout consisted of one two-sided 8.5" x 11" page. Information on the handout included our team name, group members, our university, design diagram(s), materials, installation plan, energy needs, anticipated costs, detailed description of the trash collection system, and broader impacts of operation. Team Trash Trouts achieved first place out of five teams and was awarded a cash prize.

The second semester included the construction and testing of a scaled prototype. With a team budget of $1,000 provided by the Greenway Foundation, the team's first step was to collaborate on the overall size and structure of the prototype. Several modifications were made to the conceptual design both for ease of construction and based judging feedback from Round 1.

Instead of crafting the cage frames from aluminum rods, team members with welding experience proposed aluminum flat bar to simplify the welding process and for stronger connections. Next, the number of rods making up the cattle guard were reduced to streamline construction. A third design change was inspired by a judge's comments that called for the lowering of the crossbar on the cattle guard. By adding an extension to the cage, the crossbar would be dropped to prevent the collection of trash. After receiving preliminary test flume dimensions from the client, the team generated a rough estimate of the necessary materials for the formation of the prototype. Figure 12 provides an initial sketch of the prototype's dimensions along with material estimates.

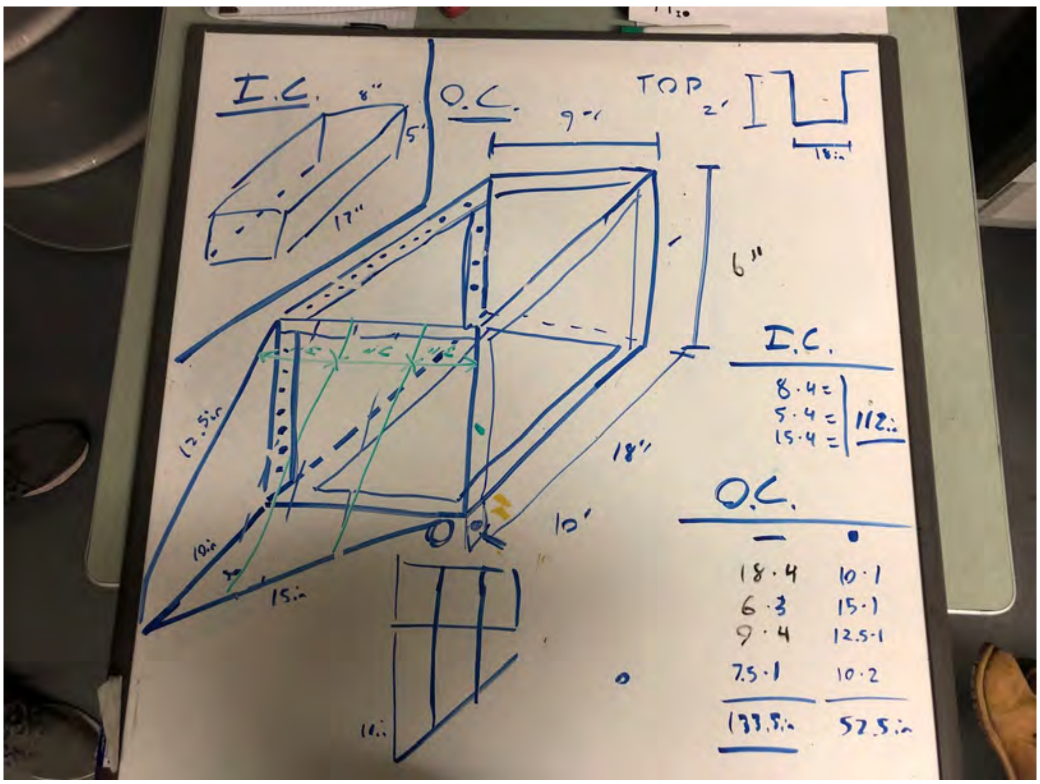


Figure 12: Dimensions of dual-cage system

Throughout the building process, Team Trash Trouts remained vigilant on future plans for design testing/analysis and risk mitigation. The trash collection system that will be installed in the South Platte River should meet all stakeholder specifications. In order to meet all of the hydraulic, structural, mechanical, and project considerations, Team Trash Trouts consistently engaged stakeholders for design feedback. The main goal for prototyping was to start early to allow for time to modify our cage system. Testing at the Bureau of Reclamation hydraulic lab facilities was accessible to our team on any weekday. To take advantage of this resource, project days were planned to improve and critique our trash collection design. Due to the scale of our prototype being significantly smaller than our full-scale design, some unforeseen issues were expected while working with the compressed subsystems. Our plan to build the prototype early and to test it frequently aimed to address any unanticipated problems in the design.

The goal of the Clean River Design Challenge is to design a device to effectively collect and remove floating trash in urban waterways. The engineered device will be constructed and implemented into the existing infrastructure at the site location in downtown Denver. With this in mind, Team Trash Trouts decided to analyze the potential impacts of our design on the surrounding environment. The health and safety of the public is an important aspect of engineering, and Team Trash Trouts believed it to be vital to analyze the risk associated with our design.

With an interactive mechanical design and the potential to be incorporated into existing infrastructure, the team agreed that a Failure Modes and Effects Analysis (FMEA) shown in Appendix A-2 would be the best risk assessment tool for our project. This tool helped the team break down the design into separate subsystems/processes to identify any potential failure modes. The FMEA is divided into two sections. The first section is used for granting numeric ratings to potential failure modes based on three criteria: 1) the likelihood that a failure will occur, 2) the likelihood that a defect will be detected by process controls, and 3) the amount of harm or damage that a defect may cause to a person or equipment. The numeric ratings are multiplied together to assign a Risk Priority Number (RPN) to that particular failure mode. After analyzing all potential failure modes, the sum of individual RPNs provides an RPN for the entire process. The second section of the FMEA provides a space for the team's recommended actions for each failure mode and the resulting impact these actions would inflict on the RPN. This rating system allows the team to compare defects and to address the most important failure modes. The team can also set goals for the overall RPN while working to improve the design.

There are a few limitations with this form of analysis. Without actual testing of our design, the team must identify any future problems using only engineering knowledge and prior experience. Unforeseen design flaws are possible. Additionally, the accuracy of the rating system is dependent on the team's expectations. The team can incorrectly rank failure modes by overestimating or underestimating the performance and hypothetical impacts of a particular subsystem. Nonetheless, the FMEA tool will be instrumental in the improvement of the team's design. Listing out failure modes and brainstorming solutions should prevent any major issues during the construction of the scaled prototype and a future full-scale model.

Potential design problems were scored according to the three criteria stated above and were assigned recommended team actions. Descriptions for the severity, occurrence, and detection scales used in the analysis can be found in Appendix A-3, A-4, and A-5 respectively. The outcomes of the analysis provide insight into possible design issues and the areas in which our team can improve. The score of 60 for the welded connections poses the highest risk to the integrity of our design. Though this score is high, often structures fail in connections, so this is not an unexpected result. To mitigate this risk, our team will focus on perfecting our welding skills in order to ensure the best welds possible for the prototype. For the full scale model, professionals will be hired to weld to ensure that the device is able to withstand the changes in the river.

To address any technical or societal risks associated with the design, the team identified mechanisms for risk mitigation. Firstly, Team Trash Trouts wanted to ensure that our trash collection system would raise awareness on the issue of trash in urban waterways. To accomplish this goal, news teams and other media platforms were a key component to this project. The Greenway Foundation reached out to local news stations in an attempt to have our project become a featured news story. Some of the media coverage included educational information on the risks of trash for wildlife and water quality. Since Confluence Park is an increasingly popular area for recreational purposes, people will likely want to keep their water clean and void of litter. If our project can educate people on the consequences of improper trash disposal, the safety and cleanliness of our waterways will improve. Included in our awareness initiative is an educational plaque that would be installed on the sidewalk directly above our device. Figure 13 presents a mockup of the educational plaque and its content.

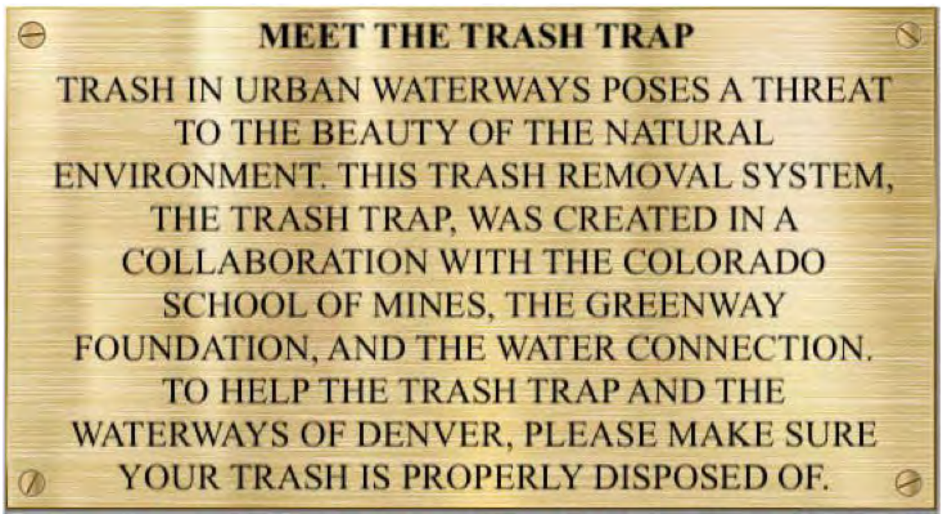


Figure 13: Trash Trap Educational Plaque

Secondly, the team held paramount the safety, health, and welfare of the public. Considerations for public safety were implemented into the design. With recreational water users in close proximity to the project site, our floating boom will be brightly colored to ward off any curious kayakers. Furthermore, "No Swimming" signs similar to Figure 14 will be strategically placed on the floating boom and sidewalk. If a person were to inadvertently enter the water, the cattle guard should block entry into the cage system. As stated above, water-bound trash can have adverse impacts on the ecosystem and water quality. Team Trash Trouts aspired to create design that would remove trash and not evolve into a piece of trash itself. Aluminum material was chosen for the cages due to its strength and erosion-resistant properties. Our design should be long-lasting and only have positive impacts on the South Platte River environment.

Figure 14: "No Swimming" Sign

4. Engineering Analysis

To create the best possible design, the team needed to account for several factors relating to the South Platte River. The site investigation played a key role in how our designs were laid out and created. The river's width spans approximately 90 ft depending on the current flow conditions, as seen in Figure 15. To address the large width, we chose to utilize a floating boom on our final design. The floating boom will assist with redirecting trash from the right side of the river to the left side towards are collection cage. The boom will require different angles for different flow rates but the range will fall in between 12 to 20 degrees, as seen in Figure 16. The boom angle is the amount of degrees away from the perpendicular distance from the side of the river. The angle was calculated based of of Urban Drainage and Flood Controls Districts flow rate averages that range from 250 to 300 cfs. As we test our prototype and in offseasonal flows this boom angle may have a larger range.

Figure 15: Aerial View of Site Location

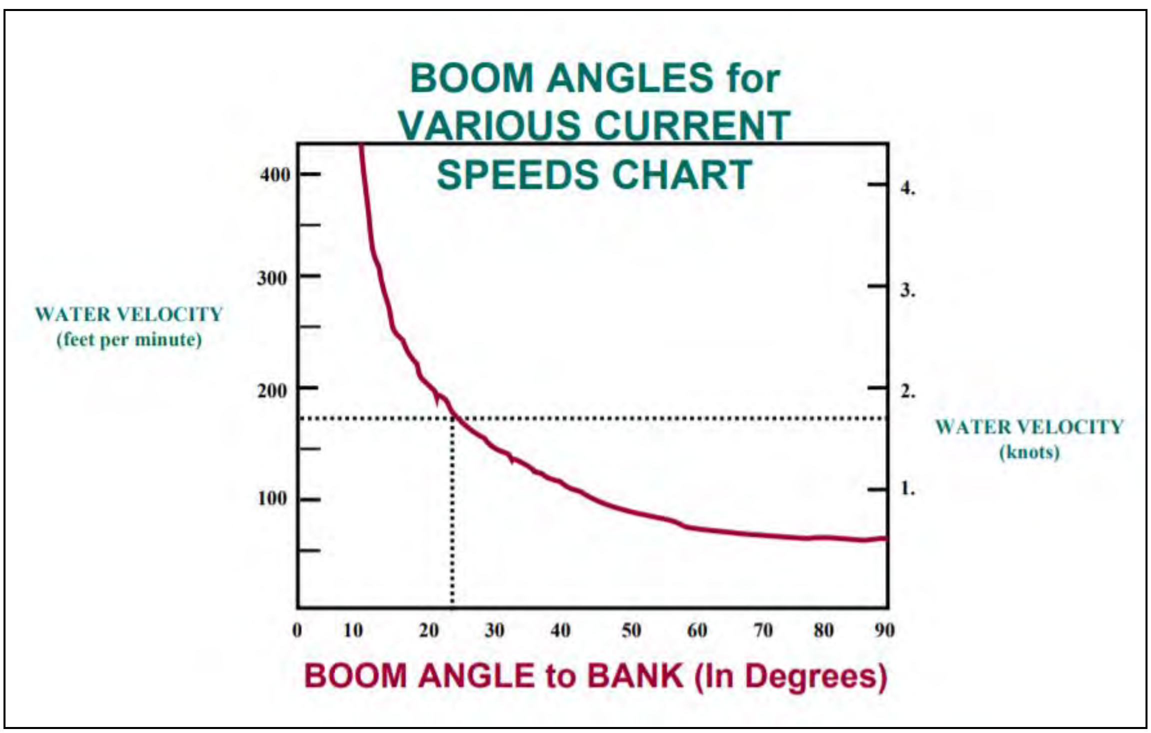


Figure 16: Required boom angle based on river velocity

The final design also needed to account for varying seasonal flows and rainfall. The Urban Drainage and Flood Control District mentioned flows from 13,000 cubic feet per second to 16,000 cubic feet per second in 2013. Figure 17 provides the annual peak streamflow in the South Platte River from 1982 - 2017 recorded at Commerce City, Colorado. During exceedingly high flows or flood conditions, the floating boom will possess a “break away” feature that will detach the boom from the cage system. The boom will continue to be secured on the other side of the river and will swing open parallel to the water flow. Without a boom obstruction, flood debris can safely pass our design without incurring any head loss.

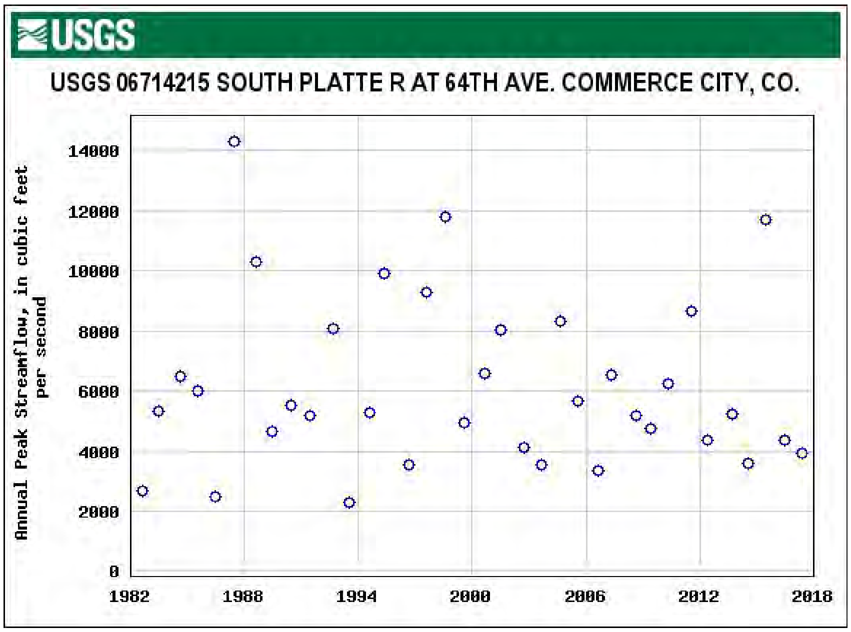


Figure 17: Peak annual flow rates for South Platte River

The next major concern was the design’s ability to adjust with the changes in water level of the South Platte River. Engineering calculations were performed to determine the required amount of buoyancy for the cage system to be halfway submerged. A simplified Free Body Diagram (Appendix C-1) was created to show the various forces acting on the outer cage. Using the FBD, an equation for the buoyant force was derived:

Equation 1 :

$$F_B = p_f * V_f * g$$

Where F_B is the buoyant force, p_f is the density of the displaced fluid, V_f is the volume of displaced fluid, and g is the acceleration due to gravity.

During the design process, along with moment and stress calculations regarding the materials used, the buoyancy force equation (Eq.1) was used. This equation was particularly important because it determined the amount of buoyant material and where to place it in order to keep the system at the appropriate level. Without appropriate flotation, trash would have the ability to float above or below the system. Based on the full scale design, the weight of the cages and the weight of collected trash was estimated to compute the necessary volume of flotation foam.

Cage material: Aluminum 1060, 2”
Inner Cage: 167.63 pounds
Outer Cage: 155.76 pounds
Total Weight: 323.39 pounds
Total Weight of Wet Trash for 50 cubic feet: 2,298.4 pounds
Total Weight of System: 2,621.79 pounds

Total Buoyancy Force = Total Force from Weight of System (to achieve equilibrium)

$$V_f = \frac{F_B}{p_f * g} = 42.02\, ft^3$$

The roughly 167 feet of aluminum tubing will take up approximately 3.6 cubic feet and if we estimate ⅓ of the volume of trash will not be saturated that will make the $V_f = 21.75 ft^3$ This amount of low density material is needed to be added to achieve equilibrium. This can be achieved with two 10’x3’x9” sections of foam attached to both sides of the outer cage or by adding foam to the bottom of the outer cage.

5. Final Deliverables

The final deliverable for the Clean River Design Challenge was a functional, scaled prototype of the design presented in Round 1 of the competition. The final scaled prototype was consistent with the initial design presented in Round 1, but the full-scale model will include modifications to improve the functionality of the device.

The Trash Trap itself was constructed using aluminum materials. For the inner cage, the aluminum flat bar was welded to create the cage shape, and the mesh sections were riveted to the cage on all faces excluding the front face, as seen in Appendix B-1. The outer cage was constructed in a similar manner to the inner cage with respect to the aluminum flat bar. The cage guard was constructed of aluminum rods, welded in the proper orientation and welded to the front face of the outer cage, as seen in Appendix B-2. Both the inner and outer cages had welded tabs that allowed for the connection to the rail system. The face opposite that mounted on the rail system held the flotation system. The flotation was a one inch thick piece of foam, chamfered to reduce head loss, that was attached to the side of the cage using epoxy.

The rail system was constructed of steel rods, flat bar, and a pulley. The rails themselves were made of steel rods, bent at 180 degrees and connected to the flat bar frame. This frame included holes that allowed for attachment to the side wall and sidewalk areas of the test flume, and can be seen in Appendix B, Figure 3. A section of flat bar extended back and was the mount for the pulley, which facilitated the removal function of the system.

The boom was made of tubular, foam insulation and was about 5 feet long. A piece of paracord ran through the boom and was fastened on one end to a tab on the outer cage and to the boom extension connection on the other end. “No swimming” signs were attached to the boom in four spots to ensure that those using the waterway are aware of the device and will not get stuck in it.

To evaluate the success of the project overall, the following chart was created. The criteria used for the evaluation were pulled directly from the judging criteria of the challenge.

Table 3: Design Constraints Pass/Fail

Design Criteria	**Pass/Fail Full Scale Design**	**Pass/Fail Scaled Prototype**
Innovative	X	X
Collects trash from surface of water and in water column	X	X
Implementable and scalable	X	X
Low impact (no sound, smell, etc.)	X	X
Educational and safety aspects	X	X
Allows for passage of fish/wildlife	X	X
Materials do not degrade in weather conditions	X	X
Functions in multiple flows	X	
Resistance to damage during flood conditions	X	
Minimal head loss	X	X

As seen in Table 3 above, the scaled prototype passed the majority of the criteria for design. Areas of failure included: functionality in multiple flows, and resistance to damage during flood conditions. During the competition, the device did not function during the high flow situation due to a failure in the flotation system. Because the flows were not high enough to test for flood conditions, the prototype also failed in this aspect. For the full scale model, there will be modifications that allow the device to retain its integrity during flood conditions.

6. Project Management

To better understand the impacts of the project, Team Trash Trouts ran Failure Modes and Effects Analysis and used the Checklist for Engineering Social Justice. The Checklist for Engineering Social Justice was used to analyze the social impacts of the device and the results can be seen in Appendix A-1. The purpose of using this impact assessment tool is to better evaluate how stakeholders, sustainability, and good practices were considered throughout the process. The final score was 15, but there were no negative scores which indicates a positive, social impact to the project.

The provided budget for the project was $1000 from The Greenway Foundation. The projected cost of the prototype, presented in the IDR (Appendix A-6), was about $90.00. The final total cost of the prototype, including all materials and services, was $377.80, as seen in Appendix A-7. Although the final cost was above the projected cost, it was still well under budget. All of the work requested by The Greenway Foundation was done in the alloted time. The deliverable of the scaled prototype was ready for testing by the Bureau of Reclamation Round 2 competition day. The full scale model cost is about $21,000 and the breakdown of the cost can be seen in Appendix A-8. The next steps for the client are to implement our full-scale design.

For future projects, a system that includes all aspects of the river collection system is important. Team Trash Trouts focused on the cage and removal system but a guaranteed winning design would have a unique boom system and removal system. Other possibilities include something unseen or never before created. Our team believes that the greatest challenges are reducing some of the trash that ends up in the rivers. Homeless communities upstream, improper disposal, and over packaging of products need to be reduced and the source of the problem could be eliminated.

7. Lessons Learned

Throughout the Clean River Design Challenge, the members of Team Trash Trouts have grown individually, and as a whole, in order to successfully collaborate on the design and construction of a prototype for trash collection in the South Platte River.

The Clean River Design Challenge has taught high-quality and considerate design. Since the device will be installed in a public place, it is necessary that it must function properly as well as be non-intrusive to the natural environmental. Reputable design is not solely about the functionality of the device, but requires that the design has been considered from multiple different perspectives. Many technical requirements for our prototype dealt with aesthetics, education, and safety. A good design takes a holistic approach to tackling a problem to ensure that the final product is highly functional, implementable, and goes above and beyond the project requirements.

Working as a team was a vital part of the process, and this team functioned very well. The competition pushed our team to further develop our technical and professional skills in order to finish the prototype on time. Sean and Isaac focused on learning about welding aluminum and steel and perfecting their skills in order to build the cage frames and rail system. By the end of the competition, they were confident in both TIG and MIG welding. The remainder of the team practiced with power tools, including drills and a variety of saws, while constructing other aspects of the prototype. When working on this team we learned the importance of communication and planning. We needed to communicate to each other how each of our individual aspects of the project were coming so we could plan for the next meeting. At the end of every session, we would meet and discuss what we needed to do during our next meeting time. These planning sessions allowed us to stay on track so we were able to finish our prototype on schedule. The variety of perspectives and inputs that working on a team provides is vital to the success of the project.

Some aspects of the construction proved harder than expected and some were easier than expected. The rail system and flotation were expected to be easy aspects of the design, but they came with issues in the particulars of construction. The rail system was difficult because the final prototype system varied from the initial design. We had to rethink the design in order to create a rail system that functioned for the removal of the device. The flotation was expected to be easy, but proved to be difficult during Round 2 of the competition, when it failed. In hindsight, more time and effort should have been spent on the flotation to ensure its success during the competition. The mesh on the cage was expected to be a difficult piece of the puzzle, especially in the connection to the cage, but once we decided on rivets, the connection was simple and took little time. Overall, the project was more challenging than expected, but the results and final prototype functioned well and the team was satisfied with the results.

Appendix A: Project Management

A-1: Engineering Social Justice Checklist

	Engineering Social Justice		**OVERALL SCORE**
	Self-Assessment Checklist		
Project:	F18-22		
Point of Contact:	Natalie Haber		
Date:	11/15/18		15
How to use this scorecard	Under each of the six categories below, check off any tools that you have used as part of your design process to address the social justice criterion listed. Then give a score for each category from -3 to +3, with 0 representing a neutral effort that neither hurts or progresses a specific social justice criterion. A -3 indicates active and immediate harm, while +3 indicates active and immediate benefit to the social justice criterion. Once done, sum the six scores and write your overall score at the top, right-hand side of the form. For more information on the six criteria review: http://ojs.library.queensu.ca/index.php/ijsle/article/view/5447		
		SCORE	**NOTES**
1) Listen Contextually		9	
0	Applied House of Quality w/Cultural Risk Indicators		
3	Interviewed stakeholders using interviewing tools from FGtoHCD*		
3	Took part in onsite observations using tools from FGtoHCD		
3	Completed one or more immersion experiences using tools from FGtoHCD		
	Other:		
2) Identify Structural Conditions		0	
0	Mapped resource flows using tools from FGtoHCD		
0	Applied iDE PRISM methodology		
	Other:		
3) Acknowledge Political Agency		2	
2	Created a stakeholder map		
0	Held a co-creation session per FGtoHCD		
	Other:		
4) Increase Opportunities and Available Resources		1	
0	Applied LEED best practices (for structures)		
1	Applied ENVISION best practices (for site development)		
0	Completed another form of assessment.		
0	Completed an aspirational mapping exercise		
0	Applied the three hypothesis from LDW Method		
	Other:		
5) Reduce Risk to Users/Community		1	
1	Completed a hazard/risk analysis (PRA/FMEA/Other)		
0	Have identified, and will measure, an impact hypothesis from LDW Method		
	Other:		
6) Increase Human Capabilities		2	
2	Applied Universal Design best practices		
	Other:		

* FHtoHCD stands for the Field Guide to Human Centered Design (available online)

A-2: Failure Modes and Effects Analysis

FMEA Form

Process/Product Name: Full-scale Trash Trap

Prepared By: Team Trash Trouts

Project Advisor Lisa Woodward

FMEA Date (Orig.): 2/26/19 (Rev.):

Process Step/Input What is the process step, change or feature under investigation?	Potential Failure Mode In what ways could the step, change or feature go wrong?	Potential Failure Effects What is the impact if this failure is not prevented or corrected?	SEVERITY (1 - 10)	Potential Causes What causes the step, change or feature to go wrong? (how could it occur?)	OCCURENCE (1 - 10)	Current Controls What controls exist that either prevent or detect the failure?	DETECTION (1 - 10)	RPN	Action Recommended What are the recommended actions for reducing the occurrence of the cause or improving detection?	Resp. Who is responsible for making sure the actions are completed?	Actions Taken What actions were completed (and when) with respect to the RPN?	SEVERITY (1 - 10)	OCCURENCE (1 - 10)	DETECTION (1 - 10)	RPN
Cattle Guard	*Bottom bar of guard could prevent trash from entering*	*Flow of trash will be blocked and render system ineffective*	*6*	*The bar is near or above water level*	*8*	*The cage system is partially submerged*	*3*	*144*	*Lower bottom bar of cattle guard*	*Issac and Sean*	*Cattle guard connection was lowered*	*1*	*1*	*2*	*2*
Hand crank or motor	*Removal system cannot lift cage*	*Trash will have to be manually removed*	*7*	*Weight of cage and trash exceeds lifting capacity*	*7*	*Limited cage size, light-weight materials*	*6*	*294*	*Use a high-capacity hand crank or electric*	*Team*	*TBD*	*2*	*2*	*3*	*12*
Cage Dumping Mechanism	*Cage cannot flip over for maintaince*	*Would complicate removal of trash*	*6*	*Cage rail connection*	*7*	*Curved rails with simple connection to cage*	*3*	*126*	*Test strength of rails and dumping process*	*Team*	*TBD*	*1*	*4*	*2*	*8*
Cage Mesh	*Trash could escape through sides*	*Design would not collect all sizes of trsh*	*6*	*Improper mesh size for sides of cage*	*9*	*None*	*10*	*540*	*Test mesh sizes to find correct size*	*Team*	*TBD*	*1*	*2*	*2*	*4*
Welded Connetions	*Forces of river could cause welds to fail*	*Design would need to be removed and repaired*	*8*	*Poor welding or stress concentrations*	*4*	*Monthly maintenance of system*	*4*	*128*	*Have maintenance workers complete thorough checks of welds each time cage is emptied*	*Team*	*TBD*	*5*	*4*	*3*	*60*
Full system	*Material degradation*	*Loss of aestethic appeal and*	*4*	*Exposure to sunlight, sediment loads, exposure to*	*3*	*Monthly maintenance of system*	*3*	*36*	*Use erosion resistant materials like aluminum*	*Team*	*Inner and outer cage constructed using aluminum*	*2*	*2*	*3*	*12*

A-3: FMEA Severity Scale

Severity Scale

Adapt as appropriate

Effect	Criteria: Severity of Effect	Ranking
Hazardous - Without Warning	May expose client to loss, harm or major disruption - failure will occur **without** warning	10
Hazardous - With Warning	May expose client to loss, harm or major disruption - failure will occur **with** warning	9
Very High	Major disruption of service involving client interaction, resulting in either associate re-work or inconvenience to client	8
High	Minor disruption of service involving client interaction and resulting in either associate re-work or inconvenience to clients	7
Moderate	Major disruption of service not involving client interaction and resulting in either associate re-work or inconvenience to clients	6
Low	Minor disruption of service not involving client interaction and resulting in either associate re-work or inconvenience to clients	5
Very Low	Minor disruption of service involving client interaction that does not result in either associate re-work or inconvenience to clients	4
Minor	Minor disruption of service not involving client interaction and does not result in either associate re-work or inconvenience to clients	3
Very Minor	No disruption of service noticed by the client in any capacity and does not result in either associate re-work or inconvenience to clients	2
None	No Effect	1

A-4: FMEA Occurrence Scale

Occurrence Scale

Probability of Failure	Time Period	Per Item Failure Rates	Ranking
Very High: Failure is almost inevitable	More than once per day	>= 1 in 2	10
	Once every 3-4 days	1 in 3	9
High: Generally associated with processes similar to previous processes that have often failed	Once every week	1 in 8	8
	Once every month	1in 20	7
Moderate: Generally associated with processes similar to previous processes which have experienced occasional failures, but not in major proportions	Once every 3 months	1 in 80	6
	Once every 6 months	1 in 400	5
	Once a year	1 in 800	4
Low: Isolated failures associated with similar processes	Once every 1 - 3 years	1 in 1,500	3
Very Low: Only isolated failures associated with almost identical processes	Once every 3 - 6 years	1 in 3,000	2
Remote: Failure is unlikely. No failures associated with almost identical processes	Once Every 7+ Years	1 in 6000	1

A-5: FMEA Detection Scale

Detection Scale

Detection	Criteria: Likelihood the existence of a defect will be detected by process controls before next or subsequent process, -OR- before exposure to a client	Ranking
Almost Impossible	No known controls available to detect failure mode	10
Very Remote	Very remote likelihood current controls will detect failure mode	9
Remote	Remote likelihood current controls will detect failure mode	8
Very Low	Very low likelihood current controls will detect failure mode	7
Low	Low likelihood current controls will detect failure mode	6
Moderate	Moderate likelihood current controls will detect failure mode	5
Moderately High	Moderately high likelihood current controls will detect failure mode	4
High	High likelihood current controls will detect failure mode	3
Very High	Very high likelihood current controls will detect failure mode	2
Almost Certain	Current controls almost certain to detect the failure mode. Reliable detection controls are known with similar processes.	1

A-6: Preliminary Prototype Cost Estimate

Item	Amount	Cost	Total Cost
Aluminum Flat Bar	244"	$2.36/36"	$16.52
Plastic Hardware Net	3'x15'	$32.48	$32.48
Rail System	6'	$16.90/13.5'	$16.90
Circular aluminum bar for "Cattle Guard"	4'	$5.04/4'	$5.04
Foam and steel wire for boom.	6' 6'	$10.55/6' $1.96/25'	$10.55 $1.96
Foam for buoyancy	1"x2'x2'	$5.98/sheet	$5.98
		Total	**$89.43**

A-7: Final Prototype Budget and Cost

February						
02/07/2019	El Dorado	Breakfast Burritos	Visa Giftcard	$23.62	$0.00	$23.62
2/14/2019	Home Depot	Prototype Materials	Visa Giftcard	$63.31	$0.00	$63.31
2/21/2019	Home Depot	Prototype Materials	Visa Giftcard	$8.25	$0.00	$8.25
2/26/2019	Home Depot	Prototype Materials	Visa Giftcard	$78.21	$0.00	$78.21
2/27/2019	Home Depot	Prototype Materials	Visa Giftcard	$16.49	$0.00	$16.49
2/27/2019	El Dorado	Breakfast Burritos	Visa Giftcard	$ 18.00	$0.00	$18.00
2/27/2019	POS	n/a	Visa Giftcard	$ (0.01)	$0.00	$ (0.01)
					Total:	$ 207.87
March						
03/04/2019	Home Depot	Prototype Materials	Visa Giftcard	$ 32.98	$0.00	$ 32.98
03/05/2019	Home Depot	Prototype Materials	Visa Giftcard	$ 22.16	$0.00	$ 22.16
03/05/2019	POS	Home Depot Return	Visa Giftcard	$ (32.98)	$0.00	$ (32.98)
03/05/2019	Home Depot	Prototype Materials	Visa Giftcard	$ 8.64	$0.00	$ 8.64
03/06/2019	POS	Home Depot Return	Visa Giftcard	$ (29.55)	$0.00	$ (29.55)
03/06/2019	Home Depot	Prototype Materials	Visa Giftcard	$ 19.91	$0.00	$ 19.91
03/08/2019	El Dorado	Breakfast Burritos	Visa Giftcard	$ 25.37	$0.00	$ 25.37
03/15/2019	Home Depot	Prototype Materials	Visa Giftcard	$ 33.88	$0.00	$ 33.88
03/15/2019	POS	Home Depot Return	Visa Giftcard	$ (48.74)	$0.00	$ (48.74)
03/22/2019	CSM	Printing	Visa Giftcard	$ 1.40	$0.00	$ 1.40
03/20/2019	POS	Home Depot Return	Visa Giftcard	$ (11.79)	$0.00	$ (11.79)
03/20/2019	Home Depot	Prototype Materials	Visa Giftcard	$ 14.92	$0.00	$ 14.92

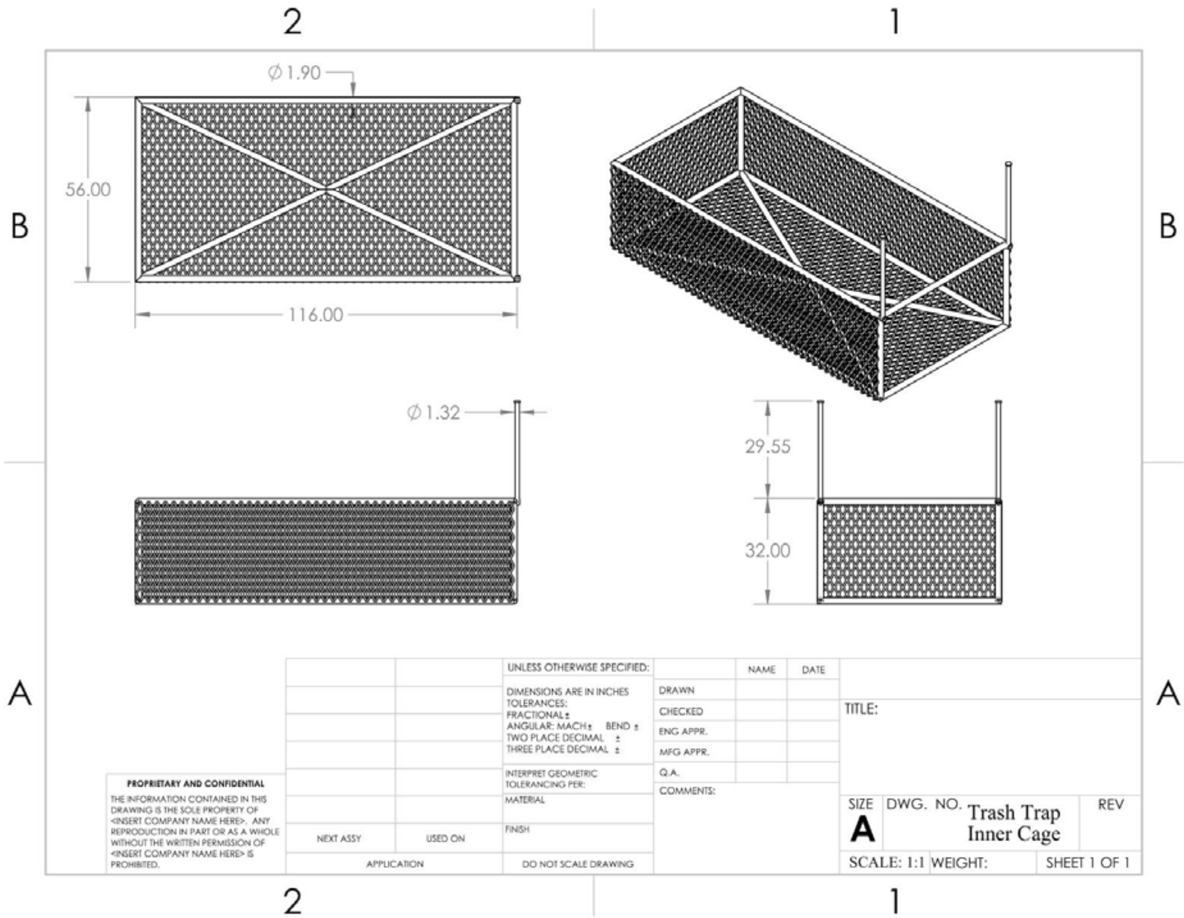
03/21/2019	Home Depot	Prototype Materials	Visa Giftcard	$ 18.25	$0.00	$ 18.25
					Total:	$ 54.45
April						
04/03/2019	The Home Depot	Paint and Aluminum Primer	Visa Giftcard	$ 27.86	$0.00	$ 27.86
04/03/2019	The Home Depot	Paint and Aluminum Primer	Visa Giftcard	$ 59.17	$0.00	$ 59.17
04/02/2019	POS	Home Depot Return	Visa Giftcard	$ (29.70)	$0.00	$ (29.70)
04/05/2019	The Home Depot	Materials	Visa Giftcard	$ 18.73	$0.00	$ 18.73
04/11/2019	POS	Home Depot Return	Visa Giftcard	$ (21.97)	$0.00	$ (21.97)
04/11/2019	The Home Depot	Materials	Visa Giftcard	$ 11.34	$0.00	$ 11.34
04/16/2019	The Home Depot	Materials	Visa Giftcard	$ 19.86	$0.00	$ 19.86
04/16/2019	El Dorado	Breakfast Burritos	Visa Giftcard	$ 24.57	$0.00	$ 24.57
04/17/2019	The Home Depot	Materials	Visa Giftcard	$ 5.62	$0.00	$ 5.62
					Total:	$ 115.48

	Date	Source	Total
Starting Budget	1/8/19	The Greenway Foundation	500
		Total Funds	$ 500.00
		Total Spent	$ 377.80
		Remaining Funds	$ 122.20

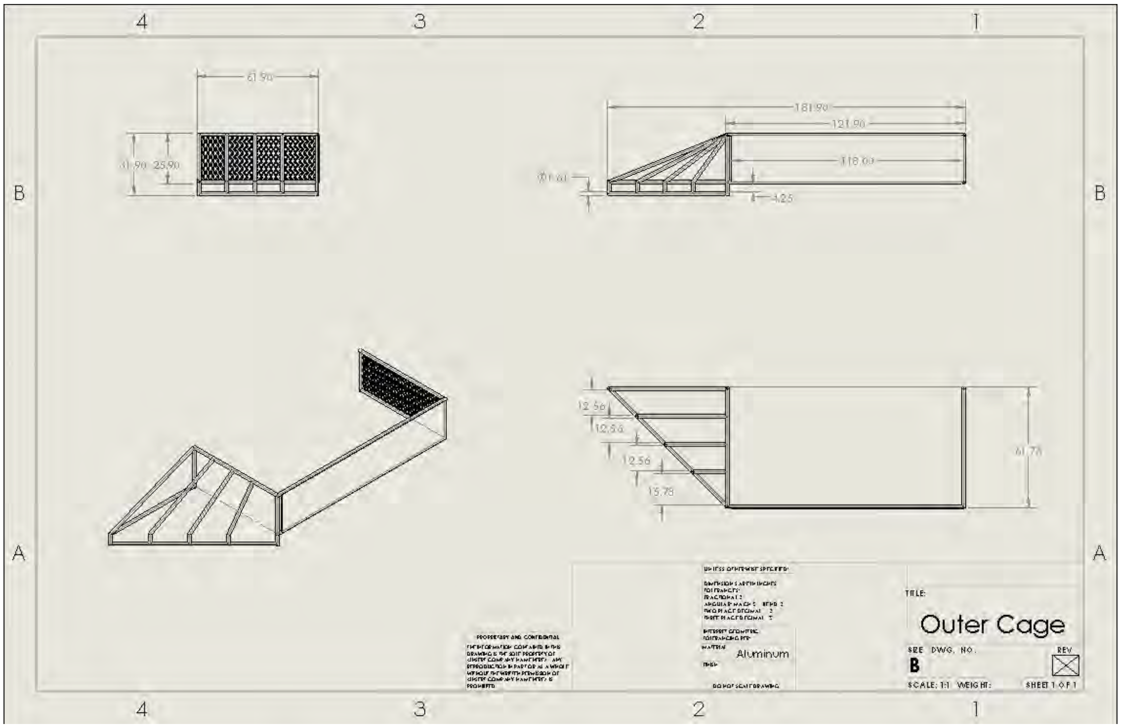
A-8: Final Full-scale Design Cost Estimate

Item	Cost	Detail/dimensions	Description
Floating Boom	$1,400.00	100' x 18"	Boom - PVC, chain - galvanized steel
Winch/ Generator	$2,300.00	2000 lb max load	Industrial Electric Winch (may be substituted for mechanical hand crank)
Aluminum Trap	$5,300.00	Roughly 10'x2'x5' Welded Aluminum Trash Trap	167' Aluminum Tubing, 166 sq.ft. mesh and 20 sq.ft. aluminum plating
Fabricated Metal Tracks	$4000.00	Vertically anchored Steel Tracks	Welded and Painted Steel
Installation	$8000.00	Small crane may be necessary, drilling of the concrete wall, scaffolding and labor	Construction Process
Total Estimated Cost	**$21,000.00**		

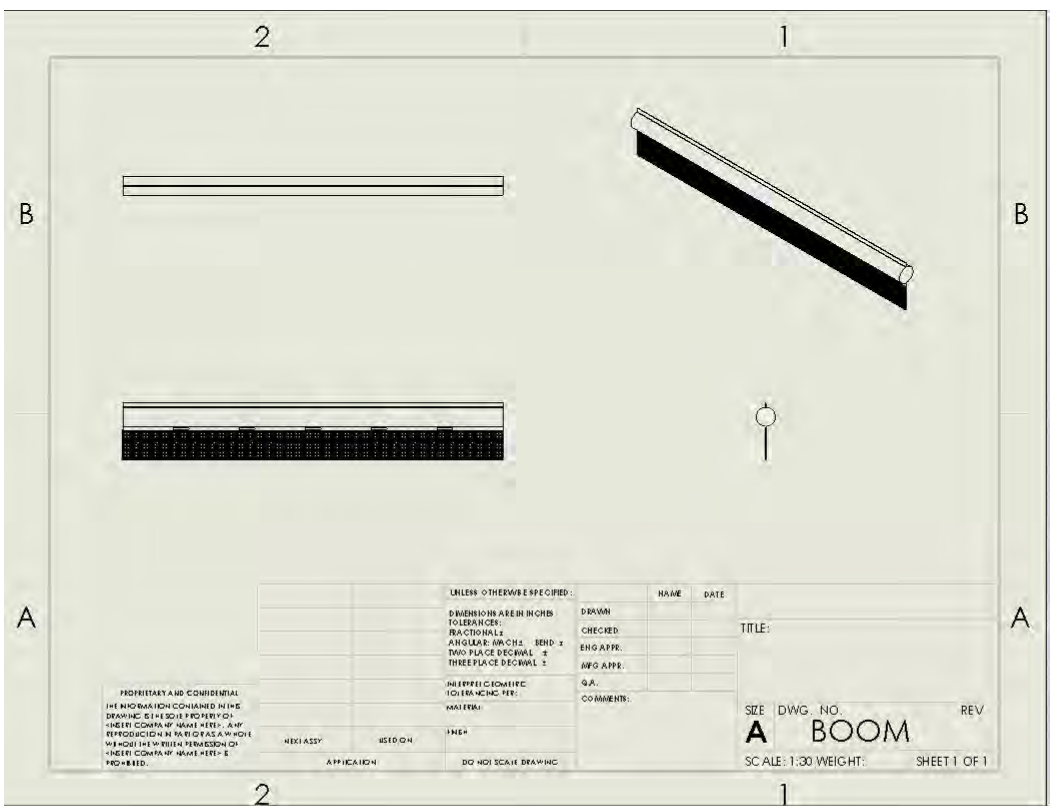
Appendix B: Final Prototype Drawings
B-1: Inner Cage Detail Sheet



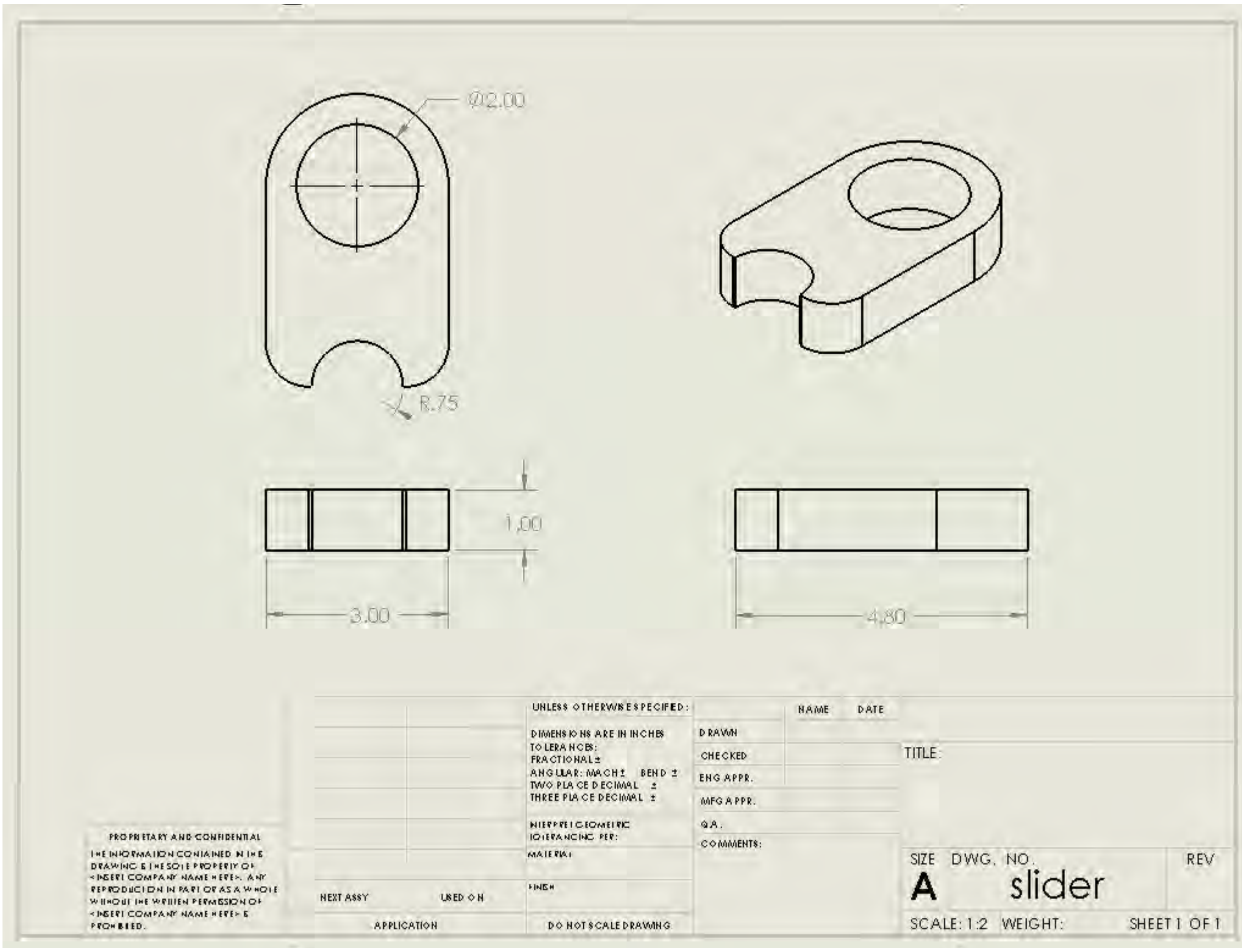
B-2: Outer Cage Detail Sheet



B-3: Floating Boom CAD Drawing



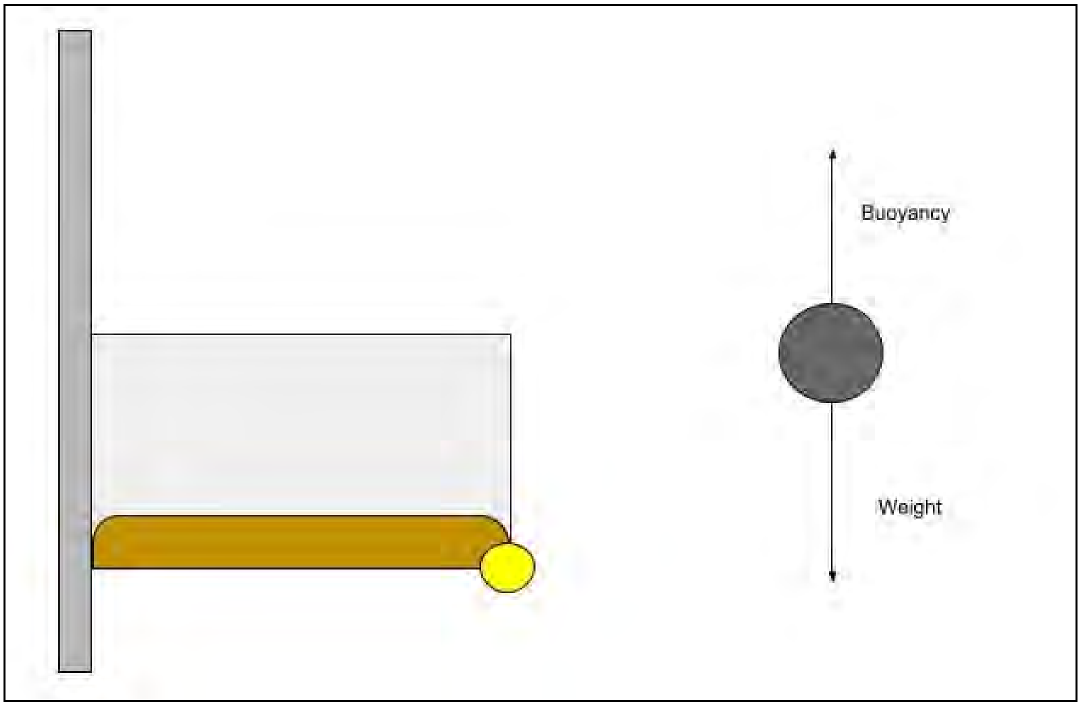
B-4: Cage Slider CAD Drawing



B-5: Prototype Cages on Rail System

Appendix C: Engineering Calculations

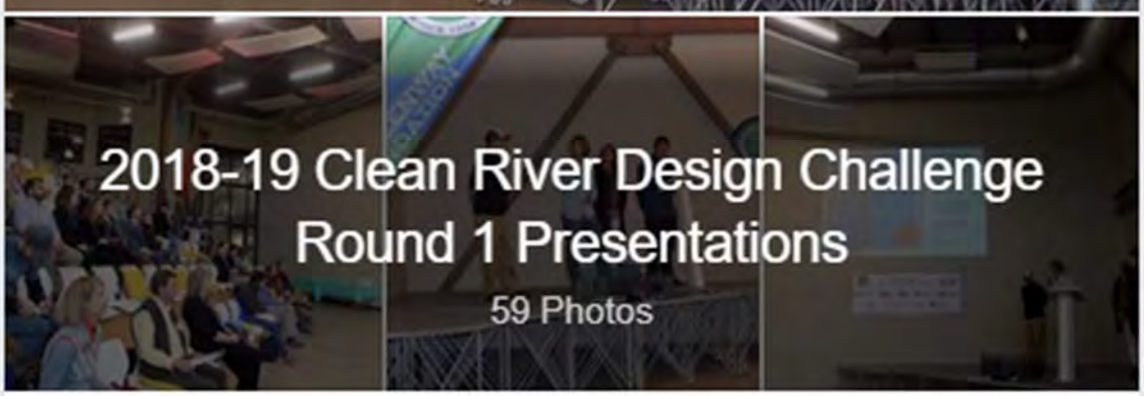
C-1: Free Body Diagram of Outer Cage



The Greenway Foundation added 59 new photos from December 6, 2018 to the album: 2018-19 Clean River Design Challenge Round 1 Presentations.

Published by Lauren Frances [?] · December 6, 2018 ·

5 teams presented their design concepts for an in-stream trash removal device to a panel of judges!



260
People Reached

66
Engagements

Boost Unavailable

You and 4 others

Like Comment Share

greenway_foundation
Industry RINO

greenway_foundation The first round of the Clean River Design Challenge is happening at @industrydenver today! Teams of college students are presenting their innovative ideas for a trash removal device for the South Platte!

31w

ferrycorstenarcher Awesome 😁 ❤️

31w 1 like Reply

View replies (1)

Liked by **ryan.aids** and **38 others**

DECEMBER 6, 2018

Add a comment...

The Greenway Foundation added 258 new photos from April 23 to the album: 2018-2019 Clean River Design Challenge, Round 2.

Published by Lauren Frances [?] · April 23 ·

After two semesters of hard work, the teams from Colorado School of Mines, Metropolitan State University of Denver, and University of Denver presented and tested the scaled models of their in-stream trash removal device! Check out the photos from the entire competition-- tag yourself!

347 People Reached	94 Engagements	Boost Post

You and 20 others — 2 Shares

Summary:

Our Previous Knowledge Surveys indicate that a majority of students had previously not known about The Water Connection/The Greenway Foundation. Results of these surveys also indicate that students had experience the issue of trash in urban waterways and that all teams visited the competition site and experienced the South Platte River.

The “all of us” response was higher in the Post Competition Survey question which asked ‘who is responsible for removing trash from our urban waterways’. This indicates that this competition may have increased a sense of stewardship in more of the student participants!

Quotes from the 2018-2019 Clean River Design Challenge Post Competition Survey:

Q3: Have your thoughts changed about who is responsible for removing trash from in and around urban waterways in Denver? Briefly explain:

“Yes. I know City works usually are responsible. Now I know how much work it really is”

“My thoughts have changed to consider that instead of it being someone’s responsibility to remove the trash, it should be people’s responsibility to not litter in the first place”

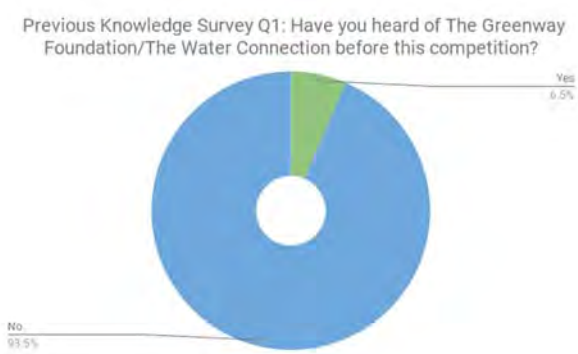
“No. It is unfortunate that the Park Dept. has to spend resources to clean up after people who dump trach in the river or on the ground”

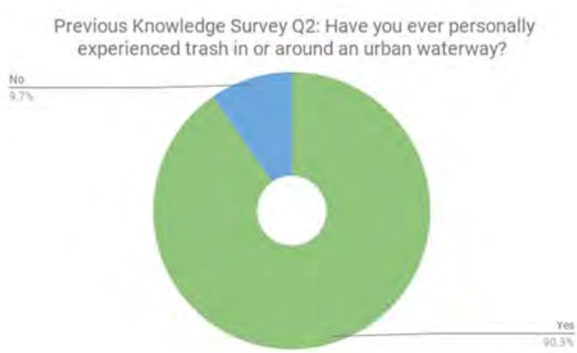
“Not really, but if someone were to make a device that collects and removes the trash, I don’t see why a private entity wouldn’t take more responsibility”

“Yes. I think that since citizens of Denver are the main source of litter that they should be more involved with removing it”

Results and Findings from the Surveys:

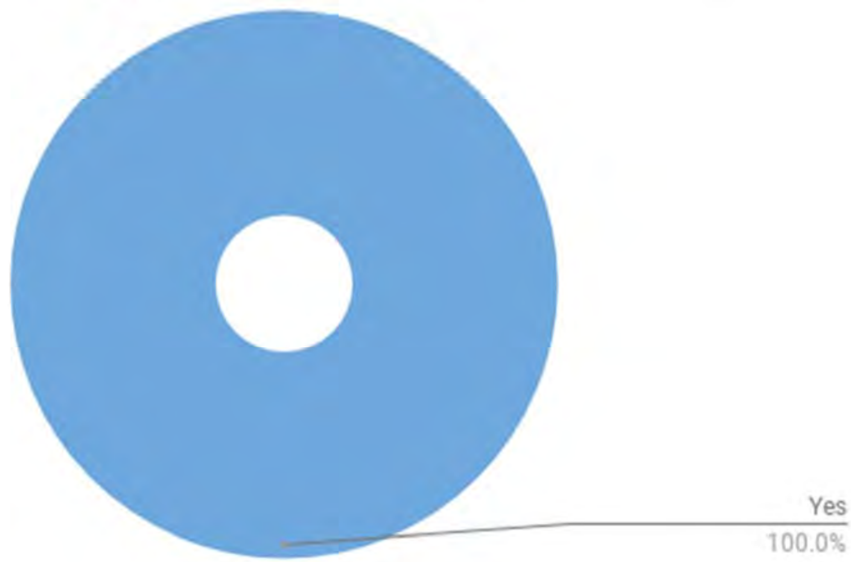
Q1 and Q2 from the Previous Knowledge Survey show that this competition is a great way to connect The Water Connection/The Greenway Foundation to an issue that most students have already experienced.





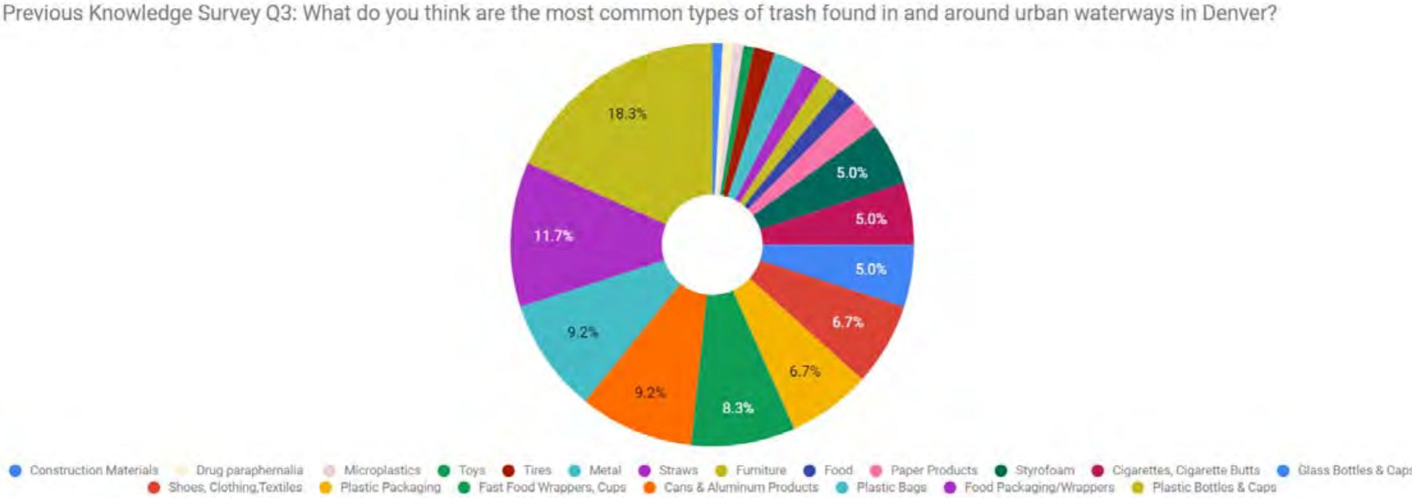
Q1 from the Post Competition Survey shows that this competition gets students to experience the urban waterways and the issues they may face.

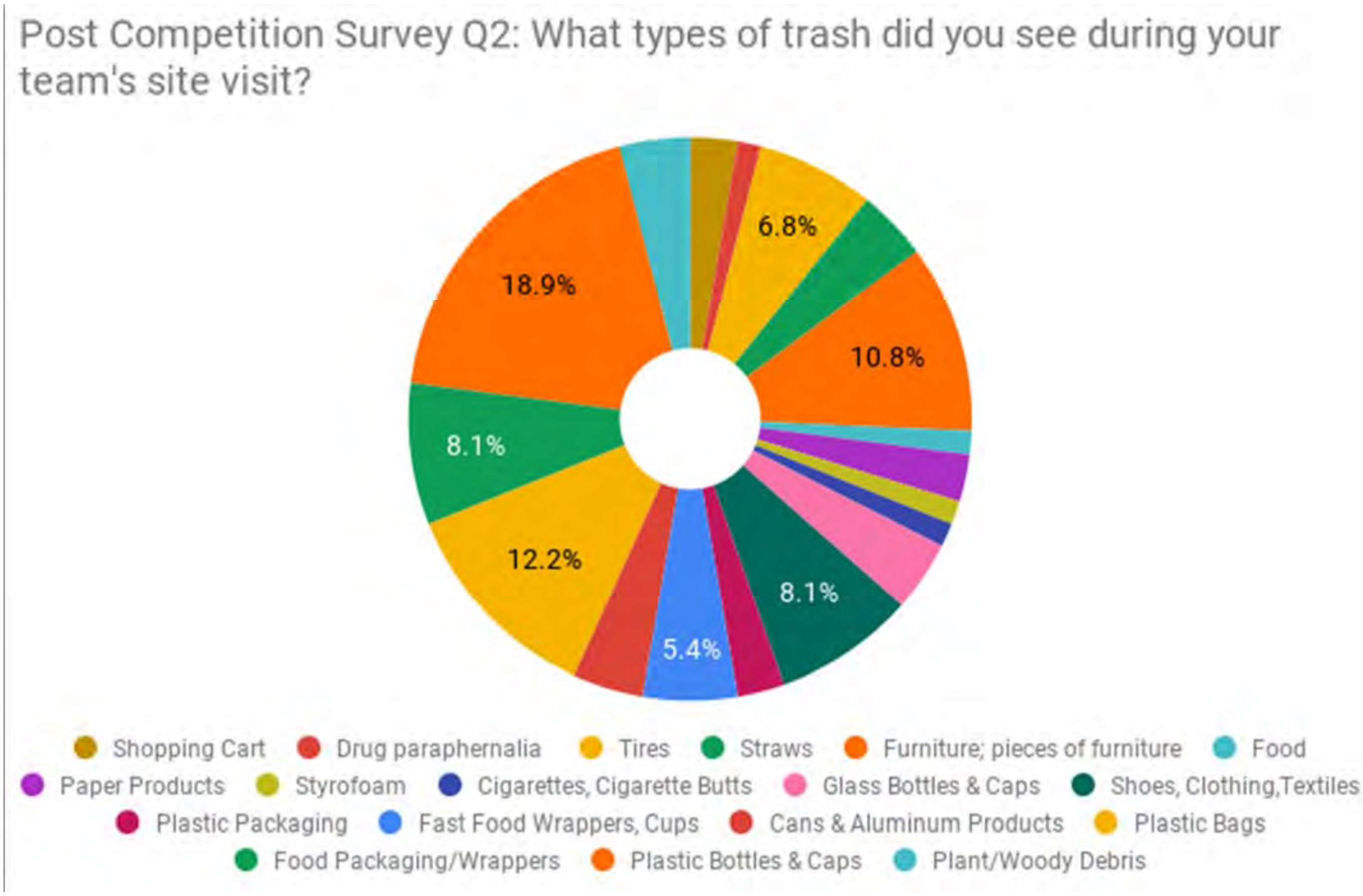
Post Competition Survey Q1: Did you/your team ever go down to the competition site?



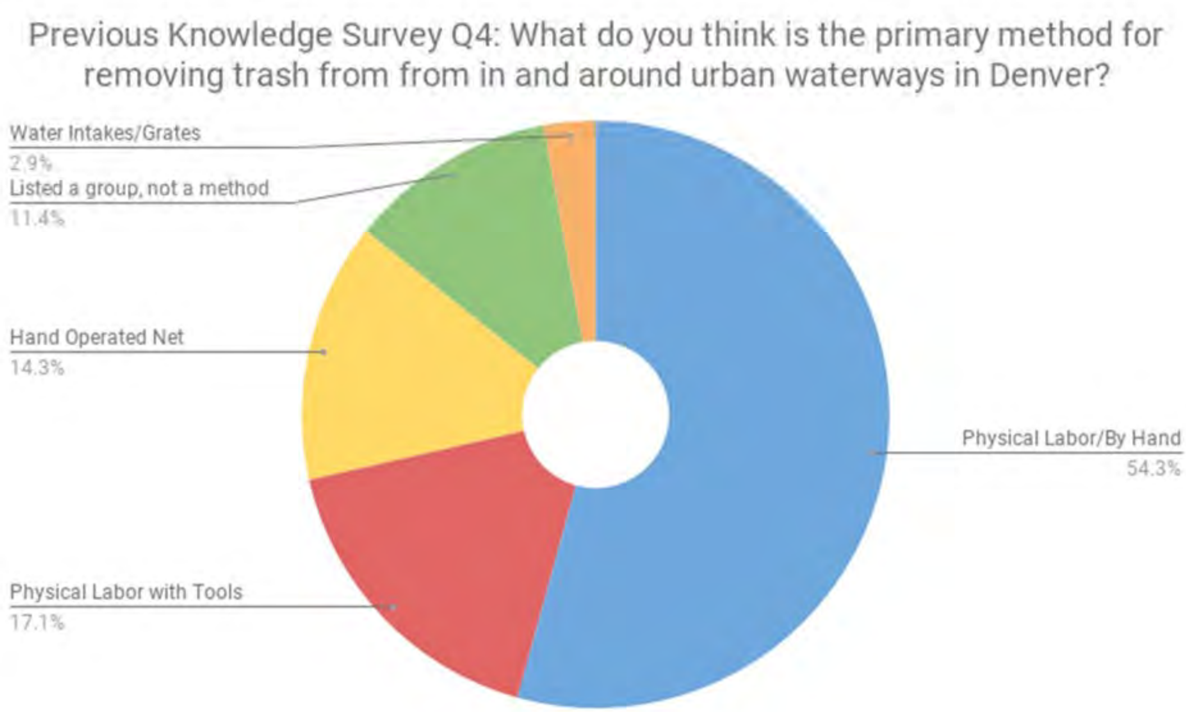
Previous Knowledge Survey Q3 and Post Competition Survey Q2 show that the trash found on our competition site is similar to trash students have experienced at other places along urban waterways in Denver. This means that our competition site was representative of the issues of urban pollution issues.

Previous Knowledge Survey Q3: What do you think are the most common types of trash found in and around urban waterways in Denver?



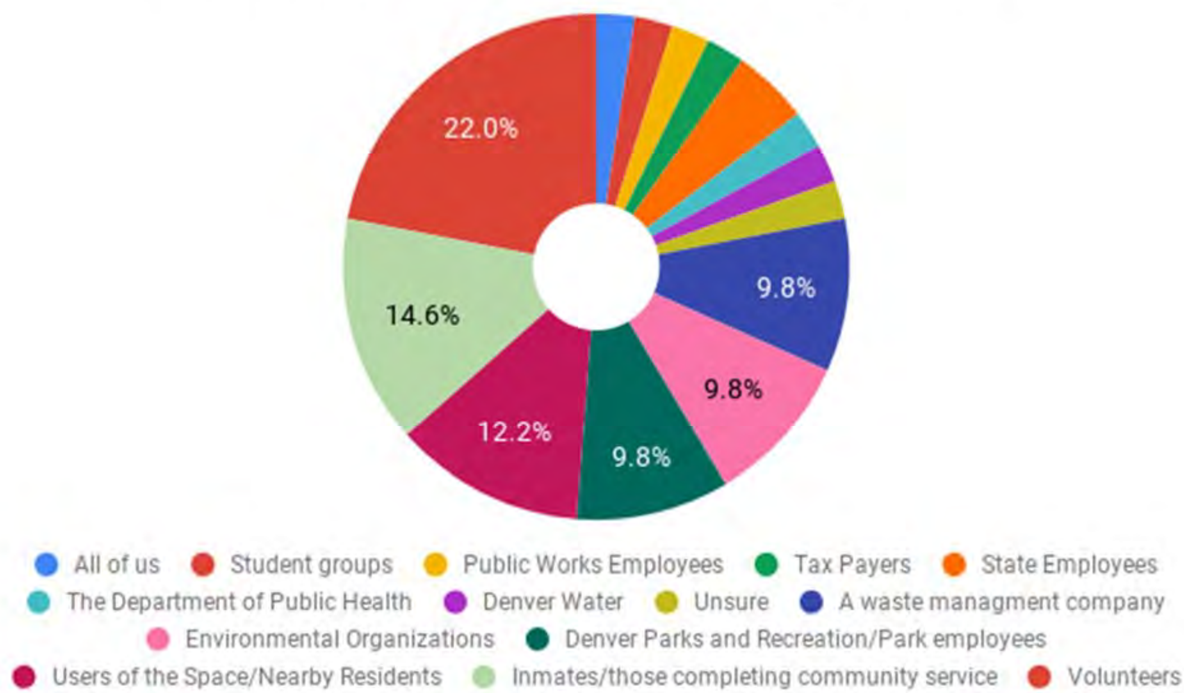


Previous Knowledge Survey Q4 indicated that the student teams had a fairly good perception of how trash is removed along our urban waterways (which is manually/by hand). However, the chart below indicates that the students believe that there are specialized tools and/or nets that people use to collect and remove trash from urban waterways. To our knowledge, Denver does not utilize such tools.

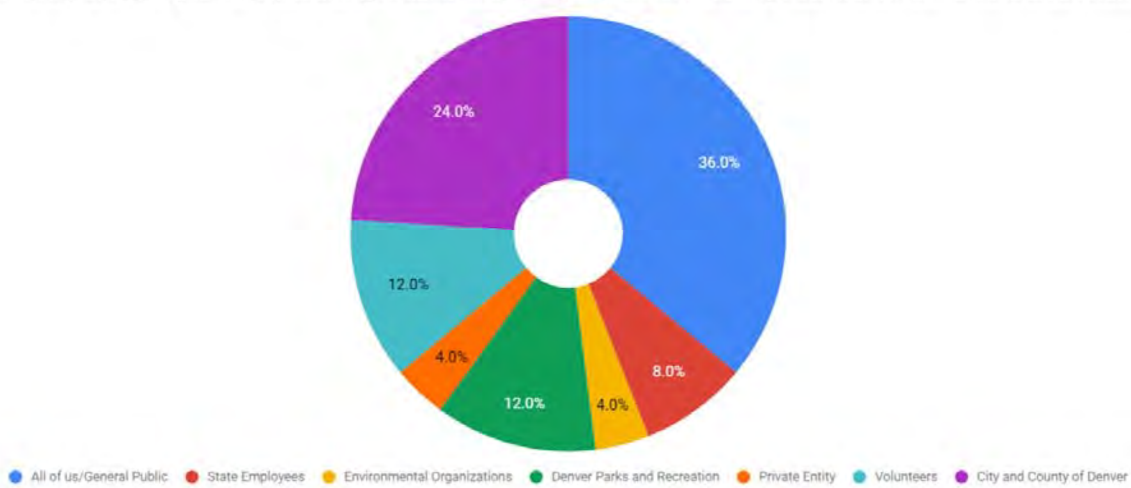


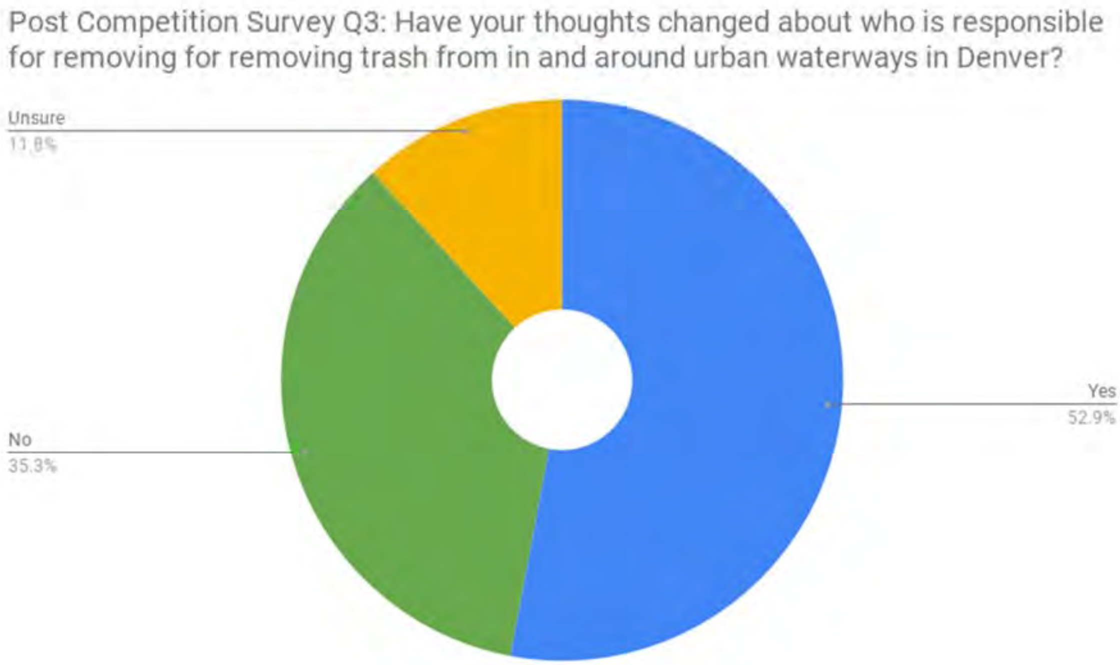
Previous Knowledge Survey Q5 shows that students had a limited understanding of who actually cleans up trash in our urban waterways. There are two charts from Post Competition Survey Q4 which indicate that some students showed a change in perception of who is responsible, and an increased knowledge of who takes care of our urban waterways. If you notice the “All of us” slice which is a bright blue color in both the Previous and Post Surveys. The Post Competition survey is significantly larger, which leads us to believe that this competition may have increased a sense of stewardship in more of the student participants!

Previous Knowledge Survey Q5: Who do think is responsible for removing trash from in and around urban waterways in Denver?

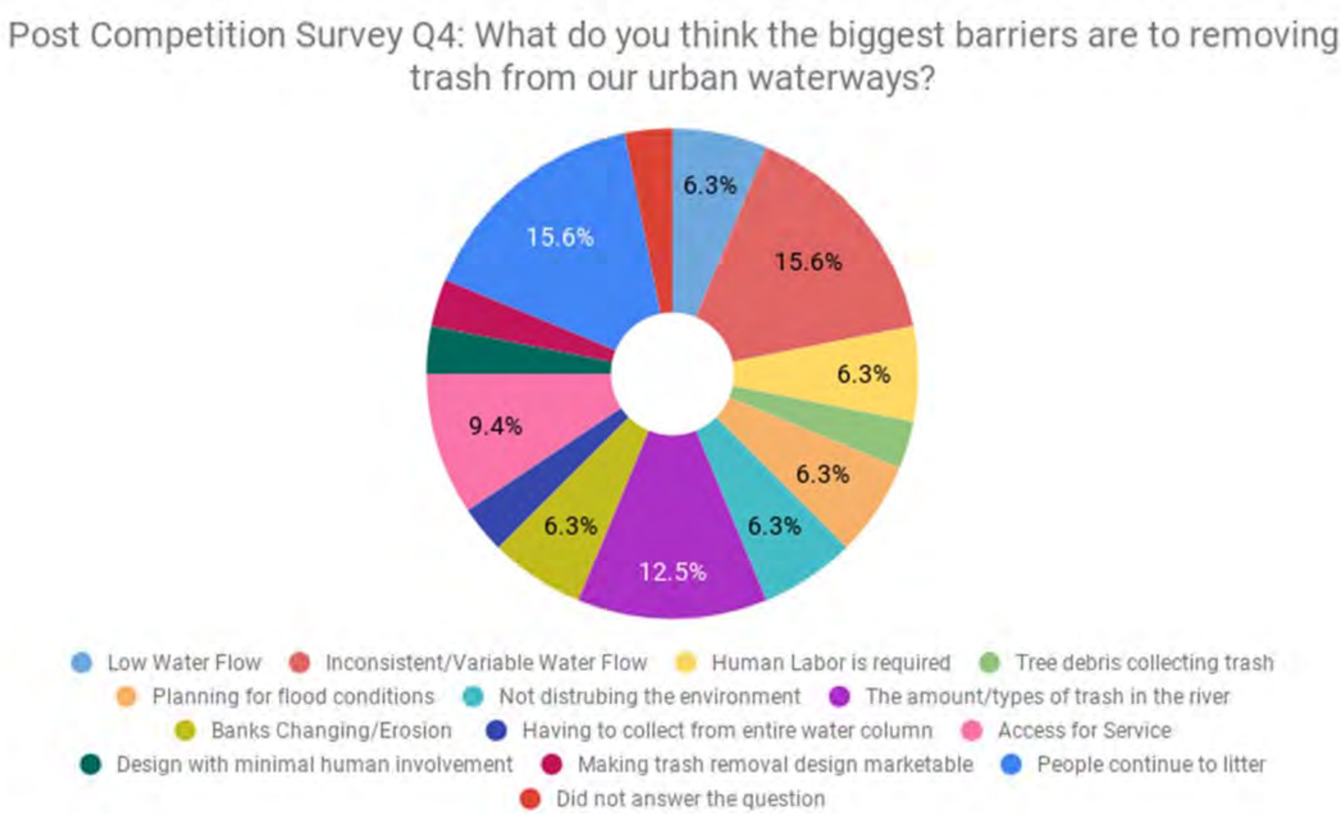


Post Competition Survey Q3: Have your thoughts changed about who is responsible for removing trash from in and around urban waterways in Denver?

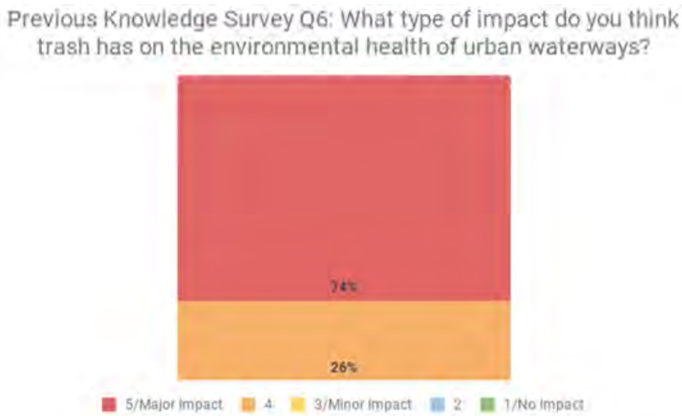


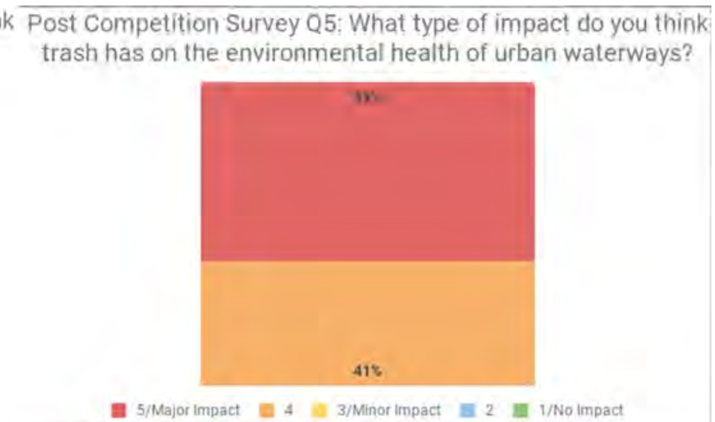


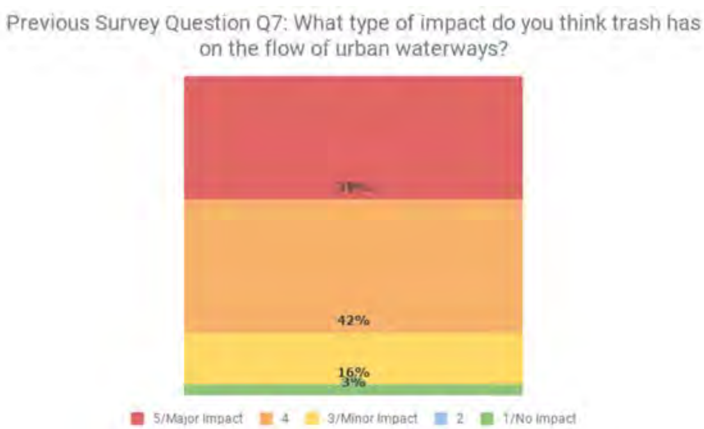
Post Competition Survey Q4 shows that the student teams have a good grasp of the complexities of designing a device to operate in an urban waterway.

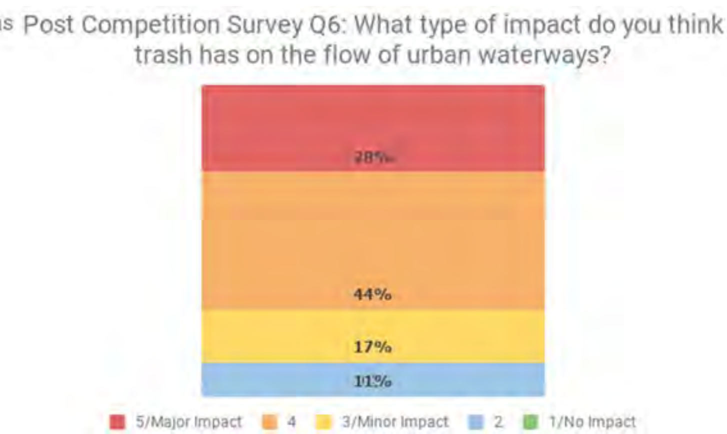


The questions regarding the environmental and hydrological impact of trash on our urban waterways do not show a major shift in the students' knowledge or perception.









CBS Channel 4 Story and Video Link:
https://denver.cbslocal.com/2019/04/18/clean-river-design-platte-pollution/

Clan River Design Challenge Focuses On Platte River

By **Joel Hillan**April 18, 2019 at 11:59 pm

Filed Under:Greenway Foundation, **Lakewood News**

LAKEWOOD, Colo. (CBS4)– Trash is making its way into our rivers and eventually to the ocean. The Greenway Foundation is trying to find innovative solutions and are turning to the next generation of thinkers for ways to remove the pollutants.

Drone4 flies over the South Platte River (credit: CBS)

This year's Clean River Design Challenge focuses on a section the Platte River adjacent to the REI building where an old Denver Water diversion gate has become a collection spot for trash and debris.

(credit: CBS)

The challenge was held at the U.S. Bureau of Reclamation Hydraulics Lab at the Denver Federal Center. There, a specially-created hydraulic lab flume simulates the specific waterway conditions at Confluence Park.

(credit: CBS)

Team Trash Trouts' Isaac Jimenez Junior from the Colorado School of Mines is proud of his team's prototype.

(credit: CBS)

“I’m just checking out to see how our trash removal is working, it looks like it’s working good, pretty proud of it.”

(credit: CBS)

The team’s prototype did well in a low-flow scenario, but didn’t do as well in the high-flow trial.

(credit: CBS)

“Our outer cage didn’t raise up so we missed a lot of trash, I mean our concept is there, our implementation wasn’t perfect,” he said.

(credit: CBS)

Lauren Berent is the Events Director for The Greenway Foundation, the environmental non-profit who organized the challenge.

(credit: CBS)

“Our goal is to have them create a scaled model of a device that would go in stream, in one of our urban water ways to pull some trash out that’s made its way into our river,” she said.

Drone4 flies over the South Platte River (credit: CBS)

Even with a year of planning, things didn't go as planned for the River Guardians, also from the Colorado School of Mines—they learned their battery fried during an earlier test.

"The last time we came here we were a lot more successful with our tests than we were today."

(credit: CBS)

Although the top prize ended up going to an industrial design team from Metro State University, Bryan Cazier was grateful for the opportunity.

“If you just try your hardest, you’re going to gain some kind of experience and some kind of skills you wouldn’t otherwise develop,” said Cazier.

(credit: CBS)

The winner of the first challenge in the 2015-2016 school year, was also won by an industrial design team from Metropolitan State University. The Greenway Foundation is currently awaiting permits from the City of Denver to pilot that prototype in a section of the Cherry Creek in Denver. They hope to have it in the water by the end of the year.

LINK: The Greenway Foundation | Clean River Design Challenge