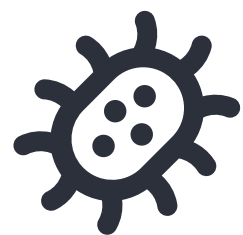




The American Society of Civil Engineers rated our drinking water system with a D+ because the age of the infrastructure, issues with legacy and emerging contaminants, and the amount of pipe main breaks annually. They estimate over \$1 trillion are needed to maintain and expand service to meet demand for the next 25 years. (ASCE, 2017)

Faucet, Retrieved from PIXABAY.COM under CCO Creative Commons.



BIOLOGICAL



PHYSICAL



CHEMICAL



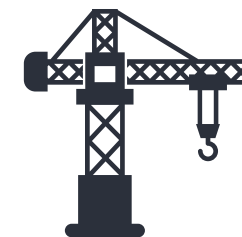
RADIOLOGICAL

Contaminants are categorized into one of four groups. Biological contaminants include bacteria, protozoa, viruses, and more. Physical contaminants include debris, such as leaves, sticks, and other organic matter. Chemical contaminants are either naturally occurring or activity-related, and are subcategorized as volatile organics, synthetic organics, and inorganic compounds. Radiological contaminants are also naturally occurring or activity-related, and include alpha and beta particles, two types of radium, and uranium. (EPA, 2016, 2017a, b, c)

Icons, Retrieved from Noun Project under Creative Commons, illustrated by Gregor Cresnar, IconsGhost, Cornelius Danger, and Martyn Jasinski.



AGRICULTURE



CONSTRUCTION



MILITARY



INDUSTRY



LANDFILL



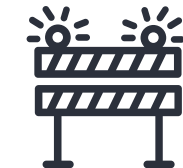
RESIDENTIAL



RECREATION



LIVESTOCK



ROADWORK

Icons, Retrieved from Noun Project under Creative Commons, illustrated by anbiluru adaleru, Hopkins, Maxim Samos, Ben Davis, Yu luck, Chanut is Industries, Jemis mali, Christine M Winn, and Thomas' design.

Contamination is a complex issue, with sources originating from natural sources and a variety of human activities, such as those listed above. As evidenced by the impacts of contamination incidents at Camp Lejeune, NC (National Research Council, 2009), Hinkley, CA (Andrews & Walker, 2016), and most recently Flint, MI (Kennedy, 2016), the severity and frequency of these threats are expanding to impact larger populations as water systems continue to grow to meet increasing demands without addressing existing treatment issues.

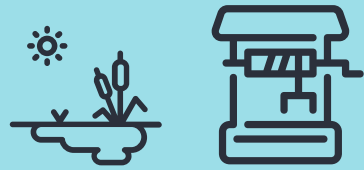
Troops training at Camp Lejeune, Retrieved from UCSUSA.org.

Pacific Gas and Electric Company Water Notice, Retrieved from iPetitions.com.

Water in Flint, MI, Retrieved from Twitter.com.



What are the stages of our drinking water system?



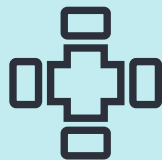
SOURCE WATER

Drinking water is sourced primarily from surface or ground waters. As ground water sources are being used faster than they can replenish, more and more systems are becoming dependent on surface waters. (The USGS Water Science School, 2005)



TREATMENT

Local governments, such as the City of Houston, are responsible for designing a water treatment system and adequately addressing the specific contamination issues of the region to ensure compliance with EPA guidelines.



DISTRIBUTION

Treated water is distributed to its customer network through a system of pipes. The size of this network can range from a few thousand to several million individuals and businesses, with a demand level that fluctuates according to time of day, season, and need.



RESIDENTIAL MAIN

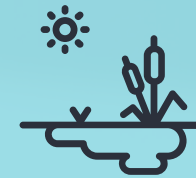
Water enters a residence through a central main, also called the "point-of-entry." This point is generally located on the ground floor of a property, and possesses a shut-off valve for maintenance and emergency situations. Some consumer-level treatment systems are installed at this point.



DISPENSING FIXTURES

The final opportunity for consumer-level treatment occurs at the dispensing fixture, also called the "point-of-use." Fixtures that provide direct contact with treated water include sinks, showers, bathtubs, and refrigerator dispensers. Indirect contact occurs through major appliances, such as dishwashers or washing machines, and toilets.

Where can the treatment burden be reduced?



SURFACE WATER

The treatment of surface water is an endeavor undertaken by few. The existing market is relatively small and dominated by a few players, making the potential for innovation great. Solutions in this context would impact the health of all who receive water from a system, and may reduce the overall treatment costs for system administrators.



LARGE SOLUTION
AREA



IMPACTS HEALTH
OF ALL



MAY LOWER
TREATMENT COSTS

Fountain, Retrieved from PIXABAY.COM under CC0 Creative Commons.

Icons, Retrieved from Noun Project under Creative Commons, illustrated by Valeria Mia Piccioni, Lewis Ngugi, Vectors Market, Bakunetsu Kaito, and Arthur Shlain.



Phytoremediation is the clean up of soil and water by plants that directly uptake “toxic chemical(s), followed by subsequent transformation, transport, and their accumulation in less toxic forms.” (Chatterjee, Mitra, Datta, & Veer, 2013) Historically, phytoremediation has been applied to wastewater and sewage effluent treatment through constructed wetlands.

Constructed Wetland, Retrieved from MLWS.LAND-FOOD.UBC.CA/STUDENTPROJECTS under Fair Use.

Icons (Modified), Retrieved from Noun Project under Creative Commons, illustrated by Cono Studio Milano.

Phytoremediation relies on five primary processes, but the three most pertinent are illustrated below. Through these processes, certain plants are capable of removing and/or degrading contaminants from the environment. Some refer to these plants as “hyperaccumulators,” due to their ability to tolerate high levels of contamination.



PHYTODEGRADATION

The plant breaks down the contaminant into its chemical degraded and releases them into the environment.



PHYTOEXTRACTION

The plant removes the contaminant from the environment and stores it in its tissues.



RHIZOFILTRATION

The plant removes the contaminant from water through its roots.



Atrazine Concentrations in Water Systems (Wu, Quirindongo, Sass, & Wetzler, 2009, p. 12)

Atrazine is the second most popular herbicide used in the United States agriculture industry. By design, atrazine resists degradation in the environment, lasting up to 14 years or more post-application. As a result, atrazine is a persistent contaminant in surface water that is capable of traveling far from the initial application site. (Wu, Quirindongo, Sass, & Wetzler, 2009)

The plants shown below have been tested to remove atrazine from water in a variety of environments. Of these, five were chosen for further study.

Assorted Plant Images (USDA, n.d.)



RYEGRASS



PALE YELLOW IRIS



PURPLE LOOSESTRIFE



COMMON RUSH



COMMON REED



POPLAR TREE



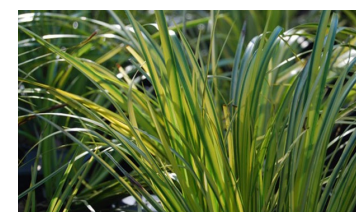
BIG BLUESTEM



FESCUE



CATTAIL



SWEET FLAG



SWITCHGRASS



CUTGRASS



Phytoremediation technology has been employed most often in constructed wetlands, effluent cleanup, and wastewater remediation. These systems have been employed to clean soil, flood-prone areas, shallow water bodies, and larger water bodies using floating rafts.

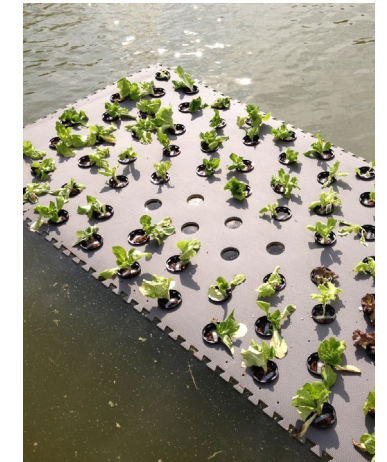
This project seeks to improve the floating raft concept by increasing usability. A review of existing precedents is shown on the next page. While each product presents its own innovations, no single design addresses six key design considerations, which are outlined in the table below.



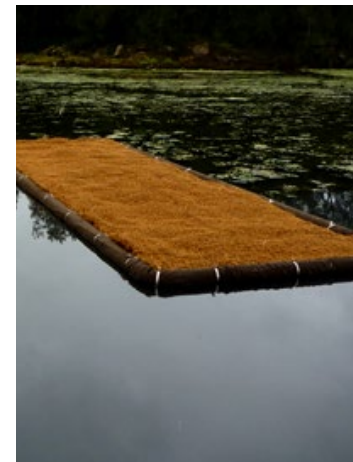
BIOHAVEN



PHYTOLINKS



BEEMATS



AQUA BIOFILTER

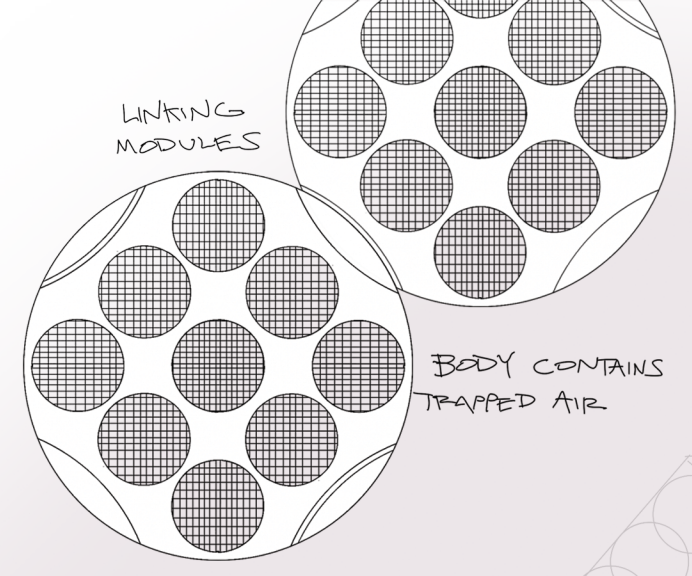
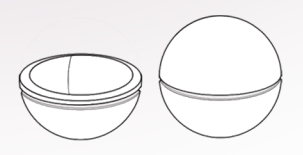
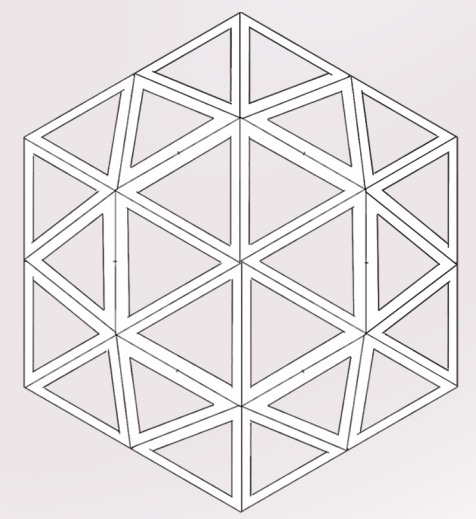
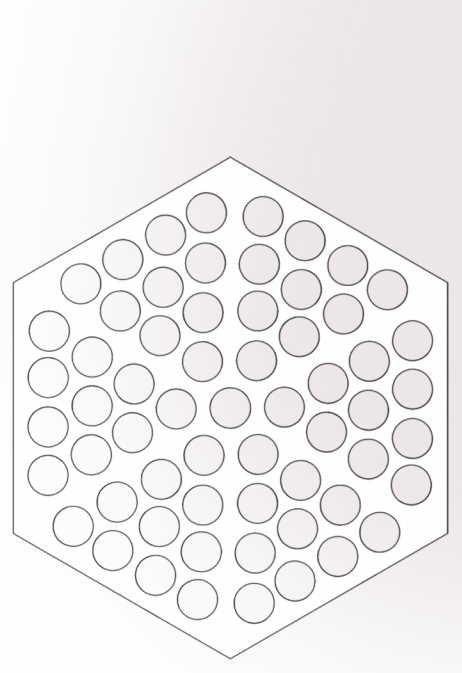
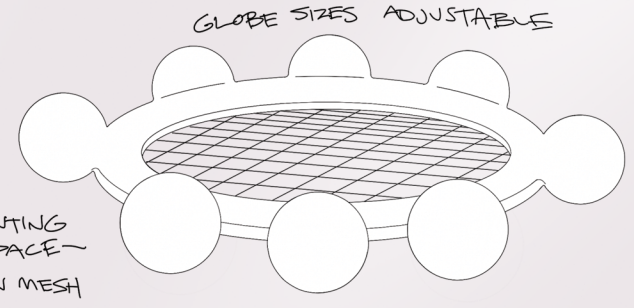
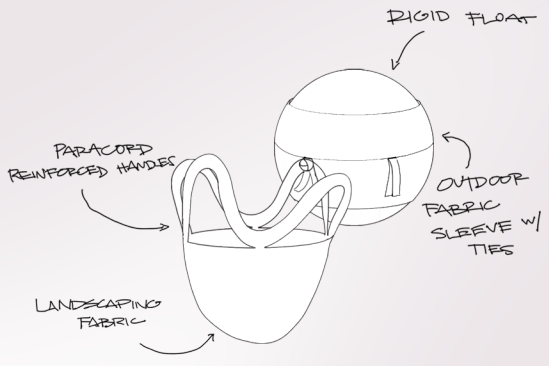
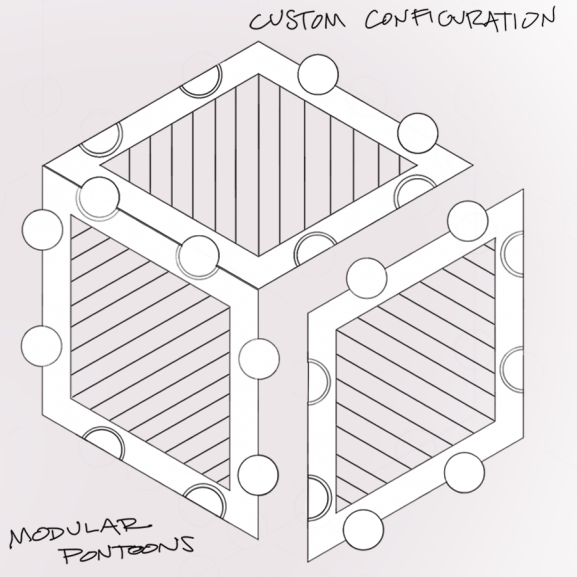
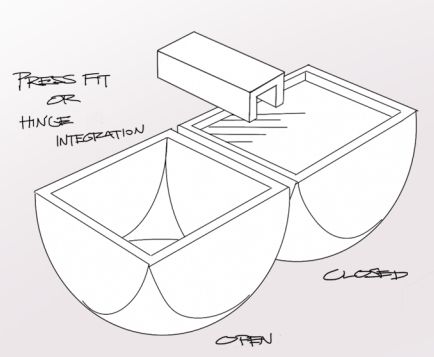


F.I.A.



XPS FOAM/"DIY"

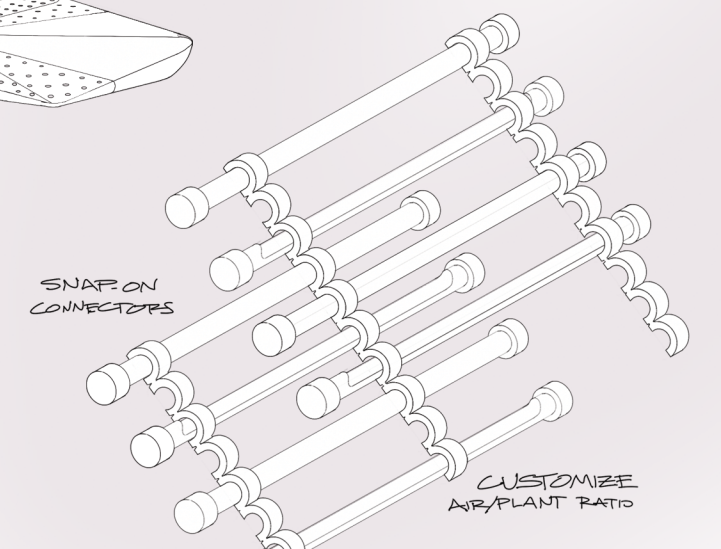
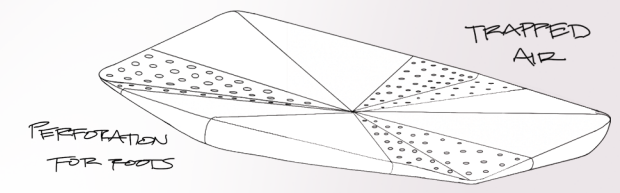
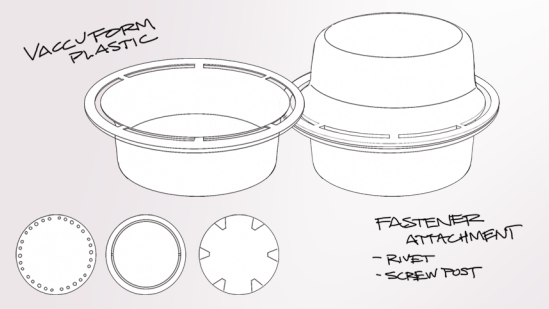
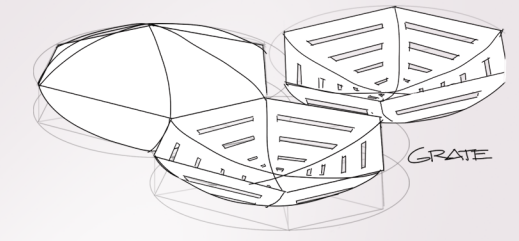
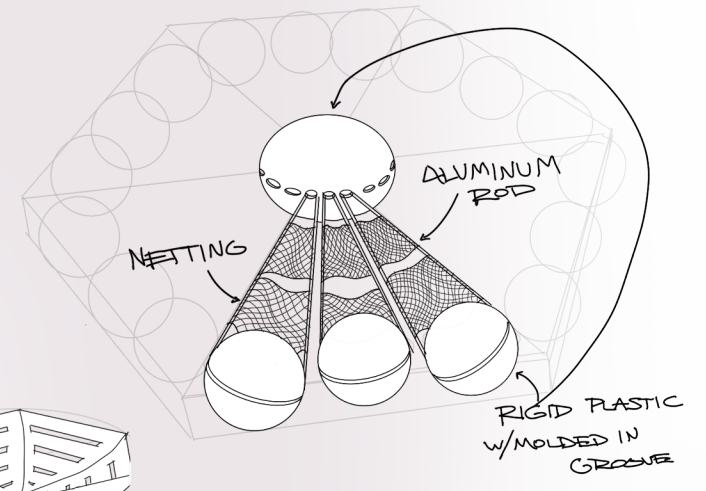
	BIOHAVEN	PHYTO LINKS	BEEMATS	AQUA BIOFILTER	F.I.A.	XPS FOAM "DIY"
WEIGHT	✗	✓	✓	✗	✓	✓
MATERIAL IMPACT	✗	✓	✗	✓	✗	✗
BUOYANCY	✗	✗	✓	✓	✗	✓
ASSEMBLY	✓	✗	✗	✗	✓	✗
DURABILITY	✓	✗	✓	✓	✓	✗
USABILITY	✗	✓	✗	✗	✓	✗

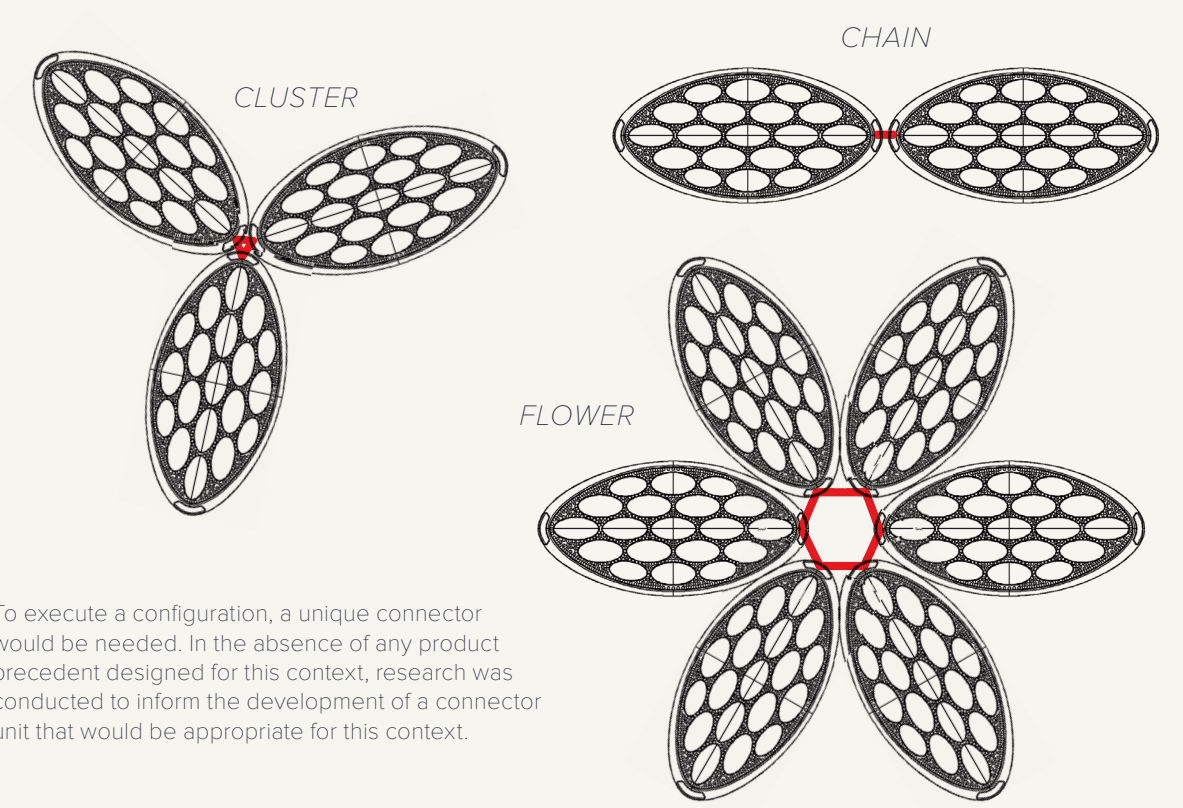
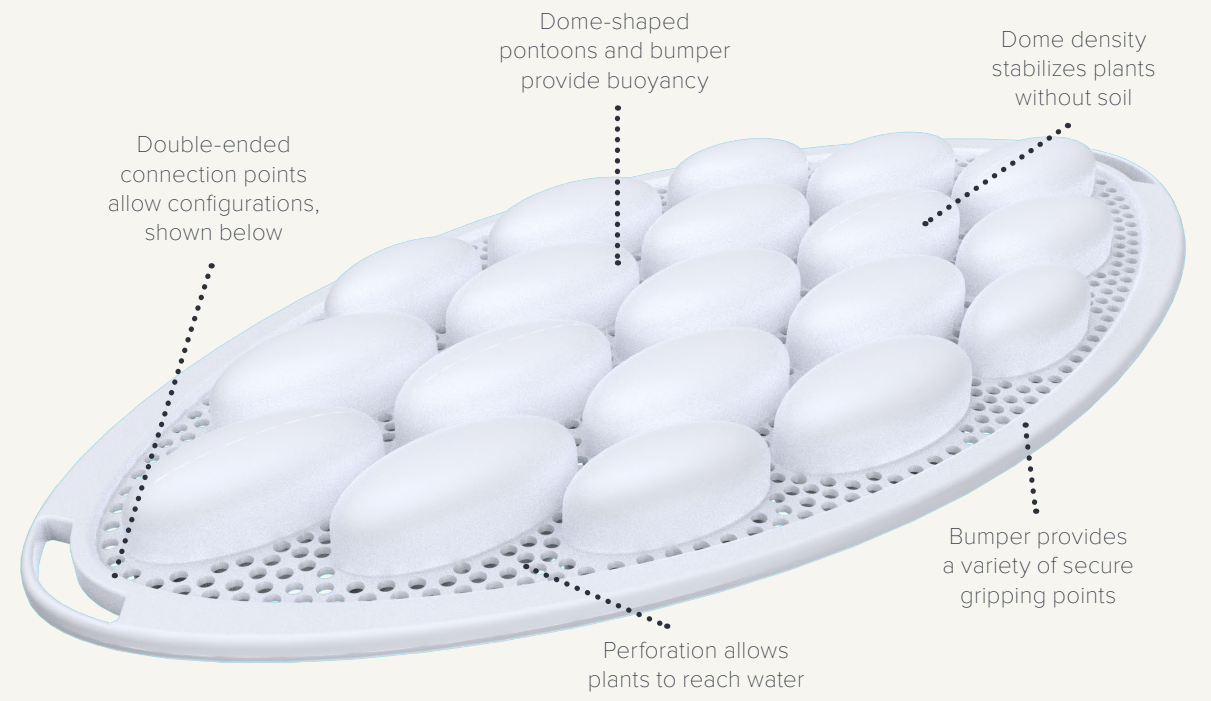


BODY CONTAINS TRAPPED AIR

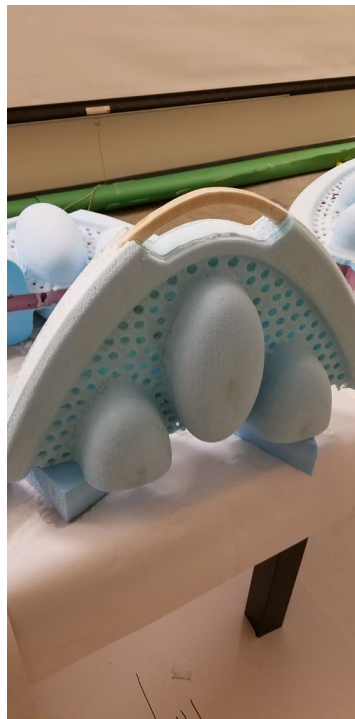
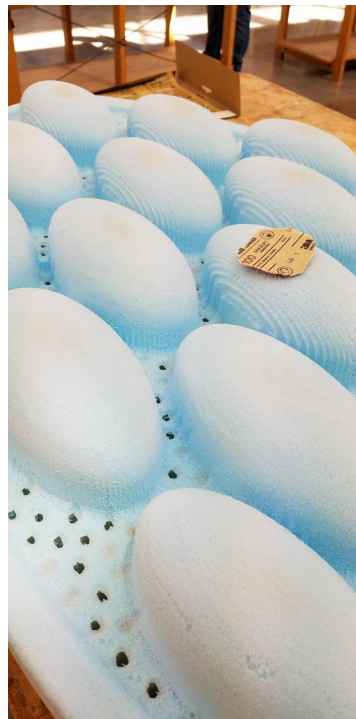
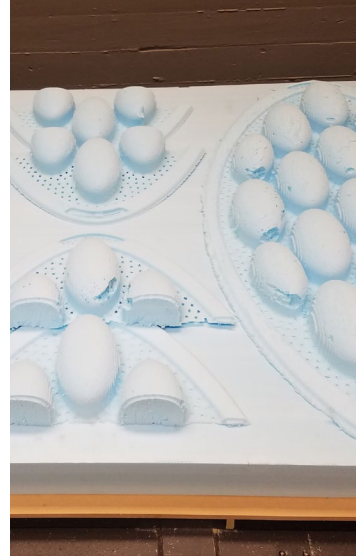
SKETCH EXPLORATIONS

- SIZE
- CONNECTIONS
- MATERIAL
- BUOYANCY
- PRODUCTION METHOD





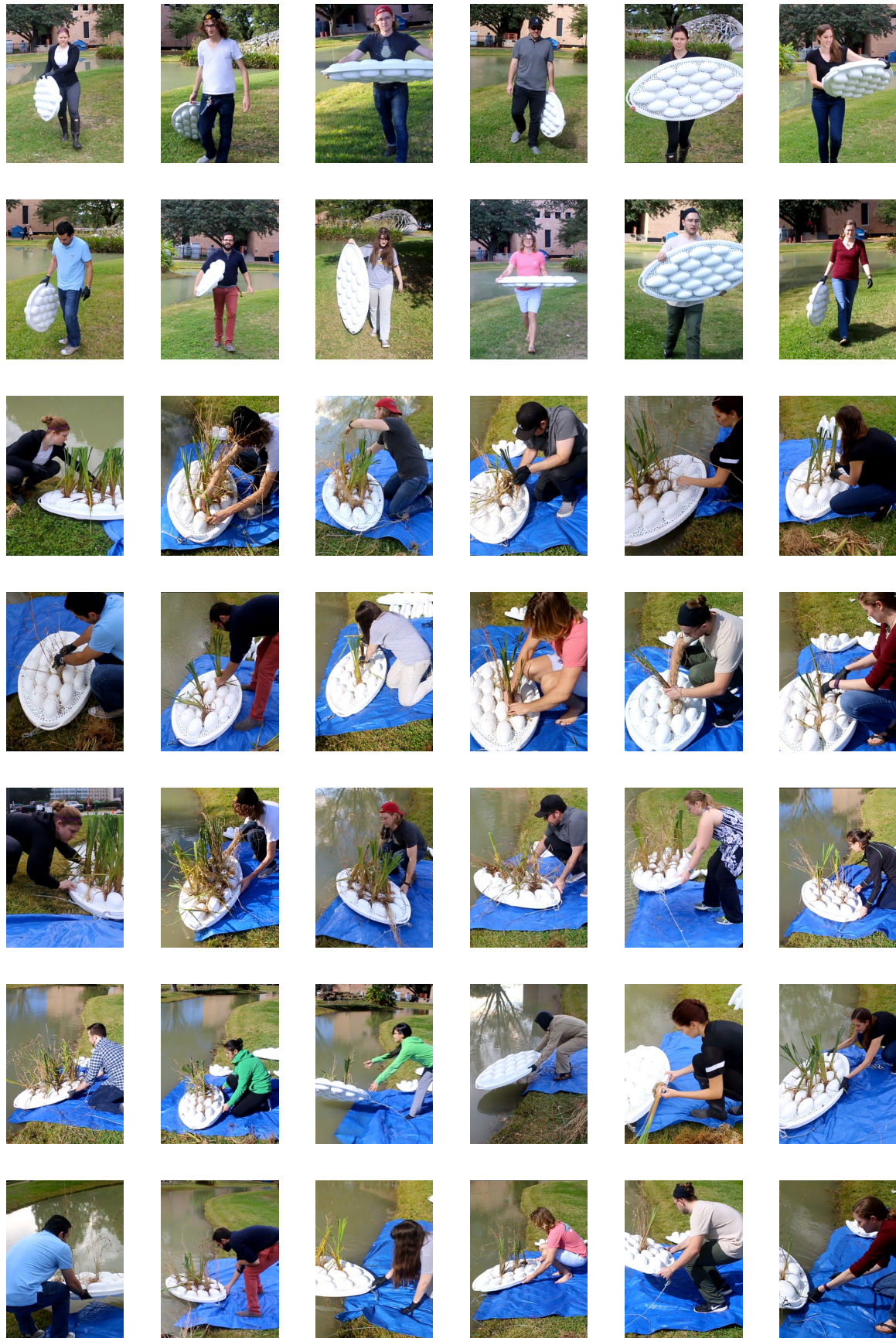
To execute a configuration, a unique connector would be needed. In the absence of any product precedent designed for this context, research was conducted to inform the development of a connector unit that would be appropriate for this context.



To conduct user testing of this concept, two full scale and four partial prototypes were constructed using CNC-milled XPS foam, which was covered with paint and pond-safe stiffeners and sealant.

Testing took place at the University of Houston's Meditation Pond, right outside the Gerald D. Hines College of Architecture and Design. Over the course of a week, 30 diverse subjects participated in a task load assessment and morphological study.





USER TESTING STUDY PART 1: TASK LOAD ASSESSMENT



CARRY



PLANT



DEPLOY

Participants were asked to carry an empty, full-size raft prototype approximately 50' along the bank of the pond.

Using provided cattail and switchgrass plants, participants were asked to plant the raft. They were given no instruction, other than to stop when they felt like it.

After planting, participants were asked to deploy the raft into the pond. The raft was attached to a safety anchor to prevent it from floating out of reach for Part 2.

Icons (Modified), Retrieved from Noun Project under Creative Commons, illustrated by Andrew Doane, Suji, and Ben Davis.

Video Stills from User Testing, Captured by Ashley Lincoln with permission from participants.



USER TESTING STUDY PART 2: MORPHOLOGICAL STUDY



CONNECTOR A
CARABINER

Stainless Steel
Clip
4.5" L
Rigid
One-Handed Use



CONNECTOR B
INDUSTRIAL TWIST-TIE

Rubber-Coated Metal Wire
Twist-Tension
18" L
Semi-Rigid
Two-Handed Use



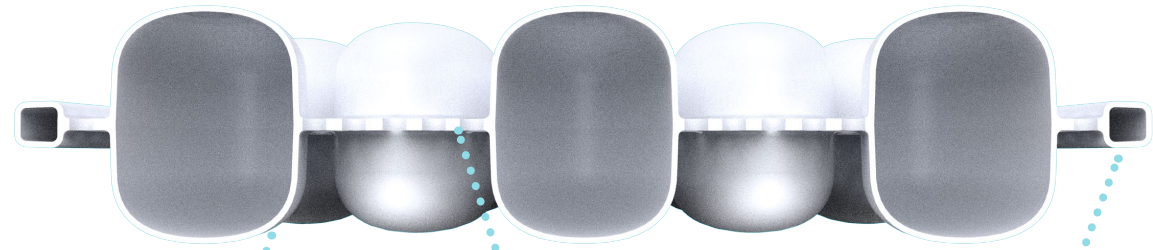
CONNECTOR C
STRAP WITH BUCKLE

Nylon Strapping
Parachute Buckle
72" L Strap, 2" L Buckle
Pliable
Two-Handed Use

Connectors, Retrieved from Home Depot.com under Fair Use.

Video Stills from User Testing, Captured by Ashley Lincoln with permission from participants.

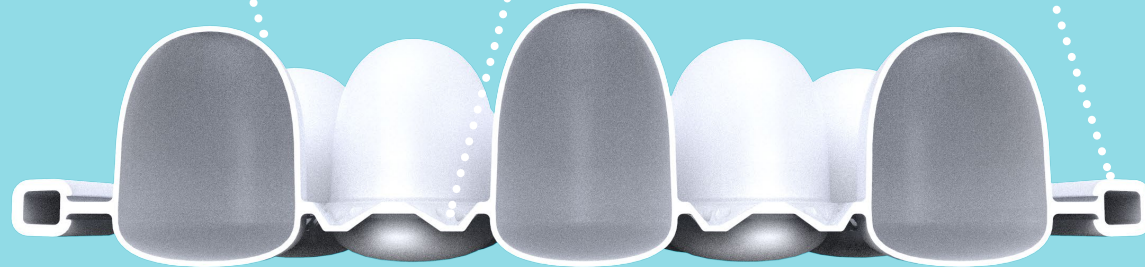
ORIGINAL DESIGN



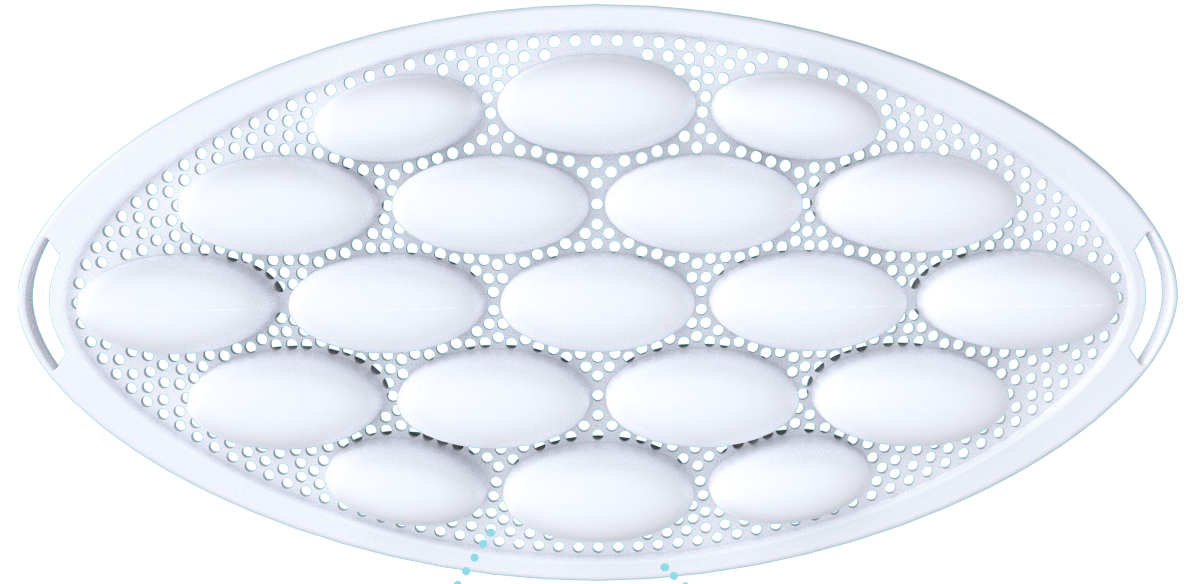
Modified pontoon shape to provide increased support to plants

Added recessed areas to indicate where plants should be placed

Lowered height of bumper to allow plants to reach the water easier



POST-TESTING REVISION



Changed shape of perforation holes from circles to capsules to prevent threading root behavior among users

Added designated grip to encourage less strenuous gripping behavior and posture



INITIAL DATA COLLECTION

CONNECTOR PROPERTIES



CONNECTOR A
CARABINER

Stainless Steel
Clip
4.5" L
Rigid
One-Handed Use



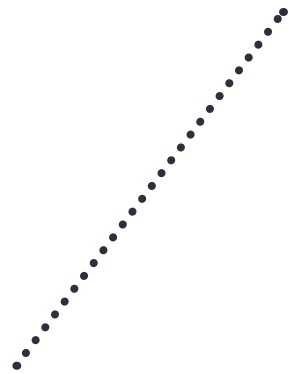
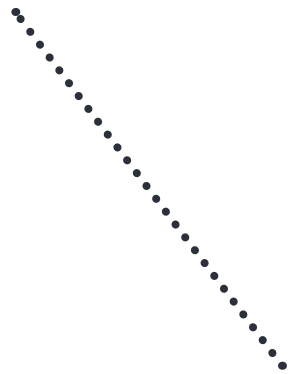
CONNECTOR B
INDUSTRIAL TWIST-TIE

Rubber-Coated Metal Wire
Twist-Tension
18" L
Semi-Rigid
Two-Handed Use



CONNECTOR C
STRAP WITH BUCKLE

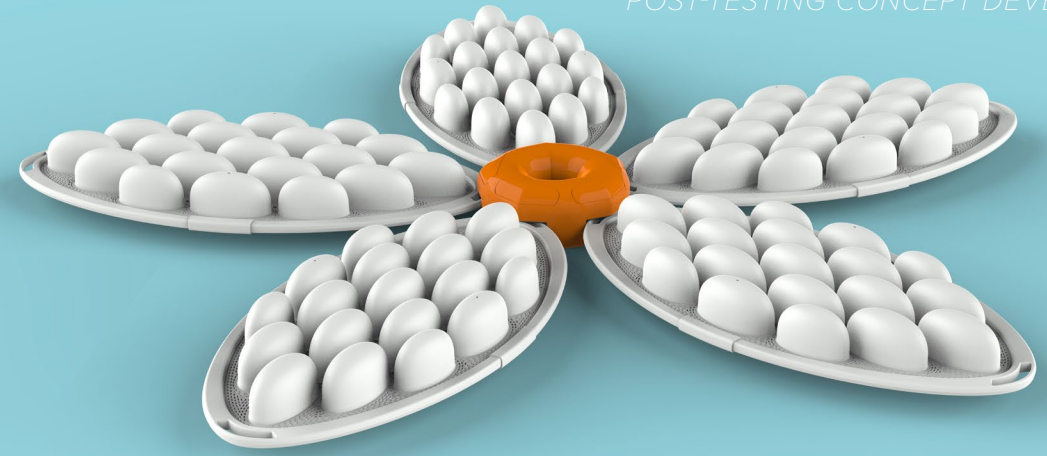
Nylon Strapping
Parachute Buckle
72" L Strap, 2" L Buckle
Pliable
Two-Handed Use



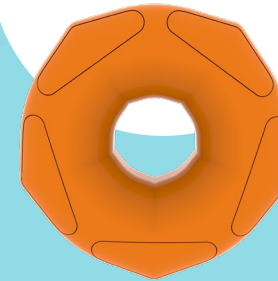
DESIRABLE ATTRIBUTES

One-Handed Use
Constrained Raft Movement
Configurable
Buoyant
"Familiar"
"Fast"

POST-TESTING CONCEPT DEVELOPMENT



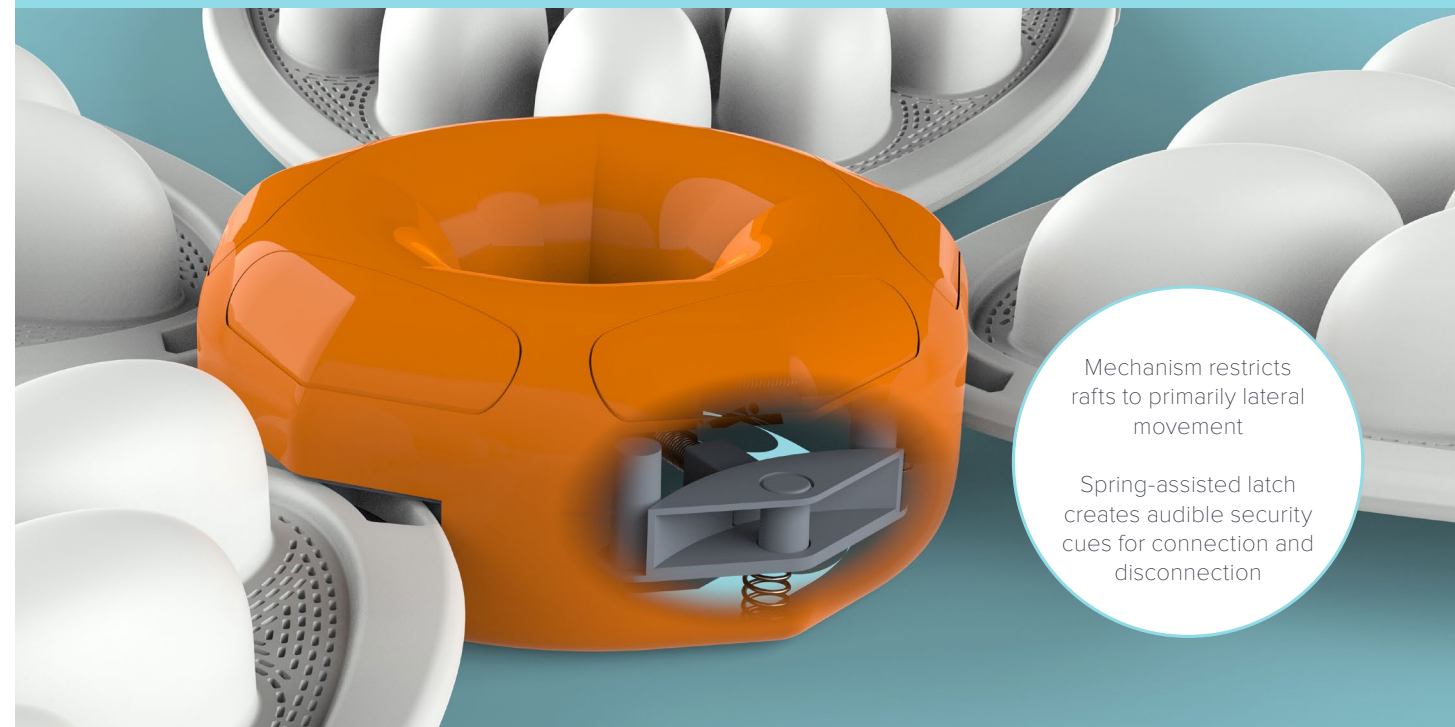
Rounded body maximizes buoyancy and reduces debris & water collection



Each unit features five slots for raft connection that utilize a seat-belt style latch

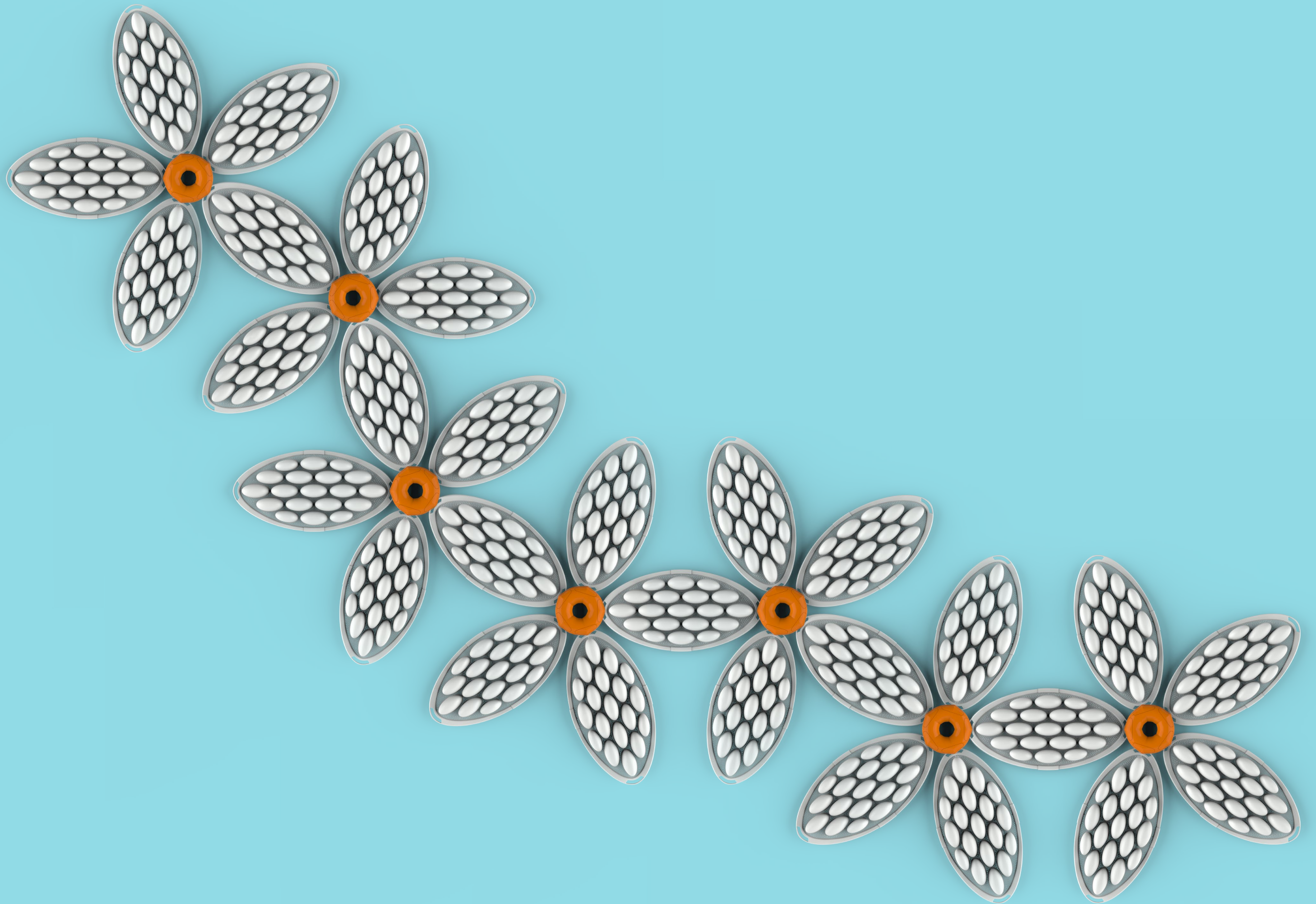


The bottom of each unit provides several secure locations for anchoring



Mechanism restricts rafts to primarily lateral movement

Spring-assisted latch creates audible security cues for connection and disconnection





References

ASCE. (2017). Infrastructure Report Card: Drinking Water. American Society of Civil Engineers. Retrieved from <https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Drinking-Water-Final.pdf>

Chatterjee, S., Mitra, A., Datta, S., & Veer, V. (2013). Phytoremediation Protocols: An Overview. In D. K. Gupta (Ed.), *Plant-Based Remediation Processes* (Vol. 35, pp. 1–18). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-35564-6_1

Environmental Protection Agency (EPA). (2017a). Chemical Contaminant Rules. Retrieved February 22, 2017, from <https://www.epa.gov/dwreginfo/chemical-contaminant-rules>

Environmental Protection Agency (EPA). (2016). Learn About the Unregulated Contaminant Monitoring Rule. Retrieved February 23, 2017, from <https://www.epa.gov/dwucmr/learn-about-unregulated-contaminant-monitoring-rule>

Environmental Protection Agency (EPA). (2017b). Radionuclides Rule. Retrieved February 22, 2017, from <https://www.epa.gov/dwreginfo/radionuclides-rule>

Environmental Protection Agency (EPA). (2017c). Stage 1 and Stage 2 Disinfectants and Disinfection Byproducts Rules. Retrieved February 22, 2017, from <https://www.epa.gov/dwreginfo/stage-1-and-stage-2-disinfectants-and-disinfection-byproducts-rules>

World Health Organization. (2003). Guidelines for drinking-water quality, Volume 1: Recommendations (3). Albany, CH: World Health Organization. Retrieved from <http://www.ebrary.com>

National Research Council. (2009). Contaminated Water Supplies at Camp Lejeune: Assessing Potential Health Effects. Washington, DC: The National Academies Press. <https://doi.org/10.17226/12618>

Andrews, D., & Walker, B. (2016, September). “Erin Brockovich” Carcinogen in Tap Water of More than 200 Million Americans. Retrieved October

27, 2017, from <https://www.ewg.org/research/chromium-six-found-in-us-tap-water>

Kennedy, M. (2016, April). Flint Water Crisis: A Step-By-Step Look At What Happened : The Two-Way : NPR. Retrieved October 27, 2017, from <http://www.npr.org/sections/thetwo-way/2016/04/20/465545378/lead-laced-water-in-flint-a-step-by-step-look-at-the-makings-of-a-crisis>

The USGS Water Science School. (2005). Groundwater use in the United States. Retrieved October 9, 2017, from <https://water.usgs.gov/edu/wugw.html>

USDA. (n.d.). Welcome to the PLANTS Database. Retrieved August 5, 2017, from <https://plants.usda.gov/java/>

Wu, M., Quirindongo, M., Sass, J., & Wetzler, A. (2009). Poisoning the Well. Retrieved from <https://www.nrdc.org/sites/default/files/atrazine.pdf>