Pre-Phase A: UAV HydroHarvester Module

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Users and Stakeholders

Users:

- FAA Certified Drone Pilot

Stakeholders:

- Puerto Rico Department of Natural and Environmental Resources
- Puerto Rico Water Resources and Environmental Research Institute
- PUPR Environmental Engineering Department.

User and Stakeholder Needs

Who has the need?	What is the need?	Priority Level	Feasibility Level	Trade-Off	Requirement
PRWRERI, PRDNER & PUPREED	A quicker, more reliable and controllable water sampling recollection instrument.	High	High	Complexity vs. Utility	Recollect two water samples from hard-to-reach enviroments.
PUPR Environmental Engineering Department	Increase operations efficiency and safety while minimizing expenses.	High	Medium	Cost vs. Quality	Guaranty a quicker and safer water sample extraction.
CWA, EPA, FAA & OSHA	Adherence to safety regulations.	High	High	Flexibility vs. Safety Standards	Comply with all regulations regarding the CWA, EPA, FAA & OSHA.

Problem Statement

Recollecting a superficial water samples from inaccessible or hazardous bodies of water, such as those surrounded by steep terrain, dense vegetation, or contaminated environments, poses significant logistical challenges. These conditions often require technicians to carry heavy gear over long distances, navigate unsafe terrain, or use specialized vehicles, all of which demand time, strength, and increase operational risk.

As a result, the efficiency of the sampling process is greatly affected, since time that could be spent on analysis or broader monitoring is instead diverted to transportation and access logistics, ultimately limiting the frequency, accuracy, and coverage of water quality assessments.

Mission Needs

1) A remote sampling solution that can access hazardous or hard-to-reach water bodies by the use of an UAV.
2) A lightweight, portable system that eliminates the need for heavy equipment transport across rough terrain.
3) An aerial platform-compatible module capable of recollecting and securing water samples from multiple locations.
4) A system that reduces operational time, allowing for faster deployment and retrieval compared to traditional manual sampling methods.

Mission Needs

5) Minimized exposure of personnel to environmental hazards such as steep slopes, contaminated areas, or dense vegetation.
6) Improved sampling efficiency through rapid deployment, sample security, and easy recovery and transfer to laboratory equipment.
7) Increased sampling frequency and site coverage, enabling more comprehensive and accurate water quality monitoring.
8) Cost-effective sampling operations that reduce reliance on boats, multiple personnel, or off-road vehicles.

Project Significance

The successful deployment of this mission would significantly enhance the reach and efficiency of water sampling operations.

- By enabling access to previously unreachable or hazardous locations, environmental technicians can collect data from a broader range of water sources, resulting in more comprehensive and accurate monitoring.
- Likewise, by reducing the physical effort and time required for each sampling task, allows technicians to focus on higher-level analysis and decision-making.

Hence, the mission would lead to a better and faster data recollection process.

Goals

1) Optimize environmental technicians' water quality monitoring duties.
2) Ensure secure and reliable sample extraction.
3) Enhance operational efficiency by minimizing recollection time and maximizing data yield per deployment.
4) Reduce long-term operational costs.

Objectives

1) Design a module capable of being installed and uninstalled on a UAV.
2) Enable the recollection of 2 water samples from different location in the same body of water.
3) Ensure the module securely transports recollected water samples.
4) Recollected time stamps for each sample extraction.
5) Maintain water samples at their original temperature.

Objectives

6) Enable visual or electronic indication of successful sample recollection.
7) Maintain sample integrity by preventing contamination or mixing during flight.
8) Design the device to withstand accidental drops from operational heights without compromising its structural integrity.
9) Minimize the weight and size of the module to avoid compromising drone flight performance.

Context

In Puerto Rico, the lack of constant monitoring of river water quality has led to a series of negative impacts. Many rivers are affected by illegal wastewater discharges, agricultural and urban runoff, and uncontrolled sedimentation, which degrade aquatic ecosystems and reduce the availability of clean water for consumption, irrigation, or recreation.

Context

The research article by Ramírez & Gutiérrez-Fonseca (2016), related to this topic, states the following:

> Puerto Rico is a highly urbanized island, with nearly four million inhabitants,16% of its area urbanized, and 40% affected by poorly planned urban expansion (Martinuzzi et al., 2007). This creates numerous impacts on water bodies, related to urban development in watersheds, such as water extraction and untreated wastewater discharges (Ramírez et al., 2009; Ramírez & Gutiérrez-Fonseca, 2014). (p.343)

Context

Therefore, without adequate data, it becomes difficult to detect these problems in time, allowing pollution to spread and harm nearby wildlife, vegetation, and communities. Moreover, this situation limits the ability of the government and environmental organizations to implement effective protection measures.

That’s why our design aims to benefit everyone by providing a reliable water sample recollection device to broaden data points and help protect Puerto Rico’s ecosystems and public health.

Scope

Within Scope:

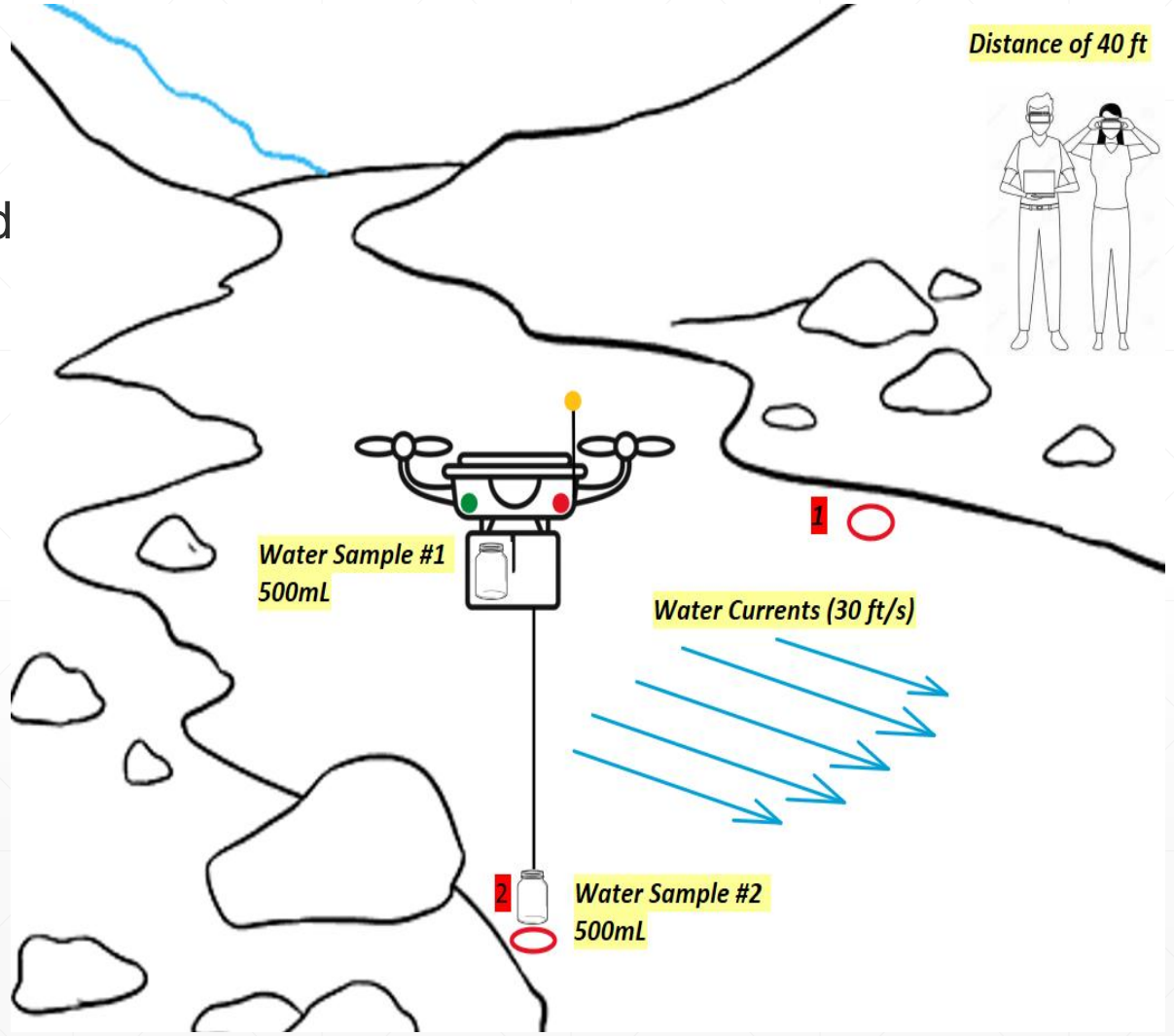
- ❑Engineer a design for a lightweight water extraction module compatible with the UAV.
- ❑Development of a secure attachment mechanism.
- ❑Incorporation of thermal isolation and timeframe log of the sample's extractions.
- ❑Design of visual indicators.
- ❑Ease of installation/uninstallation.

Out of Scope:

- ❑Desing or modifications of the UAV.
- ❑Autonomous Flight Control.

ConOps

The HydroHarvester will be a water sample recollection module designed to be deployed by a UAV in hard-to-reach environments. Its operation begins with secure attachment to the drone, followed by flight to designated sampling points. Upon arrival, the system lowers a mechanism to recollect water, simultaneously recording temperature and time data for each sample. An LED indicator confirms successful collection before the device stores the sample and prepares for the next extraction. Once all samples are recollected, the drone returns, allowing the HydroHarvester to be safely detached and its contents transferred to lab equipment for analysis.



MOE's

1. Device shall be able to hold and store 2 samples per operation.
2. The module should be easy and fast to securely installed and uninstalled.
3. Each sample extraction should be completed within a minimal and efficient time frame.
4. The recollected sample shall remain fully contained during operation, with minimal or no loss.
5. The vertical clearance above the water surface shall be sufficient to prevent UAV exposure to water splashes during sampling operations.
6. The system shall be able to withstand underwater currents without affecting UAV Flight Performance.

MOE's

7. Cross-contamination between samples shall not occur.
8. The device shall allow for unobstructed and stable drone takeoff and landing under standard operating conditions.
9. The device should be easy to clean, dry and disinfect after use.
10. The device should facilitate the straightforward transfer of samples from the recollection unit to laboratory analysis equipment with minimal handling.
11. The device shall remain fully operational after exposure to drone-induced vibrations in accordance with a vibration profile representative of normal flight conditions.

MOE’s

12. The device shall include an indicator light visible to assist in locating the unit and verifying operational status.
13. The device shall complete one full operational cycle on a single charge.
14. The module shall operate within visible medium-range distances from the base station or UAV controller.
15. The recollected samples should maintain their original temperature during transport to preserve integrity.
16. Each sample shall be time-stamped at the moment of recollection.

MOP's

1. The module shall be installable and removable in under 3 minutes each, without the use of external tools.
2. The system shall have less than 10% sample loss per recollection cycle.
3. The module shall include two 500 mL (16.91 fl oz) sealed compartments to recollect individual water samples, preventing cross-contamination during flight or transport.
4. The module shall have a visible LED indicator from 40 ft (12 meters) of distance.
5. The module shall maintain full functionality under vibration frequencies consistent with drone flight profiles.
6. The device's battery life shall exceed 30 minutes of continuous operation.

MOP's

7. The system shall recollect samples from a minimum of 2 distinct locations within 1 operational flight.
8. Samples shall be transferrable to lab equipment in under 1 minute without requiring additional tools or adapters.
9. The module shall have signal range capable of working at distances up to 40 ft (12 meters) from the base station/UAV controller.
10. The whole system (including the UAV, the HydroHarvester and the samples) shall have a total weight of less than 25 lbs (11.34 kg).
11. The system shall be fully cleanable, disinfected and dryable in less than 5 minutes.

MOP’s

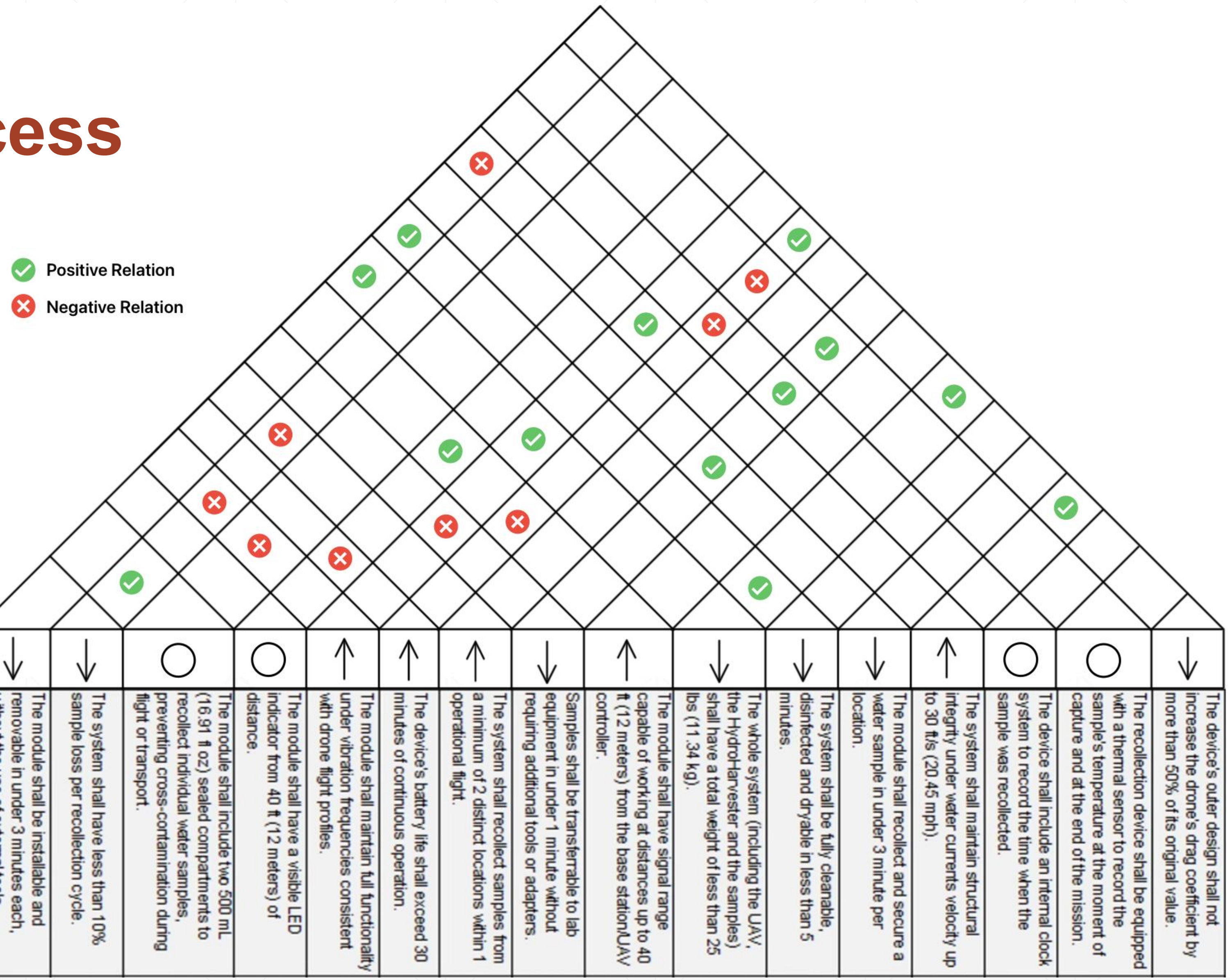
12. The module shall recollect and secure a water sample in under 3 minute per location.
13. The system shall maintain structural integrity under water currents velocity up to 30 ft/s (20.45 mph).
14. The device shall include an internal clock system to record the time when the sample was recollected.
15. The recollection device shall be equipped with a thermal sensor to record the sample's temperature at the moment of capture and at the end of the mission.
16. The device’s outer design shall not increase the drone’s drag coefficient by more than 50% of its original value.

Matrix of Success

9 = Strong Relation
6 = Moderate Relation
3 = Weak Relation

Costumer Requirements (MOEs)	Wt.	The module shall be installable and removable in under 3 minutes each, without the use of external tools.	The system shall have less than 10% sample loss per recollection cycle.	The module shall include two 500 mL (16.91 fl oz) sealed compartments to recollect individual water samples, preventing cross-contamination during flight or transport.	The module shall have a visible LED indicator from 40 ft (12 meters) of distance.	The module shall maintain full functionality under vibration frequencies consistent with drone flight profiles.	The device's battery life shall exceed 30 minutes of continuous operation.	The system shall recollect samples from a minimum of 2 distinct locations within 1 operational flight.	Samples shall be transferrable to lab equipment in under 1 minute without requiring additional tools or adapters.	The module shall have signal range capable of working at distances up to 40 ft (12 meters) from the base station/UAV controller.	The whole system (including the UAV, the HydroHarvester and the samples) shall have a total weight of less than 25 lbs (11.34 kg).	The system shall be fully cleanable, disinfected and dryable in less than 5 minutes.	The module shall recollect and secure a water sample in under 3 minute per location.	The system shall maintain structural integrity under water currents velocity up to 30 ft/s (20.45 mph).	The device shall include an internal clock system to record the time when the sample was recollected.	The recollection device shall be equipped with a thermal sensor to record the sample's temperature at the moment of capture and at the end of the mission.	The device's outer design shall not increase the drone's drag coefficient by more than 50% of its original value.	
Device shall be able to hold and store 2 samples per operation.	5	3	6	9		3	9	9	3		9	9	6	6	3	3	9	435
The module should be easy and fast to securely installed and uninstalled.	3	9		3	3	3			6				9	9			3	135
Each sample extraction should be completed within a minimal and efficient time frame.	5	6	9	6	6		6	9				3	9	3	3	3	3	330
The recollected sample shall remain fully contained during operation, with minimal or no loss.	4	6	9	9		6		9			3		3	3		6	3	228
The vertical clearance above the water surface shall be sufficient to prevent UAV exposure to water splashes during	5		3	6	3	9	3	3		9			3	6			9	270
The system shall be able to withstand underwater currents without affecting UAV Flight Performance.	4	9	6	6			3	3			3		6	9			9	216
Cross-contamination between samples shall not occur.	5		9	9	3			9	9		3	6	6	3		6		315
The device shall allow for unobstructed and stable drone takeoff and landing under standard operating conditions.	4	9		9		9	3				6	3		6	3		9	228
The device shall be easy to clean, dry anfd disinfect after use.	5	6	3	3				3	9			9	6		3	3		225
The device should facilitate the straightforward transfer of samples from the recollection unit to laboratory analysis	5	9	3	6				6	9			9	3			6		255
The device shall remain fully operational after exposure to drone-induced vibrations in accordance with a vibration profile	5	9	3			9	9	6		9				9			3	285
The device shall include an indicator light visible to assist in locating the unit and verifying operational status.	3			9	9		9	6		9	3		3		9	3		180
The device shall complete one full operational cycle on a single charge.	5			9	9		9	9		6	9		9	3	9	6	3	405
The module shall operate within visible medium-range distances from the base station or UAV controller.	4			3	9	3	9	6		9	6		3	3				204
The recollected samples should maintain their original temperature during transport to preserve integrity.	5		9	9			9	6	9	6	3	3	3			9		330
Each sample shall be time-stamped at the moment of recollection.	5		6	9			3	9	6	3	3		6		9	3		285
	Unit	min	%	mL	lm	Hz	min	N/A	min	ft	lbs	min	min	ft/s	N/A	N/A	N/A	
	Target	3	10	500	N/A	N/A	30	N/A	1	40	25	5	3	30	N/A	N/A	N/A	
		274	292	451	181	172	331	412	247	232	211	211	334	256	178	214	223	

Matrix of Success



Preliminary Requirements

Functional Requirements:

- The device shall recollect and store 2 water sample per mission.
- The module shall be attachable/removable to a UAV without the use of tools.
- The system shall prevent cross-contamination between both samples.
- The device shall operate on battery power and complete a full mission without recharge.

Preliminary Requirements

Performance Requirements:

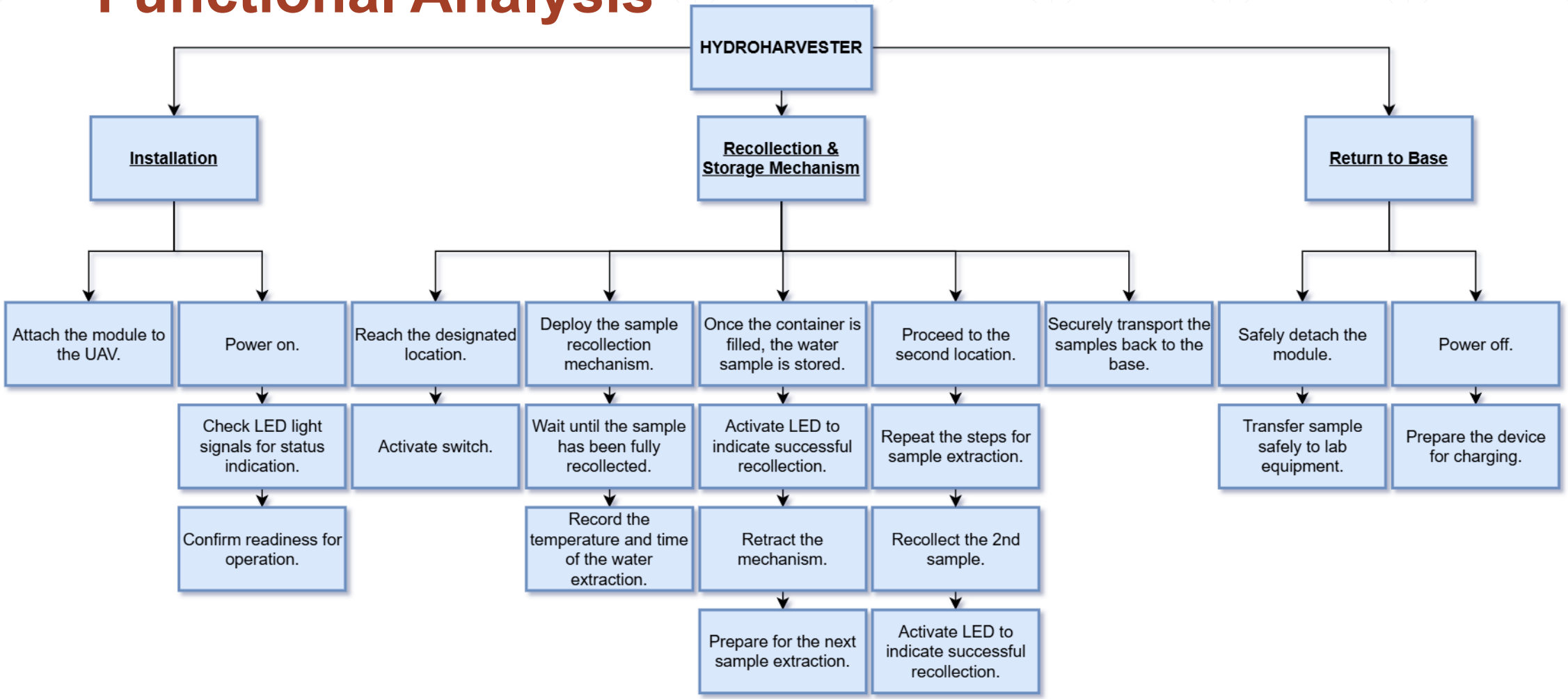
- Sample loss during operation should be limited to a 5%.
- The module shall withstand water currents up to 30 ft/s (20.45mph) without losing structural integrity.
- The device shall be installed and removed in under 3 minutes each.
- The total system weight shall not exceed 25 lbs (25kg).
- The device range should achieve the 40 ft (12 meters) of distance.

Preliminary Requirements

Compliance Requirements:

- Device must comply with the Clean Water Act, Environmental Protection Agency, and the Occupational Safety and Health Administration regulations.
- The system must comply with the Federal Aviation Administration Part 107 Regulations regarding unmanned aircraft systems (UAS).

Functional Analysis



Reference

- Fernández Valencia, M. de L., & Rivera Rivas, M. del C. (2022). Modelo geoespacial para priorizar los factores de riesgo ambiental de las comunidades sin alcantarillado sanitario en la cuenca del Río Grande de Loíza en Puerto Rico. *REVISTA UMBRAL*, 1 (18), 183–209. https://revistas.upr.edu/index.php/umbral/issue/view/2566/705 ISSN 2151-8386
- Gutiérrez-Fonseca P. E., & Ramírez, A. (2016). Evaluación de la calidad ecológica de los ríos en Puerto Rico: principales amenazas y herramientas de evaluación. *Hidrobiológica,* 26 (3): 433-441
- Martinuzzi, S., W. A. Gould & O. M. Ramos González. 2007. Land development, land use, and urban sprawl in Puerto Rico integrating remote sensing and population census data. *Landscape and Urban Planning,* 79: 288-297.

Reference

- Ramírez, A. & P. E. Gutiérrez-Fonseca. 2014. Puerto Rico. In: P. Alonso Eguía Lis, J. M. Mora, B. Campbell & M. Springer. (Eds.) Diversidad, conservación y uso de los macroinvertebrados dulceacuícolas de México, Centroamérica, Colombia, Cuba y Puerto Rico. *Jiutepec*, Morelos, México, Instituto Mexicano de Tecnología del Agua.
- Federal Aviation Administration. (2025). *Small Unmanned Aircraft Systems (14 CFR Part 107).* U.S. Department of Transportation. https://www.ecfr.gov/current/title-14/part-107
- Occupational Safety and Health Administration. (2025). OSHA's Use of Small Unmanned Aircraft Systems. (CPL 02-01-169), U.S. Department of Labor. https://www.osha.gov

Reference

- US Forest Services. (2025). *Drone (Unmanned Aircraft Systems) Use on National Forest Lands,* U.S. Department of Agriculture. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3847000.pdf