Mangrove Group: Final Report

Names: Kennedy Brown, Prithvish Ganguly, Samyukta Jayaram, Sharon Wachira, Kamron Soltani

Date: December 15, 2025

1. Problem Statement

Access to safe drinking water remains a pressing global challenge affecting over 2.1 billion people (1 in 4) globally (World Health Organization & UNICEF, 2025). Untreated water sources (such as ground water and surface water) can be contaminated with dangerous microbial groups such as viruses (e.g. Hepatitis A, SARS-CoV-2), bacteria (e.g. E.coli, Legionella), and protozoan (e.g. Giardia, Cryptosporidium). The persistence and spread of these microorganisms can lead to negative health impacts such as diarrhea and waterborne illnesses(e.g. Cholera, Sepsis) (Pickering et al., 2019).

In-line chlorination (ILC) is an effective point-of-collection treatment method for inactivating harmful pathogens in communities lacking centralized water treatment and distribution infrastructure. Current in-line chlorination technologies, such as the Turi Taqp of Mangrove Water, are designed to connect to piped or semi-piped systems for drinking water treatment. In Sub-Saharan Africa, over 200 million people rely on manual handpumps as their main source of drinking water (World Health Organization & UNICEF, 2022, Danert, K., 2022). The application of ILC technologies is limited due to difficult installation mechanics, the variation in handpump design, and the restriction of flow which can lead to handpump backflow. The lack of applicability leaves rural communities at serious public health risks, and limit global strides towards achieving UN Sustainable Development Goal #6 *Clean Water and Sanitation for All* (United Nations, 2024). Adapting passive, low-cost chlorination systems for handpumps is essential to expand the benefits of safe water treatment and improve global public health.

2. Innovation Description

Our innovation is a handpump adaptation kit for the TuriTap made up of two coordinated components: (1) a universal mounting unit that securely supports the TuriTap on diverse handpump geometries, and (2) an adapter piece that connects the handpump outlet to the TuriTap inlet while reducing overflow/backflow risk. This matters because rural handpumps vary in spout size, shape, and length, so “one-size” attachment approaches often fail or require custom, non-scalable installation work.

In practice, our current proposal is a frontal offset mount paired with either a custom-designed or off-the-shelf adapter, depending on the deployment context. This offset strategy is intentional as it helps align the handpump outlet with the TuriTap inlet to reduce unnecessary bends, which in turn can reduce headloss and overflow. Moreover, the mount architecture uses standard clamps and U-bolts to constrain loads through the steel pipe rather than relying on the printed part alone, which improves durability and tamper resistance in the field. We also used Finite Element Analysis (FEA) and simple flow simulations to iterate faster and avoid wasting material during prototyping, which makes the design process more efficient and supports a clearer pathway to manufacturable geometry.

Compared to existing alternatives, this approach is designed to balance performance and scalability. Fully custom adapters can improve alignment and overflow reduction, however they are typically more expensive and harder to source or replace locally, which can slow maintenance and increase long-term operating costs. On the other hand, purely off-the-shelf connectors are cheaper and widely available, but they often force sharper bends that increase headloss and can worsen overflow. Thus, our hybrid solution uses a single custom element only where necessary, while relying on standardized hardware elsewhere to keep costs low and maintenance simple without sacrificing hydraulic performance.

Finally, the innovation improves feasibility at scale because it is quick to install using basic tools, is designed to accommodate variability in handpump spout diameters, and is explicitly targeting tamper/theft resistance as a core requirement rather than an afterthought.

3. Target Population

Our innovation serves rural populations in Sub-Saharan Africa and South Asia who depend on manual handpumps as their primary water source. These communities face the highest burden of waterborne diseases due to a lack of reliable water treatment.

Primary Beneficiaries	**Secondary Beneficiaries**
Households,women, and children who collect water daily.	Patients, mothers, and newborns in rural healthcare facilities that rely on handpumps,

Women and girls, who are often responsible for water collection in the household, bear a disproportionate health and time burden from waterborne illness and sourcing untreated water.	for whom safe water is a critical medical necessity to prevent infection.

The characteristics of the target population typically have low and irregular income, live in areas with limited infrastructure, and have varied levels of formal education. Their primary need is a reliable, low-maintenance source of safe water that integrates seamlessly into their existing routines without requiring behavior change or significant new costs.

4. Theory of Change

Our theory of change is that the project will increase accessibility to clean drinking water by enabling wider adoption of the TuriTap, we will do this by making it compatible with the broad variety of manual handpumps used in rural settings, so it can be installed across many communities and reach a large number of people. This compatibility will enable reliable, routine chlorination at the point of collection, which will improve water quality and, over time, reduce the waterborne disease burden in communities that depend on handpumps for daily water needs. This matters because handpumps vary widely in outlet geometry and installation constraints, and earlier field experience has shown that poor fit and flow restriction can lead to backflow/overflow, reduced pump efficiency, and ultimately weaker adoption.

I. Inputs

We combine funding and team capacity with community and partner engagement (community members, community groups, installation/maintenance professionals, Mangrove Water team, and NGO partners), plus physical resources such as the TuriTap device, plumbing materials, filament/prototyping hardware, and design/testing tools (CAD and simulation software).

II. Activities / processes

We run a user-informed, iterative engineering cycle: user discovery (interviews/surveys), CAD and prototyping, and testing focused on both mechanical performance (load, stability, tamper resistance) and hydraulic performance (flow consistency, headloss, overflow/backflow), alongside chlorination efficiency checks.

III. Immediate outputs

These activities produce a handpump adaptation system (mounting + adapter) that can be installed across diverse handpump configurations, supported by standardized performance documentation (chlorination and flow quality reports) and an installation approach that can be replicated by local technicians.

IV. Short- and medium-term outcomes

If installation is reliable and the system maintains acceptable pump usability, communities gain consistent access to chlorinated water at the collection point and experience fewer operational failures related to overflow/backflow and tampering. This outcome pathway is supported by broader evidence that chlorine-based treatment improves microbiological water quality and can reduce child diarrhoea risk when implemented effectively.

V. Long-term impact

Over sustained use, improved water quality should translate into reduced prevalence of waterborne illnesses, improved public health, and downstream reductions in severe outcomes such as child mortality, aligned with expanding safe water access. This direction is consistent with evidence from point-of-collection passive chlorination trials showing health-relevant benefits (e.g., reductions in child diarrhoea prevalence) and with the wider household/point-of-use chlorination evidence base.

VI. Key assumptions

This theory rests on four explicit assumptions: (1) adding in-line chlorination to handpumps improves water quality and public health, (2) communities want clean water at their primary source, (3) communities are willing to accept minor performance trade-offs for clean water, and (4) the need for improved health outcomes exists across stakeholders.

VII. Existing Evidence and Remaining Validation Needs

There is strong existing evidence that chlorination (including point-of-collection / passive approaches) can improve water quality and reduce diarrhoeal disease risk under real-world conditions. However, several links in our specific pathway still require local validation: (i) that a universal handpump adapter can maintain acceptable flow with reduced overflow/backflow across varied pump models, (ii) that the mounting system remains tamper/theft resistant over time, and (iii) that user acceptance and sustained use remain high once installed at scale.

VIII. Field Validation and Scaling Strategy

We will generate evidence by deploying and evaluating the adaptation in real settings, including handpumps enrolled in Professor Pickering's in-line chlorination RCT (the CLEAN Trial) and additional TuriTap installations in Nigeria. This means we will combine (a) technical monitoring (flow/overflow performance and installation consistency) with (b) social impact evaluation using surveys on acceptance and use, and (c) health outcome tracking through local/county metrics on common waterborne illnesses (e.g., diarrhoea, cholera, sepsis).

5. Anticipated Impact and Research

This project has the potential to make a significant contribution toward Sustainable Development Goal 6 and to improve public health in developing communities. Many rural regions currently lack effective in-line chlorination solutions that can be integrated into existing handpump networks, resulting in continued reliance on untreated groundwater. This contributes to the spread of waterborne illnesses and increases the risk of child mortality. The proposed TuriTap handpump adaptation directly addresses this gap by enabling safe, chlorinated water delivery at the point of collection.

In Sub-Saharan Africa, more than 700,000 handpumps serve as primary drinking water sources, with each pump supporting an average of 286 people (World Health Organization & UNICEF, 2022). Using this benchmark, the project is expected to reach approximately 28,000 individuals during the pilot implementation period. This estimate is based on a production run of 100 Turi Taps, each installed on a rural handpump.

To ensure that the intervention delivers maximum impact, deployment will be guided by a data-driven "Map of Need." This map overlays publicly available data on child mortality and waterborne disease prevalence with information on handpump locations and density (focusing on Afridev and India Mark II models). The resulting analysis highlights communities where health risks and the need for such a technological innovation align. Priority areas will be validated and refined through collaboration with Professor Pickering's NGO partners in Kenya, leveraging their location-specific expertise to support effective implementation.

As the project scales, additional partnerships will be formed with NGOs operating in the high-priority regions identified by the map, creating a direct pathway into communities that would benefit most from the TuriTap adapter. This targeted approach ensures that the intervention reaches the largest possible number of people while generating measurable improvements in access to safe drinking water and reductions in waterborne illness.

In addition to improving drinking water through in-line chlorination, we intend to support the TuriTaps integration into the market by earning trust, increasing affordability, and ensuring it becomes a lasting part of community life.

I. <u>Training that Builds Trust and Local Jobs</u>

We believe in teaching skills that last rather than delivering a one-time intervention through technology. Therefore, our team will:

- **Train Local Experts:** We will teach people within the community how to install and maintain the TuriTap. This creates local repair jobs and ensures help is always nearby.
- **Teach Health Benefits:** We will hold simple, clear sessions for families on why clean water matters and how to use the tap safely, turning users into informed advocates.

II. <u>Increasing Affordability for All</u>

Our approach for pricing is flexible since we know that one price doesn't fit all, particularly in rural communities with shared water sources. We will alter making and pricing approaches for varying community partners such as:

- **Partner Organizations:** We offer a straightforward way for NGOs and governments to buy in bulk for their projects.

- **Communities & Schools:** We offer a special package that includes the tap and training. For those who can't pay upfront, we will help connect them to loan programs to make payments manageable.

III. Speaking Clearly and Showing Proof

To build trust and ensure widespread acceptability, we will use language regarding the TuriTa in a way that people understand and trust:

- **We Speak Your Language**: All our information and instructions will be available in both English and Swahili.
- **We Meet You Where You Are:** We will use radio, community meetings, and social media to share our message. We'll show, not just tell, with videos and stories from real families using the tap.
- **We Build Credibility:** By sharing success stories from our field tests in Kenya, we let the results speak for themselves.

IV. Keeping the Water Safe, Long-Term

We offer a simple way to check that the water stays safe to give our partners peace of mind,

- **Simple Check-Ins:** We can provide easy-to-use test kits to regularly check water quality.
- **Proof for Partners:** For our larger partners, we can provide clear reports showing that their investment is working and making a real difference in community health.

By combining a well-designed product with this community-first plan, the TuriTap becomes more than just a tap, it becomes a reliable source of health, a source of local pride, and a sustainable solution for generations.

6. Evaluation Methodology

The Turi Tap handpump adapter was designed to maximize impact through universal adapting and mounting, prevention of water wastage via backflow reduction, and providing a secure clean water source through tamper and theft resistance. As our team designed and developed the handpump adaptation, we evaluated the pieces through two perspectives: technical success and social impact.

A. Technical Evaluation

Throughout the iterative process of designing the TuriTap handpump mounting unit and adapter piece the team identified nine primary design evaluation criteria.

I. *Functionality-* The performance and congruence of the piece both with the handpump and the TuriTap

II. *Load Bearing-* The ability of the piece to handle the weight of the TuriTap (including internal chlorine storage), forces applied by water flow, and external loading.

III. *Reduction of Overflow-* The performance of the piece with respect to overflow reduction and internal headloss.

IV. *Tamper Resistance-* The ease with which the system is able to be removed or disturbed.

V. *Universality*- The ability of the system to be congruent with a variety of handpump configurations, specs, materials, and systems.
VI. *Modularity*- The level of “permanence” of the system, or the ability for community members to remove the system if they no longer want it.
VII. *Ease of Assembly*- The level of time, skill, and equipment required for installation.
VIII. *Manufacturability*- The ability for the system to be produced and scaled with respect to system geometries and Mangrove’s current manufacturing equipment.
IX. *Cost*- The financial requirements of production and installation.

Our team prioritized the producibility and availability of materials, specifically in geometry-specific designs, opting for alternatives using “off-the-shelf”components. System performance was assessed by evaluating strength (ruggedness and durability under excess force or tampering), overflow prevention (measured by relative overflow volume and overflow delay time), and ease of installation using tools commonly available in field settings.

Additional attributes considered included reliability in outdoor conditions, material performance, manufacturability, and tolerance to variability in handpump geometries. Prototypes were produced in PLA for rapid iteration, but the final design is intended for PETG injection molding due to PETG’s mechanical stability, UV resistance, and its proven field performance in the existing TuriTap body. Tolerances for screw holes, clamp interfaces, and gasketed connections were selected based on the availability of local tools and the need to accommodate variation in spout diameters without compromising seal integrity. Preliminary safety and quality assurance checks included FEA for mount rigidity and torque resistance, and simple fluid-flow simulations that showed an estimated pressure drop of approximately 3 kPa across the offset adapter, which was well below levels that historically caused operational overflow.

Metrics used to evaluate and prioritize design options incorporated both quantitative and qualitative criteria. Quantitative metrics included :

1) Pressure drop across the adapter (kPa)
2) Overflow volume and overflow onset time (s)
3) Rotational resistance of the mount (N·m)
4) Pull-out force of the adapter under axial load (N)
5) Installation time using basic tools (minutes).

Qualitative metrics included ease of use, universality across AfriDev and India Mark II pumps, and overall tamper resistance. Measurement protocols involve benchtop hydraulic testing, torque-slip testing of clamps, and hand-tool installation trials.

Assembly and maintenance were also central considerations**.** The design can be installed with only basic field tools, and the instructions for use are simple: position the mount, fasten the worm clamp around the spout and gasket, lock the U-bolt for rigidity, and attach the TuriTap to the backplate. The existing 90° spout geometry inherently limits rotation, while the clamps prevent axial pull-out, providing a robust connection with minimal maintenance. Instructions remain uncomplicated to ensure adoption by both local technicians and community members.

The system was designed to be simple and straightforward to use. The mounting piece is positioned in place, then secured using a worm clamp around the spout and U-bolts fastened along the pipe length. This allows the mount to accommodate a wide range of pipe diameters. The mounting system is then screwed into the TuriTap. Next, the custom adapter is placed over the spout, with a gasket ensuring proper alignment and a water-tight seal, before connecting it to the inlet of the TuriTap.

This assembly sequence keeps the instructions simple and intuitive, making it easy for technicians to install the system correctly without specialized tools or extensive training. This design ensures consistent performance and supports rapid installation and maintenance in the field. This also allows for straightforward maintenance using simple tools.

Further, we explored the financial requirements of each mounting and adapter options through the consideration of custom vs. off-the shelf adapters and modular vs. custom designs weighing cost, availability, performance and environmental trade-offs.

Custom Adapter:
Custom adapters are specifically designed to reduce overflow by aligning the chlorinator inlet with the handpump spout using a gradual, single-bend geometry. They can be adapted to fit a range of pipe diameters, offering flexibility across different handpump models. However, these adapters are more expensive to produce and harder to source in field settings. Limited availability can make replacement and repair more challenging, potentially slowing maintenance and increasing operational costs over time. It also means that the user will have to pay higher up front costs.

Off-the-Shelf Components:
Off-the-shelf pieces, such as standard elbows and connectors, are cheaper and widely available, which simplifies sourcing, replacement, and repair. They reduce production and inventory costs, making the system easier to scale. However, because they often require sharper bends to connect the chlorinator to the pump, they increase headloss and the likelihood of overflow. Overflow not only reduces the system's operational efficiency but may also result in environmental harm due to the uncontrolled discharge of treated water.

Modular versus custom designs:

Standardized, off the shelf configurations reduce production cost and simplify maintenance workflows, but may limit geometric flexibility to connect to the Turi Tap. Additionally, due to the sharp bends seen in off the shelf connectors, it further exacerbates the issue of overflow. We aimed to balance this tradeoff through the combination of modular handpump connection pieces (via gaskets, U-bolts, and worm clamps) with custom pieces for connection to the TuriTap. This hybrid approach minimizes costs while making strides towards optimal performance.

As we moved through iterations, we informally observed and noted each piece's quantitative and qualitative performance in each category, which is noted in the Technical Design Journey Section below. Moving forward in the project, we will standardize the evaluation via the following:

I. Conduct formal load testing to observe the maximum shear and torsional strength
II. Standardize handpump flowrates measurements using a metronome for consistent flow to understand the impact on overflow
III. Understand the variability of handpump configurations and size through surveys
IV. Record time and equipment for installation on new handpumps
V. Collaborate with the Mangrove manufacturing team to understand the limitations of production

B. Social Impact Evaluation

The key assumptions outlined in our theory of change are listed below:

1. Adding in-line chlorination to handpumps will improve water quality and public health
2. Communities want clean water at their primary source
3. Communities are willing to sacrifice minor aspects of handpump performance for clean water
4. The need for improved health outcomes exists over all stakeholders.

We intend to evaluate these assumptions and our overall social impact through the adaptation of handpumps enrolled in Professor. Pickering's current ILC randomized controlled trial (RCT) (The CLEAN Trial) and the application of pieces to TuriTap installations in Nigeria. In this evaluation we will use survey questionnaires to understand the community acceptance of chlorinated water at handpumps and the performance of the TuriTap at the handpumps. Further, we will evaluate the health impacts of the adaptation by collecting metrics on the health outcomes of community members using the handpump as their primary water source on a local and county level. This will include the prevalence of common waterborne illnesses such as diarrhea, Cholera, Sepsis.

7. Key Performance Indicators

We track progress and impact through a set of indicators across outputs, outcomes, and long-term goals, aligning with our Theory of Change.

Category	**Key Performance Indicator (KPI)**	**How We Will Collect Data**	**Target for Award Period**
Scale & Adoption	Number of direct beneficiaries with access to chlorinated water.	(# of installations) x (avg. 286 users per pump). Verified by installation logs.	28,000 people (from 100 pilot installations).

	Adoption/Usage Rate by communities.	Surveys & direct observation at installed pumps; spot-checks for TuriTap engagement.	>85% of installed communities report consistent use.
Technical Performance	Reduction in handpump overflow (key social outcome magnitude).	Field measurement: Volume of overflow collected vs. volume of treated water dispensed.	≥80% reduction in overflow volume compared to baseline (pre-installation).
	Universal installation success rate.	Record of successful vs. failed installations across Afridev and India Mark II pump types.	≥95% installation success rate across pump models.
Health & Social Outcomes	Consistent water quality (chlorine residual).	Regular field testing using portable chlorine test kits at point of use.	>90% of tests show chlorine residual in safe range (0.2-2.0 mg/L).
	Reduction in reported waterborne illness (social outcome proxy).	Partner with local clinics (e.g., KEMRI) to track diarrheal disease cases pre- and post-installation.	Observe a downward trend in cases; target ≥20% reduction in reports from intervention areas vs. control after 12 months.
Financial & Operational	Cost per beneficiary reached.Cost per beneficiary reached.	Total project costs (manufacturing, deployment, monitoring) / total # of beneficiaries.	Achieve a cost of < $[X] per person for initial access. [Team to calculate based on budget].
	Capital raised for scaling (non-grant).	Track revenue from product sales & service contracts initiated during the period.	Generate $[Y] in non-grant revenue, moving toward 60% sales-based income.
	Local capacity built (# of technicians trained).	Track revenue from product sales & service contracts initiated during the period.	Train ≥20 local technicians in installation and maintenance.

8. Cost and Potential Cost-Effectiveness

Current Cost Structure & Scaling Projections

The TuriTap handpump adaptation is currently in the final R&D and prototyping phase. All development to date has been funded by grants, including from UC Berkeley and philanthropic partners. The current pilot-scale costs are not yet representative of scaled production.

Variable Costs:

1. Materials & Manufacturing: Raw PETG for injection molding, custom adapter, gaskets, and standard hardware (U-bolts, clamps).
2. Installation & Training: Labor and logistics for technicians to install and train community members.

Fixed Costs (Program-Level):

1. R&D & Design: Engineering and testing (currently grant-funded).
2. Regulatory & Certification: Fees for approvals (e.g., Kenya Bureau of Standards).
3. Marketing & Partnership Development: Digital campaigns and NGO outreach as outlined in our strategy.
4. Program Management: Salaries for coordination, monitoring, and evaluation.

The total cost for the pilot phase of 100 units is approximately $16,000, covering final prototyping, initial production, deployment, and impact monitoring in Kenya.

Cost-Effectiveness

TuriTap vs. Boiling or No Treatment: Our solution eliminates ongoing fuel costs for boiling and prevents high healthcare costs and productivity losses from waterborne illness. The one-time hardware cost + low chlorine refills provide a significantly lower lifetime cost.

Our non-profit structure is a key driver for our path to cost- effectiveness. All surplus is reinvested into R&D to further drive down costs and into open-source knowledge platforms, which reduces barriers to adoption and improvement across the WASH sector, multiplying our impact beyond direct sales.

Revenue Prospects for Sustainability & Growth

To achieve financial sustainability and growth, we have a diversified revenue model. The foundation is core product sales, which we aim to constitute 60% of our income through direct sales of the TuriTap adapter kit to NGOs and government bodies implementing water projects.

To support and enhance these sales, we will offer technical services projected to contribute 25% of our revenue. We anticipate that strategic grants will continue to provide 10-15% of our funding, specifically dedicated to advancing R&D and subsidizing access for the most vulnerable communities, ensuring our innovation reaches those who need it most while maintaining a trajectory toward earned-income sustainability.

This diversified model ensures sustainability. While not a direct "carbon market," the significant reduction in the need to boil water (by providing a clean source at the point of collection) creates a verifiable carbon offset opportunity. This could become a future revenue stream or impact metric in partnership with climate-focused funders, further enhancing the long-term financial and environmental impact of the project.

9. Anticipated Risks

While the handpump adapter and mounting system aims to improve accessibility to clean drinking water, there are risks that could arise during large-scale implementation. Recognizing these early can help ensure that the intervention remains effective, sustainable, and accepted by the communities it is aiming to serve.

A. **Compatibility Issues:** Variations in handpump design, size, and dimensions could lead to poor fitting, leaks, or difficulty during installation.
B. **Tampering and Misuse:** Users might remove, bypass, or repurpose components, especially if they perceive the system as limiting flow or altering familiar routines.
C. **Flow Restriction:** The adapter or mounting design could unintentionally reduce water flow or pressure, discouraging consistent use. It could also worsen overflow issues if the design is not optimized for the pump's fluid dynamics.
D. **Social Resistance:** Communities may resist adoption if they view the system as unnecessary, foreign, or if it disrupts long-standing water collection habits.
E. **Shift to a B2C Model:** Moving from a B2B to a B2C model could create financial strain, as the upfront cost and recurring chlorine expenses may burden households. This challenge may affect long-term adoption and trust in the system.
F. **Equity and Access Concerns:** If the system becomes available only in certain regions or through specific NGOs, it may unintentionally widen inequality between communities with and without TuriTap access.
G. **Increased Cost from Design Complexity:** The addition of a custom adapter and mounting system may increase manufacturing and installation costs.
H. **Chlorine distribution:** If a consistent chlorine supply chain is not maintained, communities may be unable to refill or replace cartridges. Limited access to chlorine would lead to discontinuation of use, pushing people back to untreated water sources and undermining trust in the Turi Tap system.
I. **Overflow Use Risk:** If overflow issues persist during handpump operation, community members may begin collecting or consuming the untreated water that overflows, increasing the risk of exposure to unsafe water and undermining the intended benefits of the system.
J. **Risks of Direct Mounting:** A direct mounting solution is recommended to reduce overflow and minimize headloss within the handpump pipes. However, implementing this approach requires cutting the existing handpump spout, which could create a burden for the community if they choose to remove the Turi Tap in the future and need to restore the original configuration.

10. Lead Organization

Mangrove Water is the lead organization for this project. It is a California-based nonprofit dedicated to revolutionizing safe water access through innovative in-line chlorination, with work spanning research and development, field implementation, and technology scaling. The organization developed the TuriTap, a passive in-line chlorinator that uses hydraulic principles to disinfect water without electricity, making it suited to rural contexts where handpumps are the primary water source and power infrastructure may be limited. To expand the reach of this technology, Mangrove Water is pursuing the development of a universal handpump adapter and mounting unit, enabling more communities to adopt the TuriTap and access safe, chlorinated drinking water at the point of collection.

Mangrove Water's relevant past experience is grounded in developing and deploying in-line chlorination solutions that can function under real-world constraints. This matters because the core barrier highlighted in the problem statement is not only water disinfection efficacy, but also whether the intervention can be installed reliably across diverse handpump geometries, maintained over time, and scaled across many rural sites. In this context, Mangrove Water's experience across R&D, field implementation, and scaling directly supports the project's goal of moving from a promising technology to a broadly deployable system.

In terms of core competencies, Mangrove Water brings capabilities that align closely with the demands of this project. First, it has technical expertise in in-line chlorination and the operational requirements needed for safe and consistent disinfection in low-resource settings. Second, it has deployment and scale-up orientation, meaning design decisions are guided by installation practicality, repeatability, and long-term use rather than laboratory performance alone. Third, the organization's focus on technology scaling supports the development of a universal adapter approach that prioritizes compatibility, manufacturability, and replicable installation workflows, which are essential to increasing adoption across a large number of handpump sites.

Client oversight and technical support are provided through a defined team led by Mangrove Water, with research input from UC Berkeley's Pickering Lab. Dr. Megan Lindmark (CEO, Mangrove Water) is the primary organizational lead; she is an environmental engineer whose work has focused on in-line chlorination implementation models and technologies, and she now leads Mangrove Water's efforts to scale in-line chlorination globally. This means she anchors the project around deployment realities, refining the system design, validating technical feasibility, and ensuring the solution remains practical for long-term implementation.

In addition, UC Berkeley-based advisors contribute research guidance and testing capacity through the Pickering Lab, which focuses on low-cost, scalable interventions to interrupt disease transmission in low-income settings and has a strong track record in evaluating in-line chlorination technologies. Professor Amy Pickering (UC Berkeley) provides strategic guidance on scientific rigor, project direction, and public health implications. Jeremy Lowe (PhD Candidate, Environmental Engineering, UC Berkeley) supports technical input on adapter design and alignment with current research directions in water treatment. Aidan Mahoney (Graduate Research Assistant, Pickering Lab, UC Berkeley) supports the practical evidence-generation side, including lab-based performance testing, experimental design, and prototype evaluation.

11. Key Personnel

The Mangrove Project Team brings diverse expertise across international innovation, in-line chlorination, and product design. Members have backgrounds in mechanical engineering, prototyping, and production, supported by access to the UC Berkeley Jacobs Institute of Design Innovation. In addition, the team offers strengths in project management, business modeling, and strategy, ensuring both the technical and commercial viability of the solution.

Kennedy Brown - M.S., EIT PhD. Environmental Engineering

Roles & Responsibilities:
Kennedy served as a primary liaison, alongside Samyukta Jayaram, to bridge communication between Mangrove Water and the DevEng team. She helped ensure clear communication, coordinated progress updates, and created timely feedback loops. She also contributed to design iteration, prototype testing, and the development of the business model for the TuriTap adaptation.

Skills & Experience:
Kennedy is a first-year PhD student in Dr. Amy Pickering's lab at UC Berkeley, where her research focuses on in-line chlorination techniques for health care facilities in Kenya. With prior experience as an instructor in Civil and Environmental Engineering and a background in sustainable waste management, she brings strong expertise in simulation, data analysis, and community-based research to guide technical and strategic decisions across the project.

Kamron Soltani - B. S./ M.S. Mechanical Engineering

Roles & Responsibilities:
Kamron contributed to the mechanical design and hardware prototyping of the TuriTap adapter and mounting system, including brainstorming, CAD modeling, 3D printing, design iteration, and supporting the development of functional test setups. He also provided technical feasibility assessments for proposed design solutions and serves as the main submitter for project documentation.

Skills & Experience:
Kamron is an M.S. student in Mechanical Engineering at UC Berkeley, specializing in mechatronics and human-centered design within transportation systems. His experience includes roles at Siemens Mobility, research in motion-tracking sensing for tele-surgical applications at Nanyang Technological University, and serving as the lead GSI for ME100, an upper-division course focused on circuitry and microcontroller design, bringing strong technical and manufacturing expertise to the project.

Sharon Wachira - M.DevEng (Energy & Environment)

Roles & Responsibilities:
Sharon spearheaded the market research, product positioning, and business adaptation strategies for the TuriTap handpump adaptation. She ensured that design decisions aligned with

Mangrove Water's goals for scalability and expansion, grounding project outcomes in real-world feasibility and long-term sustainability. She also worked alongside Prithvish Ganguly as one of the project managers responsible for management of the planning and execution of project deliverables.

Skills & Experience:
Sharon is a Master of Development Engineering student at UC Berkeley specializing in energy, water, and environmental systems. With three years of professional experience in Kenya's energy sector and a background in founding and managing social enterprises in Nairobi, she brings practical expertise in East African markets, community engagement, and implementation challenges, which directly informed the strategic and operational aspects of this project.

Samyukta Jayaram - B.Des., M.Des. (Design Engineering)

Roles and Responsibilities:
Samyukta contributed to design and technical development activities, including brainstorming, design iterations and prototyping, and the creation of functional test setups. She helped create the evaluation matrix for the final prototype selection and acted as a liaison alongside Kennedy Brown in coordinating communication between the Mangrove Water and the DevEng team.

Skills and Experience:
Samyukta is a Master of Design student in Design Engineering at UC Berkeley's Jacobs Institute of Design Innovation. She has a background in Industrial Design, Systems Thinking, and Human-Centered Design. She also brought professional experience as an experience designer and consultant at Deloitte, where she designed and delivered digital platforms across multiple industries and managed projects through the full development lifecycle.

Prithvish Ganguly - B.Eng., M.Eng. Bioengineering

Roles & Responsibilities:
Prithvish contributed to the hardware and design stream of the project, supporting brainstorming, CAD modeling, prototyping, testing, and iterative design refinement for the TuriTap adapter and mounting system. He also assisted with the development of functional testing setups that informed the team's design decisions. In addition to his technical contributions, he served alongside Sharon Wachira as one of the project managers responsible for coordinating tasks, timelines, and cross-team communication.

Skills & Experience:
Prithvish is an M.Eng. student in Bioengineering at UC Berkeley with an undergraduate degree in Biomedical Engineering from King's College London, where he specialized in medical device development, prototyping, and hardware integration. His interdisciplinary experience across automation, robotics, and device testing at King's College London, St. Thomas' Hospital, and Nanyang Technological University supported both the technical execution and organizational management of this project.

12. Partner Organizations

The Mangrove Water TuriTap project works directly with NGO's, research organizations, academic institutions, grant-funding organizations, and commercial and distribution partners to distribute and install the devices. The collaborations with key partner organizations listed below ensures that the product is scientifically tested, locally accepted, and widely available. All organizations listed below have previous experience with Mangrove Water and the TuriTap through the Pickering Lab's CLEAN Trial.

I. UC Berkeley is the primary academic institution partner which collaborates with Mangrove Water through the Pickering Lab where the Mangrove Water team (inventors and technical experts) conduct research and development for publications, academic credibility, and further funding for the TuriTap.

II. CARE and Self Help Africa are local NGO who are able to support field adoptions of the TuriTap adaptation through pre-developed community-trust and relations which support their own public health initiatives.

III. KEMRI (Kenya Medical Research Institute) and PATH are Africa-based research organizations who are able to test and validate the performance of the TuriTap adaptation to help further their research projects in public health initiatives and use the device to improve water safety in government-run clinics and rural water projects.

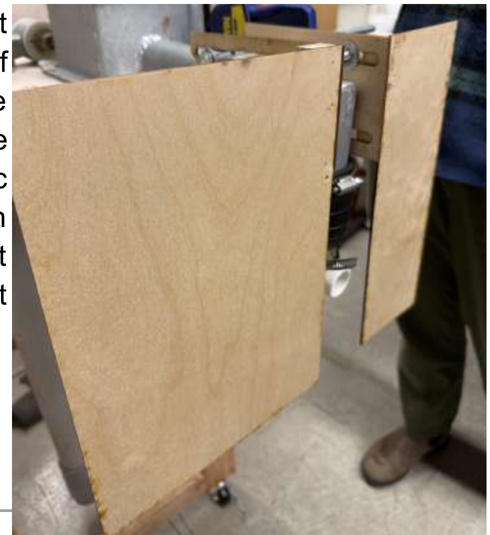
IV. Grant funding organizations (GiveWell, Uduma, Global Development Incubator, Open Philanthropy) provide funding for R&D, market scoping, and pilot programs that are not covered by traditional commercial investment to maximize social impact per dollar and de-risk innovative solutions.

V. Davis & Shirtliff and other local commercial and distribution partners are water equipment suppliers who can integrate the TuriTap adaptation into their project portfolio to serve their existing market. They are at the forefront of marketing the TuriTap (including the adapter and mounting unit) and their ability to reach individuals and communities via culturally sensitive market streams will be necessary for production and impact success.

13. Technical Design Journey

Iteration v0: Initial Prototyping (Low Fidelity Frontal Mount) - 9/13/25

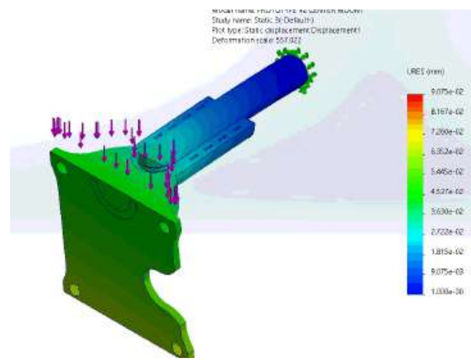
The initial prototype consisted of a few laser cut plates fixed together with wood glue and staples. It was an initial concept that fixed large bolts through the two plates around the spout of the pipe, fixing the Turi-Tap to the front of the mount. When we tested it, the wood could not hold the Turi-Tap and yielded. We also found out that we needed something that was concentric and not tangential to the pipe to increase the contact area with the steel pipe. While this initial prototype failed, it helped us get the ball rolling with physical prototyping and informed us what will not work for a frontal mounting system.



Functionality	Able to hold TuriTap, obstructs adapter
Load Bearing	Low bearing, high axial rotation, cross-screws add force to top and bottom of plates
Reduction of Overflow	Central mount requires additional bends for adapter
Tamper Resistance	Bolts easily removed, no horizontal structure
Universality	Average, height slots need adjustment based on pipe diameter for flush contact
Modularity	High, easy to remove
Ease of Assembly	Very easy assembly and few parts
Manufacturability	Very easy geometries
Cost	Lower Cost. Uses off the shelf parts which reduce overall cost

Iteration v1.0: Frontal Centered Mount with worm-clamps - 10/17/25

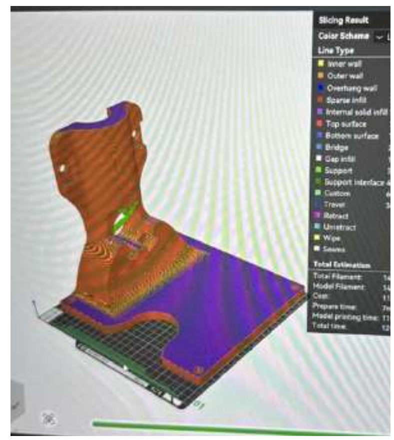
For the second iteration, we drastically changed the design from two parallel plates to a concentric cut for the spout with pipe clamps to fix onto the handpump itself. This prototype was originally made to test fits, but turned out to be able to support the weight of the tap itself and provided us a template to base other frontal mount designs on. This mount utilized pipe clamps to fix itself onto the pipe, and has the benefit of being able to conform around different diameters and shapes. Because of this, the pipe clamps were seen as a good alternative to the first prototype with the large bolts running through the two plates. In addition, we utilized the 90 degree bend in the spout itself to fix another pipe clamp to prevent rotation and help as another fixture. This is verified by the FEA as the two points of contact allow for the pipe itself to take the load rather than the plastic part itself.



Functionality	Able to hold TuriTap with space for adapter piece
Load Bearing	Low axial rotation, worm clamp on 90 degree spout for support, central weight distribution
Reduction of Overflow	Central mount requires additional bends for adapter
Tamper Resistance	Medium resistance, worm clamps are more difficult to remove/tamper with
Universality	High, worm clamps are able to adjust to fit several pipe diameters
Modularity	Easy removal
Ease of Assembly	Easy assembly, need minimal tools for tightening of worm clamp
Manufacturability	Easy/Medium Difficulty geometries
Cost	Average costs, uses off the shelf parts and specialized piece with simple geometry

Iteration v1.1: Frontal Centered Mount full assembly with U-Bolts 10/28/25

For the second iteration of the centered offset mount, we tweaked a few aspects of the design based on the first iteration. We printed this mount in one piece instead of just the top half. However, we had to cut some of the material on the sides such that it would fit on the build plate, and especially near the mounting holes. The material between the edge and the mounting holes here was too small, but wouldn't be a problem if we had access to a larger printer. The second design change was the addition of U-Bolt holes. We found that over time the pipe clamps loosened under the constant load of the Turi-Tap itself. Thus, we opted to have a combination of both the U-Bolts and pipe clamps for this design, as the pipe clamps would act as locators of sorts to hold the Turi-Tap in place, while you can U-Bolt later on. We also included holes on the top for a future cover for a padlock. This prototype was printed out of PLA plastic and held up quite well, despite being lighter than the previous iteration.

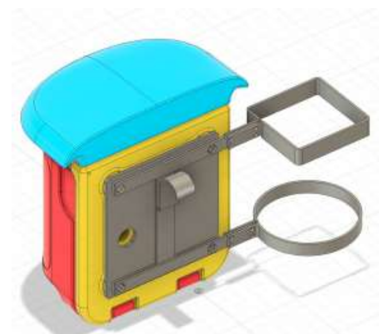


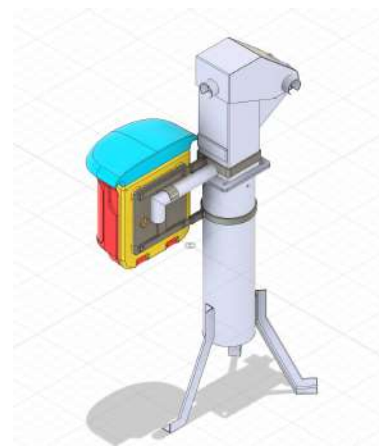
Functionality	Able to hol by d TuriTap with space for adapter piece
Load Bearing	Low axial rotation, worm clamp on 90 degree spout for support, central weight distribution
Reduction of Overflow	Central mount requires additional bends for adapter
Tamper Resistance	Medium resistance, worm clamps are more difficult to remove/tamper with
Universality	High, worm clamps are able to adjust to fit several pipe diameters
Modularity	Easy removal
Ease of Assembly	Easy assembly, need minimal tools for tightening of worm clamp
Manufacturability	Easy/Medium Difficulty geometries
Cost	Average costs, uses off the shelf parts and specialized piece with simple geometry

Iteration v2: Side Mount with direct adapter piece - (10/17/25)

In this iteration, the team developed a side-mounted, modular mounting system with two attachment strategies based on handpump spout length. For shorter spouts, flat aluminum connector arms secure the TuriTap backplate to the pump's vertical body. The arms are cut from a single sheet and assembled with standard fasteners, creating a rigid connection without complex machining and keeping fabrication low-cost.

For longer spouts, an optional hook-style clamp attaches to the spout to provide extra support. This distributes the TuriTap's weight across multiple structural points. Additional hooks can be added where needed, reducing mechanical strain, minimizing slippage risk, and improving adaptability across regional handpump geometries. Structural components use flat aluminum sheet stock, enabling production with basic cutting and drilling tools. Moreover, standardized fasteners and simple interfaces were chosen to enable rapid on-site installation, inspection, and replacement by local technicians with minimal training. Custom parts were kept geometrically simple to support quick assembly, easy replacement, and straightforward scaling using standard fastening methods.

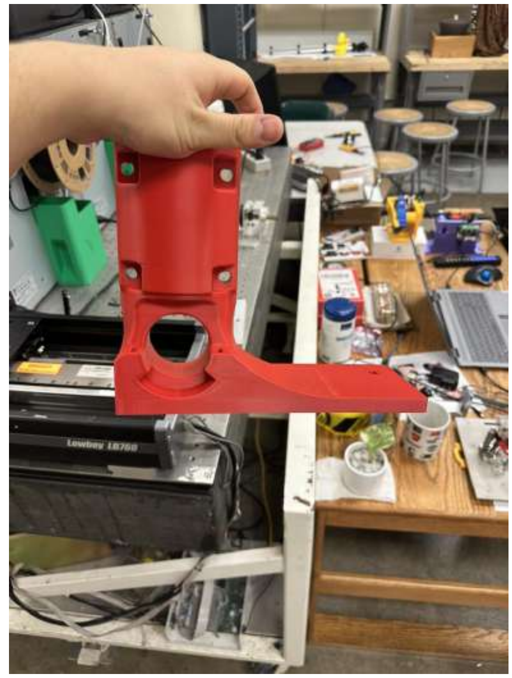




However, the team did not progress this design for three reasons. First, the body-mounted arms cannot be fully universal because handpumps vary in spout length, height, and alignment; achieving fit would require pump-specific adjustment, reducing scalability. Second, the flow route still relies on multiple elbow joints to redirect water into the TuriTap, so it does not address backflow and headloss from sharp turns. Finally, metal introduces feasibility concerns: preventing rust would require treated or stainless materials that are costly and hard to source locally, while 3D-printed substitutes lack outdoor rigidity.

Functionality	Mounting system that leverages the length of the spout to mount the TuriTap
Load Bearing	Excellent load distribution, large moment around spout.
Reduction of Overflow	Only 1 elbow joint, potential to reduce headloss
Tamper Resistance	Medium resistance, worm clamps are more difficult to remove/tamper with
Universality	Worm clamps and U-Bolts make it more conformable to various spout surfaces. Initial iteration incompatible with long pipes/spouts
Modularity	Easy removal
Ease of Assembly	Easy assembly, need minimal tools for tightening of worm clamp
Manufacturability	Easy/Medium Difficulty geometries, dependent on material used
Cost	Average costs, uses off the shelf parts and specialized piece with simple geometry

Iteration v3.0: Frontal Offset Mount - 11/06/25 (The Boot)



The next iteration of the frontal mount was offset rather than the symmetrically mounted one like that in v1. During this stage in the design process, we started to focus our attention more on the overflow issue. One of the ways to mitigate this is to make the outlet of the handpump in the same plane as the inlet of the Turi-Tap. Originally we were against this idea because it induces a moment on the mount itself because it is not mounted in the center of the pipe. However, because of the increasing issue of overflow, we changed the v1 design to make the Turi-Tap offset to be in line with the outlet of the handpump. This initial prototype had rough contours and non-uniform edges. We printed the top half of it to see the fits on the Turi-Tap, and printed it out of PETG.

Iteration v3.1: Frontal Offset Mount Full Assembly - 11/19/25

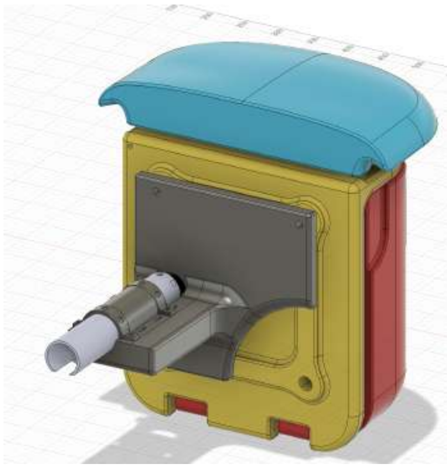
The next iteration for the frontal offset cleaned up the boot design and reinforced surfaces with larger fillets to strengthen the part and reduce the overall torsional force. We printed it in two pieces and put them together with dowels and no glue. This turned out to be our technical innovation we came upon due to its fleshed out design, more DFM ready contours, and really fast mounting which took around 5 minutes. It utilizes pipe clamps and U-Bolts like the previous designs, but also reduces the number of pipe clamps by integrating it with the gasket.

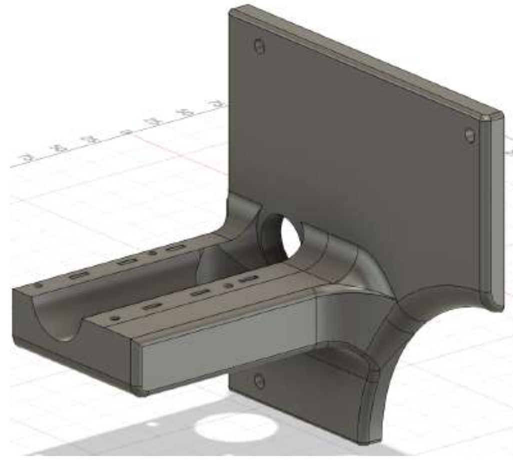
Functionality	Able to hold TuriTap with space for adapter piece in line with the outlet spout
Load Bearing	Higher moment, worm clamp on 90 degree spout for support, unequal weight distribution
Reduction of Overflow	Offset mount requires one bends for adapter, more successful in overflow elimination
Tamper Resistance	U Bolts are more rigid than worm clamps
Universality	Use of worm clamps, U-bolts, and gaskets expand application to differing pipe sizes
Modularity	Easy removal
Ease of Assembly	Easy assembly ~5 minutes
Manufacturability	Easier/Medium Difficulty geometries
Cost	Average costs, uses off the shelf parts and specialized piece with simple geometry

Iteration v4.0: Cut Frontal Mount - 11/28/25

For the final iteration of the semester, seeing how the overflow issue could not be fully mitigated with our current solutions, we opted to go with a mount that integrates the Turi-Tap onto the handpump spout. We accomplish this by cutting off the 90 degree spout angle and using set screws to prevent rotation and translational motion. We plan to test this idea out in the future.

Functionality	Mounting system compatible with cutoff spout to reduce points of headloss
Load Bearing	Higher moment, no 90 degree spout for support, unequal weight distribution
Reduction of Overflow	Field tests with cutoff spout shows complete elimination of overflow
Tamper Resistance	Low/Medium resistance, worm clamps and U-bolts are more difficult to remove/tamper with, but lack of horizontal support.
Universality	Worm clamps and U-Bolts make it more conformable to various spout surfaces.
Modularity	Low modularity, requires permanent alteration to the handpump and rewelding of spout if removed
Easy of Assembly	Difficult since it requires cutting off the spout arm. The mounting unit is easy to assemble + needs minimal tools
Manufacturability	Easy/Medium Difficulty geometries
Cost	Average costs, uses off the shelf parts and specialized piece with simple geometry





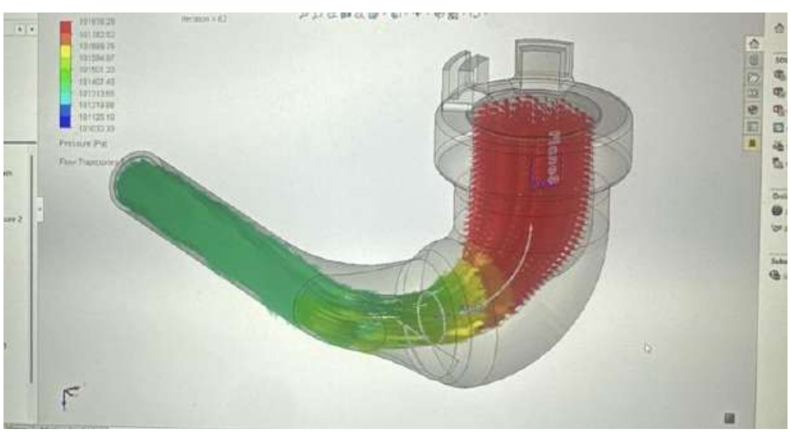
Adapter Technical Design Journey:

Iteration v1.1_frontal: Frontal Mount Adapter 1: - 10/27/25

For the initial frontal mounts, the adapters feature a smooth gradient from inlet to the outlet with a tapering reducer. This initial design was more of a fit test, as there is a flat spot at the bottom of this adapter. This part was incredibly difficult to model properly, and was not tested with actual water due to cracks in the print itself.

Iteration v1.2_frontal: Frontal Mount Adapter 2: - 10/27/25

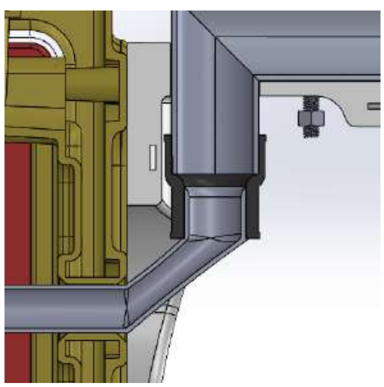
For the next iterations, we optimized the adapter geometries and tried out different iterations between nozzle shaped internal geometry to large filleted ones. We tested one of these adapters on the handpump and they did not fix the overflow issue. Because of this, we made the decision to scrap the frontal mount and switch our focus on a design with a planar adapter.



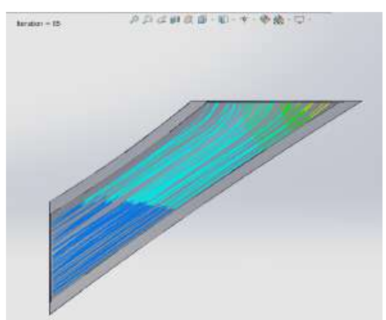
Functionality	Smooth fit with mounting piece and gentle redirection of flow
Load Bearing	–
Reduction of Overflow	Central mount requires additional bends for adapter, not successful in overflow elimination
Tamper Resistance	Locked in place by mounting system and Turi Tap, difficult to remove.
Universality	Currently fitted to specific pipe diameters, could use gasket to expand applications
Modularity	Easy removal
Ease of Assembly	Easy assembly, direct fit
Manufacturability	Difficult to manufacture due to the custom internal geometries of these adapters, limits scale
Cost	High cost due to specific internal geometries

<u>Iteration v1.3_frontal: Frontal Offset Mount Adapter 3: - 11/24/25</u>

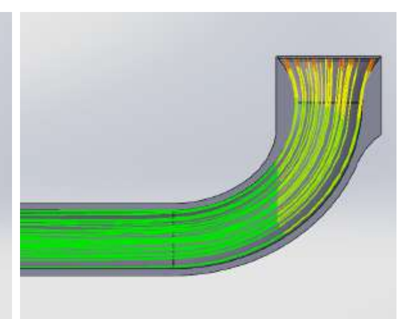
For the final iteration, we designed new adapters that did not have any sharp bends like the frontal mount. Because this mount was offset, the adapter piece itself did not need to make another turn. Thus, we were able to optimize the geometry more. We discovered that the lofted adapter piece proved to be the best internal design as the overflow issue was mitigated longer than the other adapter pieces, roughly 18 seconds.



Section view of assem.



Lofted adapter CFD*



Normal CFD*

*Computational Fluid Dynamics

Functionality	Smooth fit with mounting piece and gentle redirection of flow
Load Bearing	–
Reduction of Overflow	Offset mount requires one bends for adapter, more successful in overflow elimination

Tamper Resistance	Locked in place by mounting system and Turi Tap, difficult to remove.
Universality	These adapters can be used specifically for the offset mounting system, using a gasket and secondary worm clamp can be applied to many pipe diameters
Modularity	Easy removal
Ease of Assembly	Easy assembly, direct fit
Manufacturability	Easier to manufacture due to the one planar internal geometries of these adapters
Cost	Lower cost due to specific internal geometries

14. Citations

1. Danert, K. (2022). *Stop the rot report I: Handpump reliance, functionality and technical failure* (Ask for Water GmbH, Skat Foundation & RWSN). Estimates that almost 200 million people in sub-Saharan Africa rely on handpumps for their main drinking water supply. Retrieved from https://ask-for-water.ch/wp-content/uploads/2022/03/2022__3_Stop-the-Rot-I_Handpumps-DOI.pdf
2. Pickering, A. J., Crider, Y., Sultana, S., Swarthout, J., Goddard, F. G., Islam, S. A., & Luby, S. P. (2019). Effect of in-line drinking water chlorination at the point of collection on child diarrhoea in urban Bangladesh: a double-blind, cluster-randomised controlled trial. *The Lancet Global Health*, *7*(9), e1247-e1256.
3. United Nations. (2024). *Water and sanitation*. https://www.un.org/sustainabledevelopment/water-and-sanitation/
4. World Health Organization (WHO), & United Nations Children's Fund (UNICEF). (2022). *Progress on drinking water, sanitation and hygiene in households 2000–2020: Five years into the SDGs*. WHO and UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene.
5. World Health Organization & United Nations Children's Fund (UNICEF). (2025). *Progress on household drinking water, sanitation and hygiene 2000–2024: Special focus on inequalities* (WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene). https://cdn.who.int/media/docs/default-source/wash-documents/wash-coverage/jmp/jmp-2025-wash-households-lowres-launch.pdf?sfvrsn=12ccab42_3&download=true