



The Pollution of the Beressa River

OPPORTUNITY ASSESSMENT REPORT:

How might we collaborate with government agencies, industries, local residents, and other stakeholders to restore and maintain the Beressa River as a safe, reliable water source for daily use and livestock?

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GPSI Problem: Resource at Risk

Opportunity Assessment Report

Pioneer GPSI

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15 December 2024

Acknowledgment

We would like to express our heartfelt gratitude to the individuals who made this research journey possible and impactful. First, we extend our thanks to Ato Ramiro, our college counselor, for presenting us with the opportunity to participate in the rigorous 12-week research program hosted by GPSI Pioneer Academics. Your encouragement and support have been invaluable. We are also deeply grateful to Professor Mark Jones for guiding us every step of the way, offering tips, advice, and unwavering support throughout our journey. Finally, our sincerest thanks go to Ato Demis, our mentor, whose dedication and expertise were instrumental in our success. His vast knowledge of the topic, connections to key stakeholders, and help in organizing interviews provided us with insights that solved many challenges. To each of you, thank you for your incredible support and belief in us!

Table of Contents

Acknowledgment	3
Table of Contents	4
Subproblem and Target Audience	8
Overview of the Problem	8
Introduction to the Study Area	8
Introduction to the Problem	9
The Journey: Explanation of How the Problem was Identified	9
Overview of The Process and Tools Used	10
Influence of Disciplinary Areas	10
Evidence to Support the Problem Statement	10
Your Original Consolidated Causal Loop Map	12
Themes from Inspirational Activities (Stakeholders’ Needs Assessment)	15
Identification of Key Stakeholders	15
Stakeholder Needs and Themes	15
Debre Birhan City Health Department: Public Health Emergency Operation Center	15
Debre Birhan Town Water Supply and Sewerage Service Office	16
Debre Birhan University	18
Environmental Protection Bureau	19
Debre Birhan Blanket Factory PLC	19
Residents and Regular Users Around the Beressa River	19
Evidence from Inspiration Activities	20
Discussion of Trade-offs Among Stakeholder Needs	20
Impact of Disciplinary Perspectives	20
Updated Consolidated Group Map	21
What Changed?	22
Updated Problem (“How Might We?”) Statement	24
The First How Might We Statement: Geochemistry and Engineering Considerations	24
Second Set of HMW Statements: Public Health Considerations	24
Design-Thinking and Stakeholder Research in Shaping HWM Statements	25
Rationale for Revisions	25
Benchmarking Existing Solutions, Their Strengths and Limitations	27
Debre Birhan University’s Liquid Waste Filtration System	27
Analysis and Solution for DB University’s Filtration System	27
Existing Solution	27
Conventional Activated Sludge (CAS) System	27

Pump Replacement and Maintenance	28
Alternative Filtration Technologies	28
Evaluation of Strengths and Limitations	28
CAS System	28
Pump Replacement and Maintenance	28
Alternative Filtration Technologies	29
Alternatives Matrix	29
Repair and Maintenance of the CAS System	29
System Enhancements	30
Long-Term Alternatives	30
Sources of Information for Evaluation	30
Fines by the Environmental Protection Office	31
Analysis of Fines in for Pollution Control in the Beressa River	31
Existing Solutions	31
Evaluation of Strengths and Limitations	31
Alternatives Matrix	33
Proposed Comprehensive Solution	33
Strengthen Enforcement Mechanisms	33
Expand Public Awareness and Pressure	33
Incentivize Sustainable Practices	33
Establish Collaborative Forums	34
Sources of Information for Evaluation	34
Brainstormed Ideas	35
The Process	35
Summary Table of Brainstormed Ideas	35
Criteria Used to Narrow Down Brainstormed Ideas	36
Most Impactful, Most Feasible, and Wildest Ideas	37
Description	38
The Target Audience	38
Key Implementation Strategies	38
Stakeholder Needs Addressed	39
Difference From Existing Solutions	39
Justification for Potential Impact	39
The Most Feasible Idea	39
Description	39
Target Audience	39
Stakeholder Needs Addressed	40
Feasibility Considerations	40

The Wildest Idea	40
Description	40
Target Audience	40
Stakeholder Needs Addressed	40
Rationale for Calling it the ‘Wildest Idea’	41
Strengths and Limitations	42
Evaluation of Strengths	42
Evaluation of Limitations	42
Challenges Faced	42
Lessons Learned and Next Steps	43
Our Understanding of Systems-Thinking and Design-Thinking	43
Recommendations for Future Work	45
Reference	50
Appendix A	51
Appendix B	55

Subproblem and Target Audience

Overview of the Problem

Introduction to the Study Area

About 130 kilometers northeast of Addis Ababa, in the Amhara region of Ethiopia, sits the city of Debre Birhan. Since its founding by Emperor Zara Yaqob, the city has grown to rank among the most advanced in the nation.

The following is a Study Area Map, done by the team using the ArcGIS software, to show the location of Debre Birhan which is the study area for this research.

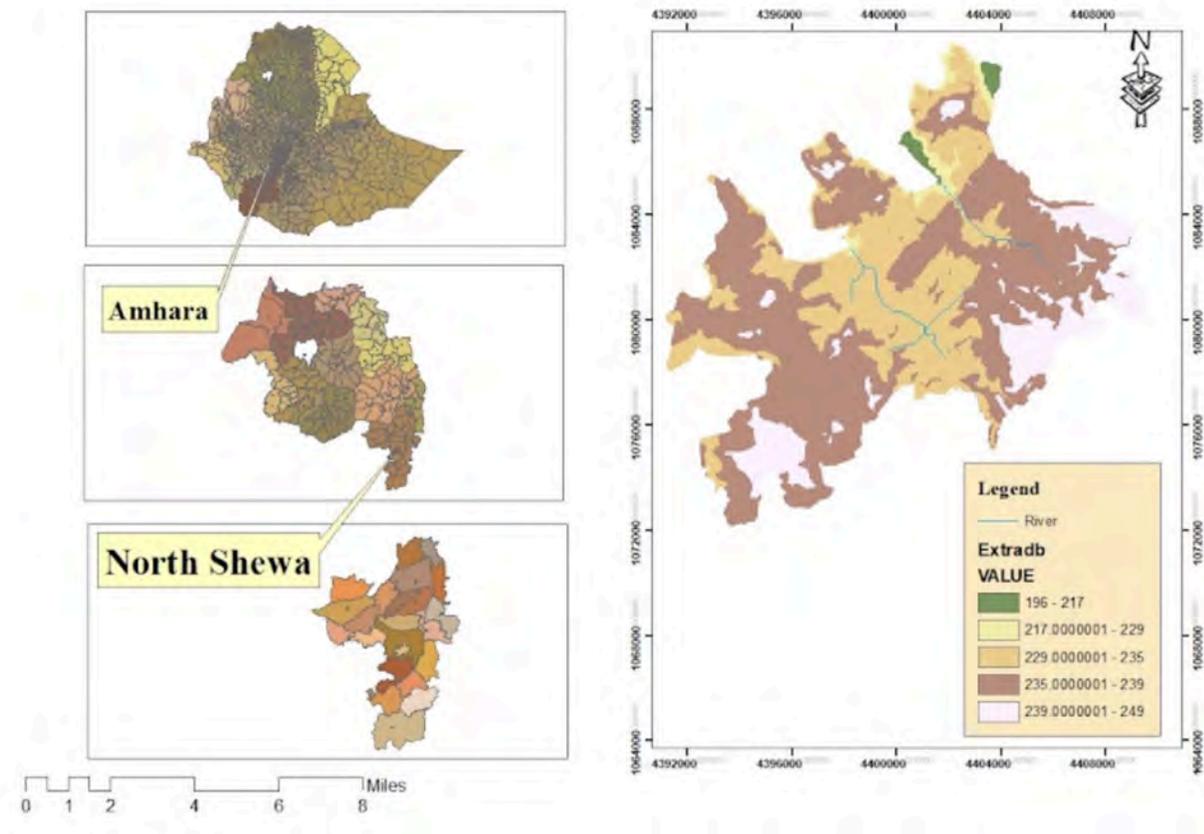


Figure 1

Study Area Map of Debre Birhan

Introduction to the Problem

The problem of lack of access to clean water is one of the pressing problems the city of Debre Birhan is facing. The biggest and the only river — the Beresa river — is being polluted due to different factors, including population growth, industrial discharges, inadequate water management systems and insufficient infrastructure for the water treatment process. The pollution of the Beresa river exacerbates the situation, making it unsafe as a water source for drinking, agriculture and other domestic purposes.

The Journey: Explanation of How the Problem was Identified

The group first identified six issues, such as water hyacinth, rain-fed agriculture, and others. After learning the various risk prioritization techniques, we later divided our issues into three groups according to various standards. The severity and accessibility of these issues were the main criteria we employed. Ultimately, we decided to concentrate on the Beresa River's water pollution by domestic and industrial wastewater.

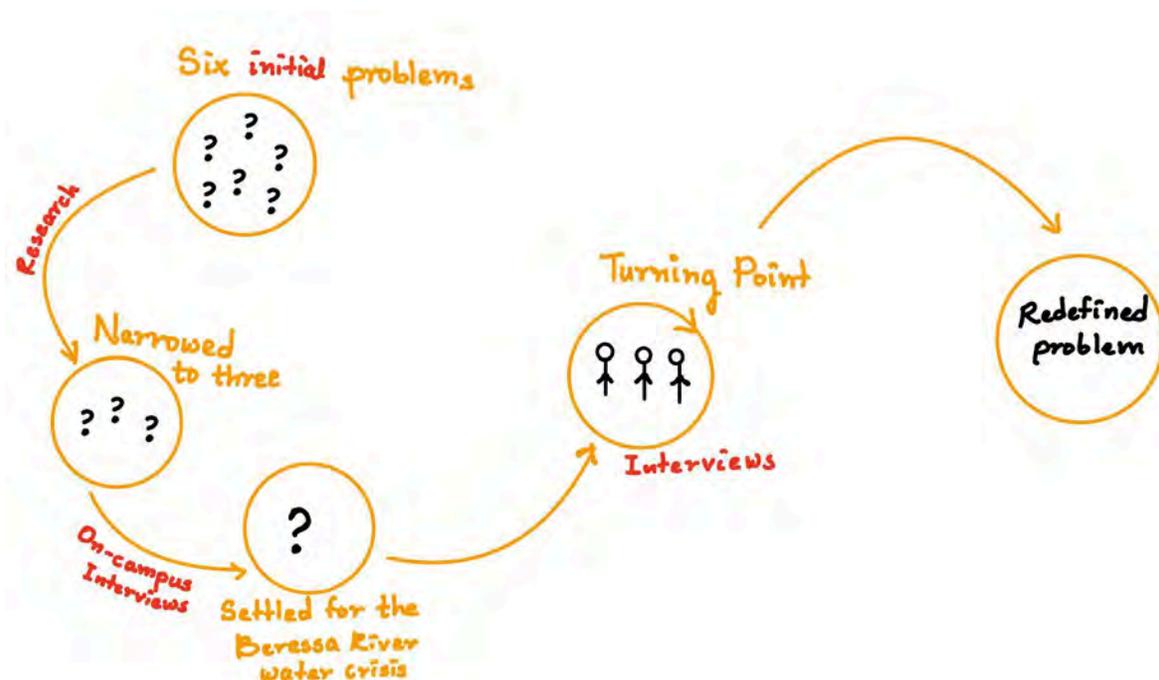


Figure 2

Journey Map that Summarizes Our Problem Identification Journey

Overview of The Process and Tools Used

The team used a methodical technique to pinpoint and characterise Debre Birhan's water contamination issue. These consist of systems thinking, design thinking, and risk prioritisation.

Design Thinking: Using various design thinking concepts, the team aimed to gain a thorough understanding of the issue by speaking with locals and farmers, as well as by interviewing the Debre Birhan Town Water Supply and Sewerage Service Office and other offices.

Systems Thinking: The group discovered the interrelated issues that lead to the contamination of the river by putting the systems thinking process into practice. These include urbanisation, and population increase.

Influence of Disciplinary Areas

Design: Through direct engagement with stakeholders-Residents, farmers, local authorities-the problem was enlightened by the knowledge of user needs and pain points. Those insights helped to map user-centric challenges regarding the access issue of clean water.

Engineering: The more technical understandings of the mechanisms involved in water management systems and in the controlling of pollution, therefore, underlined infrastructural gaps; for example, incomplete treatment and a lack of pollution abatement technologies are present within Debre Birhan.

Business: Economic feasibility, resource allocation, and sustainable solution considerations helped address the long-term challenge of water accessibility.

Design-Thinking Tools Used:

Empathy Mapping: Interviews and surveys with local stakeholders were conducted to understand their lived experiences and needs.

Evidence to Support the Problem Statement

Stakeholder Research

In the process of pollution of the Beresa River, stakeholder research involves the identification and analysis of roles, interests, and concerns of groups or individuals affected by or contributing to the river's pollution in developing informed and inclusive solutions.

Disciplinary Content

Theoretical knowledge in water pollution of the Debre Birhan Beresa River means an understanding of scientific principles, sources of pollution, environmental impacts, and possible solutions. It includes knowledge of pollutants, their effects on ecosystems and communities, relevant regulations, and strategies for mitigation.

Literature Review

1. Studies on water pollution due to industrial discharges in urban areas.
2. Reports on the Beresa River pollution and its socio-economic impacts.
3. Articles on sustainable water management practices in developing countries.

Your Original Consolidated Causal Loop Map

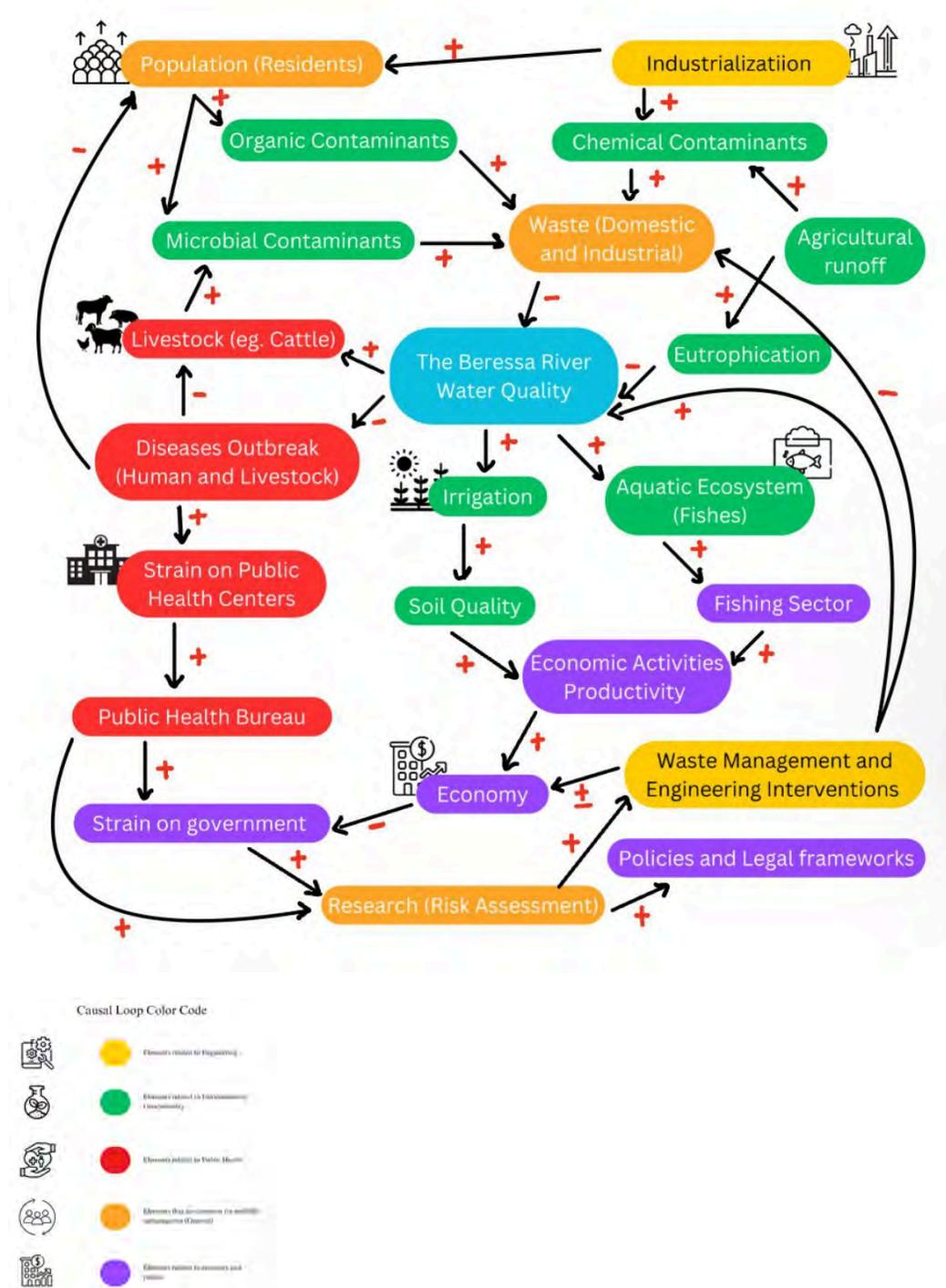
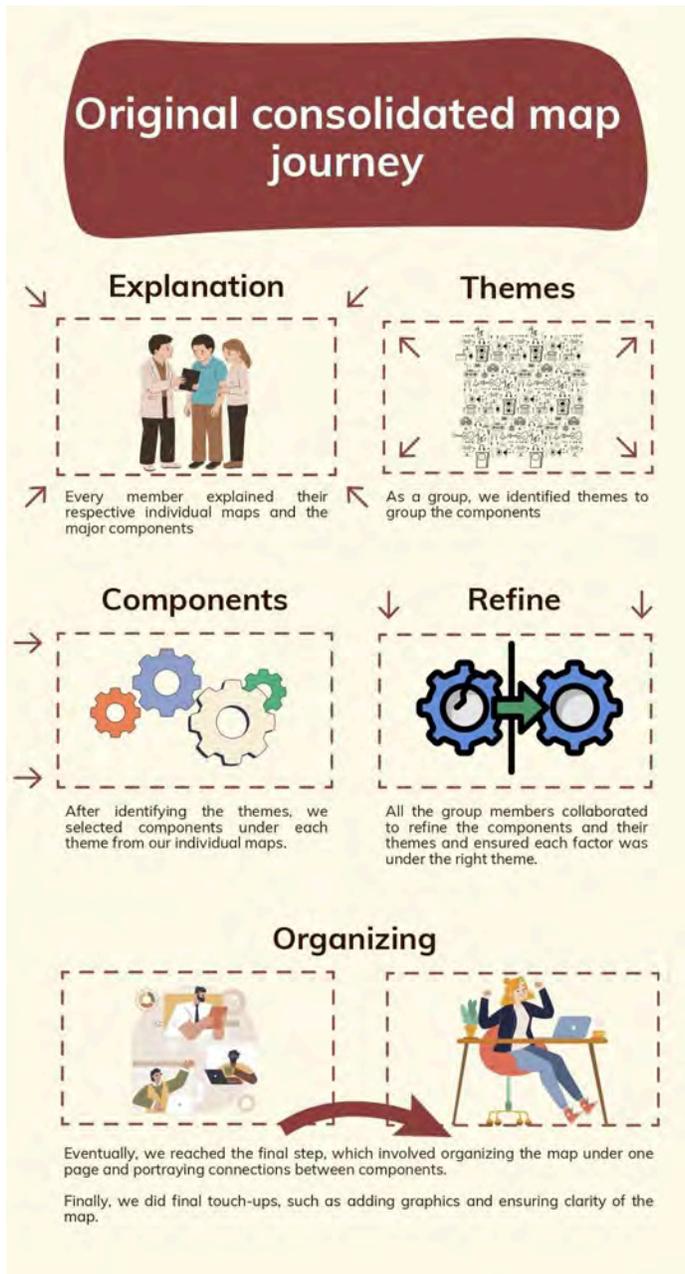


Figure 3

Original Consolidated Map and Map Legend

The process of making the consolidated group map involved an extensive discussion among the group members to identify the major themes and their components.

The consolidated causal loop map contained 5 themes, three of them being the three intensives: engineering, environmental geochemistry, and public health.



- **Engineering:** Included elements related to treatments and waste management, especially in industries.
- **Public Health:** Focused on health care facilities and their access to the public as well as livestock, with relation to their effect on water quality, which subsequently affected public health.
- **Environmental Geochemistry:** Related to soil quality, chemical pollution, contaminants, eutrophication, and waste from agricultural activities.
- **General Category:** Included elements common to every intensive, such as social awareness, population, and risk assessment. These elements were grouped here because they affected every other component and couldn't be grouped under a single intensive.

Figure 4

Original Consolidated Map Journey

- Politics and Economics: Included legal policies and frameworks posed by the government, either directly regarding environmental protection and water quality or other issues. Also covered the population's economic activities that directly affect water quality and pollution

In conclusion, Stakeholders and their needs were the major priorities considered during the making of this map. Therefore, the map addressed the identified stakeholders in general terms. However, it lacked specificity as it was made before we conducted interviews with various stakeholders, including the public health bureau, water and sewage office, environmental protection and assessment authorities, the textile industry, and Debre Birhan University.

Themes from Inspirational Activities (Stakeholders' Needs Assessment)

Identification of Key Stakeholders



Figure 5

Summary of Stakeholder Groups

Stakeholder Needs and Themes

The group considered all stakeholders who contribute, are affected and who try to protect the river from pollution. We identified them as the key stakeholders in our problem and took steps to analyze their needs. Based on our closer look at the stakeholders through our interview session, we have identified the following needs of each key stakeholder group in the presented order of priority.

Debre Birhan City Health Department: Public Health Emergency Operation Center

- Financial Resources and infrastructure: is a major need. Efficient waste disposal sites should be constructed to avoid microbial contamination of the river. Financial resources are necessary for extending awareness campaigns. Overall, the office needs financial

resources to carry out its responsibilities and have a noticeable impact on the community around Beresa. The absence of infrastructure and the resource shortage at the bureau is causing a rapid growth in pollutants and risk of disease. It is a problem that is clearly visible in the area.

- Information and Research: The bureau needs to be equipped with enough educated man-power and materials needed for continuous and informative research and information dissemination. This will aid the office in addressing health issues more effectively. The public health sector of any area should be equipped with data about the community to function properly. Every action of the sector should be determined by tangible evidence and proof
- Educational and Awareness revising resources: The office needs the collaborative effort of the community and educated individuals to extend health awareness campaigns regarding the use of the river. This includes educating both the affected, residents, and causes, industries and other individuals.
- Rigorous law enforcement: The bureau needs help from the government and law enforcement to take extensive measures on illegal dumping of waste into the river, causing huge health problems
- Collaboration with other governmental offices and NGOs: The bureau needs help from offices, such as the likes of the Water and Sewerage bureau, to resolve problems that cause the river's pollution and health problems that come with it. It needs a financial collaboration which can aid actions being taken and planned to be taken.

Figure 6

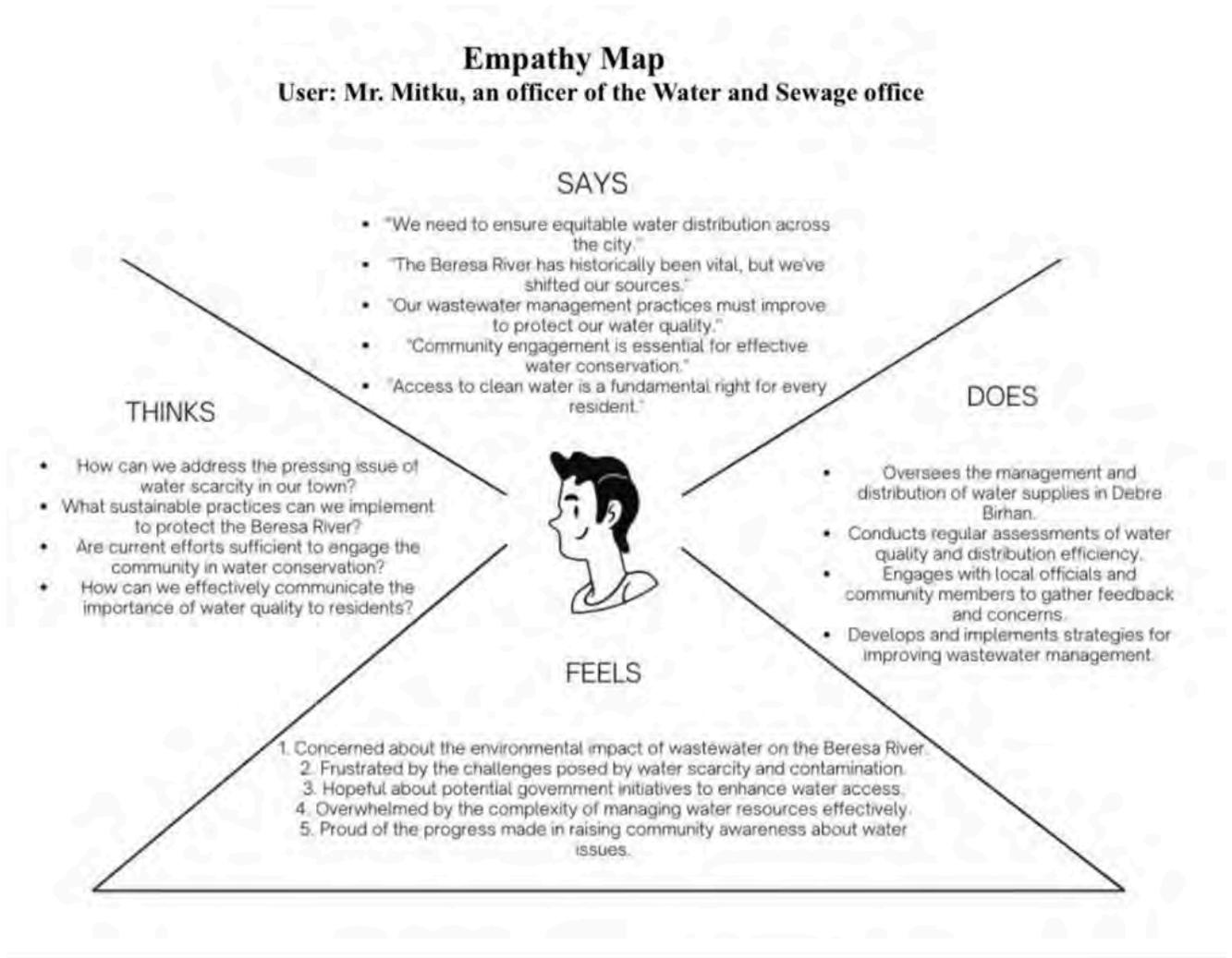
Visit to Debre Birhan City Health Department Bureau

<insert Figure 6: Visit to Debre Birhan City Health Department Bureau; Appendix A>

Debre Birhan Town Water Supply and Sewerage Service Office

- A more sustainable source of water for supplying the city: Since groundwater will be depleted in the coming years, the city must have a reliable source of water. The river is the only other option, but it is highly contaminated and there are no infrastructure built. The bureau needs the river to be a reliable source of clean water that can resolve the current scarcity problem.

- Technological and Systematic water management systems: are needed to provide clean supply to the city and treat the waste that comes out. Chlorination, the technique used until now, is highly unhealthy and unsustainable.
- Research and Information: are highly in demand as they are essential for formulating any potential solution for the city's problem.



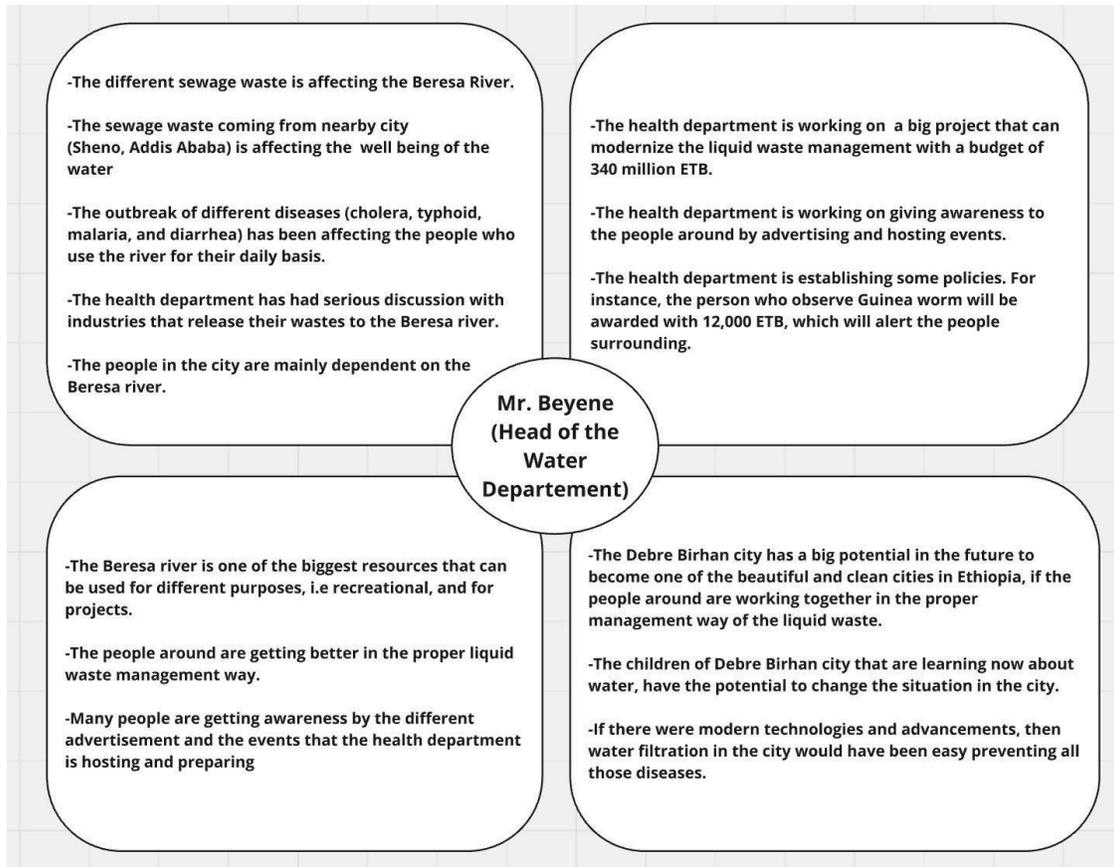


Figure 7

Empathy Maps from Previous Individual Assignments Used to Aid Need Assessment

Figure 8

Visit to Debre Birhan Town Water Supply and Sewerage Service Office

<insert Figure 8: Debre Birhan Town Water Supply and Sewerage Service Office; Appendix A>

Debre Birhan University

- Enough funds to repair the pump: they need help from the government to allocate money for the repair.
- An organized team and reliable budget source to maintain the function of the pump: They need their own source of money apart from the government and a team fully dedicated to the river and the plant.
- Research on the river: As an educational institute tightly related to the river, they need a funded and equipped research department which focuses on the river.

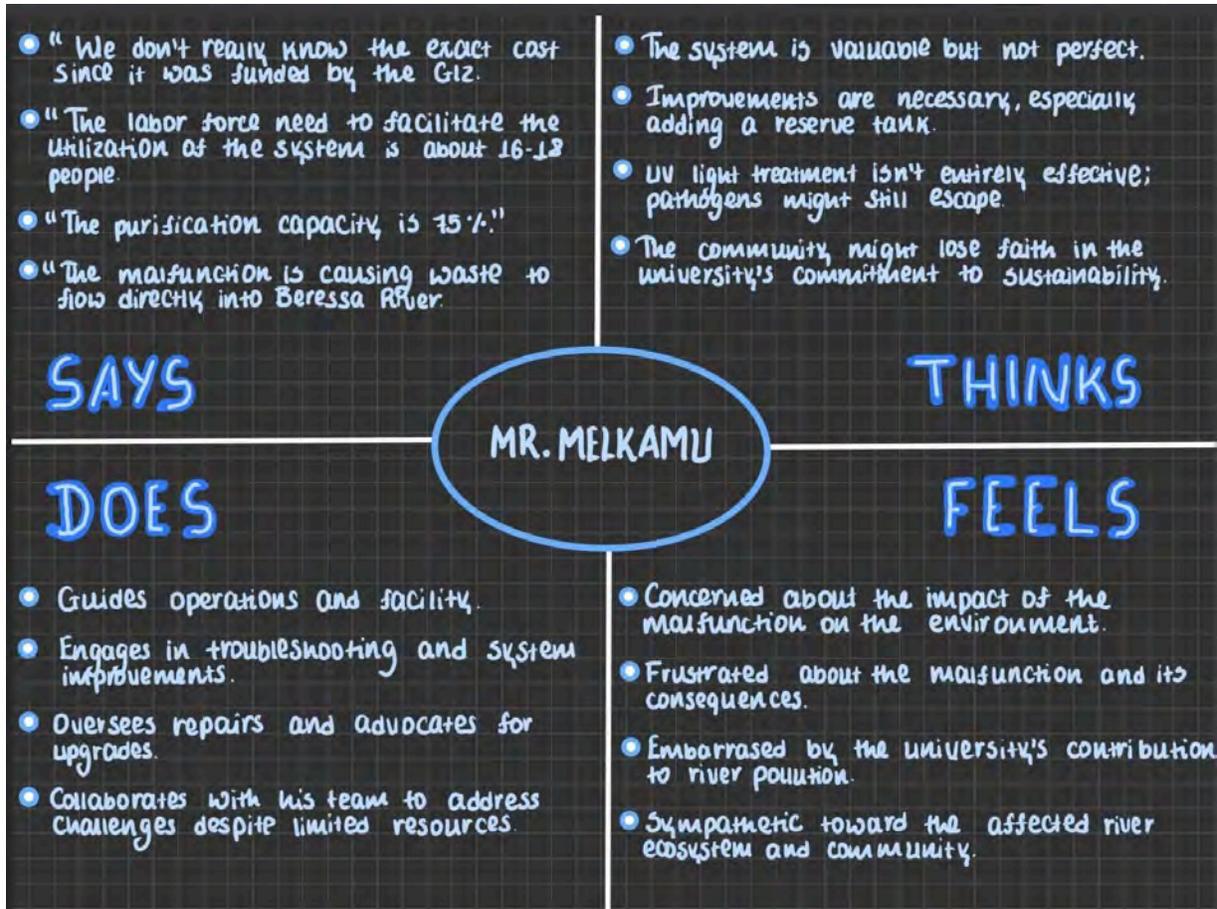


Figure 9

Empathy Map from Previous Individual Assignment Used to Aid Need Assessment

Figure 10

Visit to Debre Birhan University

<insert Figure 10: Debre Birhan University; Appendix A>

Environmental Protection Bureau

- Independence from governmental influence: The office needs to be fully independent to carry out actions on institutes polluting the river.
- Research and information: Regular chemical, physical and microbial testing of the river water is needed for a basis to start remedial actions.

Figure 11

Visit to Environmental Protection Bureau

<insert Figure 11: Environmental Protection Bureau; Appendix A>

Debre Birhan Blanket Factory PLC

- Cost effective waste management systems: They need a cost effective waste management system so that they do not try to avoid the high cost and pollute the river in the process.

Figure 12

Visit to Debre Birhan Blanket Factory PLC

<insert Figure 12: Debre Birhan Blanket Factory PLC; Appendix A>

Residents and Regular Users Around the Beressa River

- Reliable water source: Whether it is from the river, from the city supply, rain water or other sources, residents need an uncontaminated and safe water source to during, wash and carry on other daily activities.
- Safe and clean environment: Residents need an environment that is free from health risks and enjoyable to live in.
- Fully equipped and designated area to carry out daily activities: The barber shop, people taking showers, children playing, and other regular user need specific places to carry out these activities to avoid contaminating the river.

Figure 13

Observation Field Trip to Beressa River

<insert Figure 13: Observation Field Trip to Beressa River; Appendix A>

Evidence from Inspiration Activities

Our primary evidence for the process of framing our problem were the interviews we conducted. This activity gave us the opportunity to look at the problem through different lenses and gave us insights of its effect on people. Empathy maps were created for every stakeholder group to further organize and analyze the information we got from the activity. These maps contained direct quotes, feelings and actions that were observed from the visits and interviews, and supposed thoughts of each stakeholder based on their surroundings and current conditions.

Discussion of Trade-offs Among Stakeholder Needs

During our interview sessions with each stakeholder, specific problems were repeatedly mentioned. We prioritize these needs as they were already identified by the stakeholders themselves. For all stakeholders, financial barriers were prioritized. This was because it is known that the government cannot afford to adequately fund these institutions. This need was prioritized because it directly affects various other factors like research and mitigation efforts. This need was prioritized for each stakeholder because it has the potential to change the way stakeholders approach their individual problems. It can significantly improve their positive impact on the community if they were solved. There were also needs we prioritized for specific stakeholders; Independence for the Environmental protection office can be taken as an example. This stakeholder needed freedom from governmental and individual influence to carry out its function in the community, and that is why it was prioritized. Overall, we prioritized the needs of each stakeholder in terms of the degree of their negative influence on the stakeholders' activities.

Impact of Disciplinary Perspectives

We selected stakeholders that worked on a specific discipline from Public health, Engineering and Environmental Geochemistry. We went to the health office, where we gained insights of the office's needs regarding sustaining and promoting health in the problem space. The water supply and sewerage office engaged in water usage strategies from the ground. The office's needs were directly related to the composition and quality of the ground water, and other Environmental geochemistry concerns. The university, on the other hand, had needs of effective management of their waste. Engineering plays an important role here as it characterizes the needs of the university.

Updated Consolidated Group Map



Figure 14

Updated Consolidated Map and Legend

This section presents the updated consolidated causal loop map, reflecting significant changes made in response to stakeholder research and secondary activities. The evolution of the map was driven by engagement with stakeholders, including representatives from the public health bureau, water and sewage office, environmental protection authorities, the textile industry, and Debre Birhan University.

What Changed?

Initially, the map encompassed broad themes and components related to water quality and contamination of the Beresa River. However, through our discussions and interviews with stakeholders, we identified specific issues that warranted adjustments.

Public Health

For instance, feedback from the public health bureau highlighted the need to emphasize the direct impact of water quality on community health, leading us to refine the public health theme further. We incorporated new components addressing specific health concerns related to waterborne diseases, which had not been adequately represented in the original version.

Environmental Protection

Additionally, the insights gained from environmental protection authorities prompted us to enhance the environmental geochemistry theme. We included detailed components related to specific contaminants, such as heavy metals and agricultural runoff, which are prevalent in the region. This more granular approach allowed us to draw clearer connections between pollution sources and their environmental impacts, thus strengthening the causal relationships depicted in the map.

Political and Economic Aspects

The updated map also reflects changes in the political and economic theme. Stakeholders from the textile industry provided valuable input regarding regulatory frameworks and economic incentives, which influenced our understanding of how policy and economic activities intertwine with environmental issues. We highlighted the role of government policies in encouraging

sustainable practices within industries, illustrating how these policies can mitigate negative impacts on water quality.

Social Awareness and Community Engagement

Moreover, we consolidated elements related to social awareness and community engagement, recognizing their critical role in addressing water quality challenges. Through our research, we discovered that enhancing public awareness and community involvement could significantly influence risk assessment and management strategies. This realization led us to create links between social awareness initiatives and their potential effects on both public health and environmental outcomes.

The updated consolidated causal loop map now presents a more comprehensive and visual representation of the feedback loops and interactions among various components affecting water quality in the Beresa River. It integrates the perspectives and needs of stakeholders, ensuring that the map serves as a relevant tool for addressing the complex issues surrounding water contamination in the Beresa river, Debre Birhan, Ethiopia. By incorporating specific findings from our stakeholder interviews, the map not only enhances our understanding of the systemic relationships at play but also acknowledges the diverse voices involved in this critical environmental issue.

Updated Problem (“How Might We?”) Statement

During our design thinking journey, we identified a significant obstacle in our search for solutions: the lack of cohesion among stakeholders of the problem. Our final HMW statement focused on collaboration and involvement of these stakeholders to ideate solutions that perfectly fit the community and help maintain the community’s health and economic prosperity.

How might we collaborate with government agencies, industries, local residents, and other stakeholders to restore and maintain the Beressa River as a safe, reliable water source for daily use and livestock?

After conducting several field trips and gathering valuable insights, we gained a deeper understanding of the stakeholders and their needs. Based on this information, we have revised our problem statement to:

- Include various stakeholder groups
- Focus on restoration and remedial
- Address maintain ace of the river’s quality

The First How Might We Statement: Geochemistry and Engineering Considerations

How might/can we help the residents around Beresa river get uncontaminated and clean water from the Beresa river on which their lives rely?

Our first problem statement was focused on the pollution of the river and its effect on the residents, one of the many stakeholders. It had not brought the other stakeholder groups into consideration. It was characterized by:

- Consideration of only the residents
- Focusing solely on pollution and excluding the other aspects of water insecurity regarding the river
- The problem identified and addressed is concerning the qualitative aspect of the river water.

Second Set of HMW Statements: Public Health Considerations

How might we ensure that the communities surrounding Beresa river have access to safe and uncontaminated water that doesn’t pose a risk to their health and wellbeing?

How can we address the health issues faced by residents around the Beresa River due to contamination, ensuring they have access to clean and safe water for their well-being?

Some of our initial problem identification statements focused exclusively on health impacts related to the river and water insecurity.

They were formed with the theme of reducing health risks and remediation of health problems.

Table 1

Summary Table of HMW Statements

<insert Table 1: Summary Table of HMW Statements; Appendix B>

Design-Thinking and Stakeholder Research in Shaping HWM Statements

Engineering: We identified the chemical pollution, primarily due to industrial and domestic waste of the river as a significant threat to water quality. This insight led us to frame the problem around water safety and the need for technical solutions, such as risk assessment and contamination mitigation.

Public Health: Waste from industries, the university, and cattle farms increases harmful pathogens, posing serious health risks to the surrounding community. The public health disciplinary area plays a big role in addressing these problems. We tried to use what we learned in the module and apply it in our problem space. These considerations drove us to shape statements focused on public health.

Environmental Geochemistry: Chemical contamination from industry emissions, particularly from the nearby blanket factory, was identified as a major contributor to the river's pollution. We used our experience from the environmental geochemistry module to assess this problem and incorporate it to our problem statement.

Rationale for Revisions

When we initially drafted our HMW statement, we had not yet conducted interviews with key stakeholders mentioned in Section 3. As a result, it was focused primarily on pollution affecting the river with limited consideration of the broader community dynamics. After week 10, we conducted interviews with each stakeholder group to gain a clear visual of our problem. Our

interactions with these stakeholders, and others, revealed the complexity of the problem. As a result, we revised the HMW statement to incorporate the perspectives of all relevant stakeholders, ensuring the final statement reflects a collaborative effort of restoring and maintaining the river's quality for the community's wellbeing.

Stakeholders we interviewed included :

- Residents
- Industry workers
- Representative of the Public Health Emergency Operation office
- Representatives of Debre Birhan University
- Stakeholders in the Environmental Protection Bureau of Debre Birhan
- Employees of the Debre Birhan town Water Supply and Sewerage Service Office.

Benchmarking Existing Solutions, Their Strengths and Limitations

Debre Birhan University's Liquid Waste Filtration System

Analysis and Solution for DB University's Filtration System

DB University relies on the Conventional Activated Sludge (CAS) System for wastewater treatment, a widely used and effective technology. However, a critical failure in the pump component has halted operations, preventing the treatment of wastewater and posing potential environmental risks. This document provides an in-depth evaluation of the solution as a whole, its strengths, limitations, and alternatives to address the problem effectively.

Figure 15

Images of the Debre Birhan University Filtration Plant

<insert Figure 16: Images of the Debre Birhan University Filtration Plant; Appendix A>

Existing Solution

The problem centers around the wastewater filtration process at DB University, specifically the malfunction of the conventional activated sludge (CAS) system. Existing solutions to address this issue include:

Conventional Activated Sludge (CAS) System

The CAS system is the current solution in place at the university. It is a widely used wastewater treatment process that relies on microorganisms to degrade organic material in wastewater. Its components include:

- Primary screening to filter out large debris.
- Equalization (EQ) tank where microorganisms decompose organic waste.
- Clarifying tank to settle flocs and clarify water.
- Tertiary filters and UV filtration for enhanced cleaning and disinfection.

Pump Replacement and Maintenance

One solution to the university's malfunction issue is to replace the broken pump and introduce a robust maintenance schedule. This would restore the CAS system to full operation, ensuring continuous treatment of wastewater.

Alternative Filtration Technologies

Consideration could be given to alternative systems, such as membrane bioreactors (MBR) or constructed wetlands. These systems could complement or replace CAS to enhance efficiency and reduce the risk of similar failures.

Evaluation of Strengths and Limitations

CAS System

- Strengths:
 - Reliability: Has proven to treat wastewater effectively (up to 75%).
 - Familiarity: Easy to find skilled technicians for maintenance.
 - Versatility: Can handle various loads and produce biogas/electricity.
 - Environmental Safety: Prevents ecological damage to river ecosystems.
- Limitations:
 - Fragility of Components: A single-point failure, such as the pump breakdown, can halt operations.
 - Maintenance Demands: Requires consistent attention to avoid breakdowns.
 - Incomplete Filtration: While effective, the system only removes 75% of contaminants, requiring additional filtering.

Pump Replacement and Maintenance

- Strengths:
 - Restores the system to its designed functionality.
 - Ensures minimal downtime in future through preventative measures.
- Limitations:
 - Cost-intensive, especially if the pump design or specifications are unique.
 - May not address other potential vulnerabilities in the system.

Alternative Filtration Technologies

- Strengths:
 - Advanced systems like MBR can achieve higher filtration efficiency (90%+).
 - Constructed wetlands offer a natural, low-maintenance solution.
 - More sustainable long-term options with fewer mechanical components.
- Limitations:
 - High initial setup costs for advanced technologies.
 - Requires training and familiarity with new systems.
 - Space requirements for constructed wetlands may be prohibitive.

Alternatives Matrix

Table 2

Alternative Matrix

<insert Table 2: Alternative Matrix; Appendix B>

Gaps in Solutions

- CAS and pump replacement do not address efficiency beyond 75%, leaving room for improvement.
- Advanced alternatives like MBR, though efficient, may not be feasible due to high costs and training requirements.

Proposed Comprehensive Solution

To address the pump failure and enhance the university's wastewater treatment system, the following steps are recommended:

Repair and Maintenance of the CAS System

The immediate priority is to replace the broken pump to restore the functionality of the existing system. A robust maintenance schedule should also be implemented to prevent future disruptions. This includes regular inspection of critical components, early identification of potential failures, and periodic system optimization.

System Enhancements

While the CAS system has served well, additional measures can improve its efficiency and reliability:

- **Install Backup Components:** A redundant pump or critical spare parts should be on hand to minimize downtime in case of future failures.
- **Integrate Tertiary Systems:** Advanced tertiary filtration methods, such as membrane bioreactors (MBR), can enhance filtration efficiency beyond 75%, improving water quality for discharge or reuse.

Long-Term Alternatives

If further issues arise with the CAS system or if the university seeks a sustainable solution, alternative technologies can be considered:

- **Membrane Bioreactor (MBR):** Offers superior filtration (90%+ efficiency), but requires higher initial investment and technical expertise.
- **Constructed Wetlands:** A low-maintenance, environmentally friendly option suitable for treating smaller volumes of wastewater.

Sources of Information for Evaluation

- **Industry Literature:** Comparative studies on CAS, MBR, and other wastewater treatment technologies.
- **Tour provided by the system operator:** Specifications for pumps, tertiary filtration systems, and alternative technologies.
- **User and Expert Feedback:** Insights from facilities on system performance and maintenance strategies.
- **Operational Data:** Analysis of the university's system performance since 2018 to identify patterns and potential improvements.

Fines by the Environmental Protection Office

Analysis of Fines in for Pollution Control in the Beressa River

The Environmental Protection Office of Debre Birhan has implemented a system of fines and educational initiatives to address the pollution of the Beressa River. However, the enforcement of these measures faces significant challenges, especially concerning high-profile facilities like hotels, which complicates the effectiveness of the solution. This document provides an in-depth evaluation of the existing solutions, their strengths and limitations, and proposes alternatives to address the issue more comprehensively.

Existing Solutions

The Environmental Protection Office employs the following strategies to mitigate pollution in the Beressa River:

Imposing Fines on Polluting Industries

Polluting facilities are fined based on the severity and frequency of their environmental violations. This measure aims to discourage improper waste disposal practices and enforce accountability among stakeholders.

Educational Campaigns for Polluting Facilities

The office also conducts educational campaigns to inform industries and facilities about the importance of adhering to environmental standards. The campaigns focus on raising awareness about the ecological damage caused by improper waste disposal and the benefits of compliance.

Collaboration with Stakeholders

Efforts are made to collaborate with industries, advocating for the adoption of environmentally friendly waste management practices.

Evaluation of Strengths and Limitations

Strengths

- **Accountability through Fines:** The system of fines ensures that industries are held responsible for their actions, creating a financial deterrent against polluting practices.

- Awareness through Education: Educational efforts provide stakeholders with the knowledge required to adopt sustainable practices, promoting long-term behavioral change.
- Collaborative Potential: Partnerships with facilities create an opportunity for mutual understanding and gradual adoption of improved waste management solutions.

Limitations

- Selective Enforcement: High-profile facilities, such as luxury hotels, are often exempt from penalties or scrutiny due to their perceived importance, undermining the system's fairness and effectiveness.
- Limited Impact of Education: Despite repeated educational efforts, many facilities fail to implement changes, indicating a lack of enforcement or insufficient motivation to comply.
- Inconsistent Monitoring: The office lacks the authority to inspect or enforce regulations uniformly across all facilities, creating loopholes in the system.

Alternatives Matrix

Table 3

Alternative Matrix

<insert Table 3: Alternative Matrix; Appendix B>

Gaps in Existing Solutions

- The inability to impose fines on all polluting facilities undermines the system's effectiveness and creates unequal enforcement.
- Educational campaigns alone are insufficient to motivate facilities to comply, especially when non-compliance carries minimal consequences.
- Collaboration efforts, while promising, lack adequate support and oversight to ensure meaningful changes.

Proposed Comprehensive Solution

Strengthen Enforcement Mechanisms

- Introduce stricter laws that mandate inspections for all facilities, including high-profile ones, without exceptions.
- Empower the Environmental Protection Office with more resources and authority to enforce fines and oversee compliance.

Expand Public Awareness and Pressure

- Conduct public awareness campaigns about the Beressa River's pollution, encouraging community advocacy and stakeholder accountability.
- Highlight the environmental consequences of pollution caused by specific industries or facilities to foster public pressure for compliance.

Incentivize Sustainable Practices

- Provide financial incentives or subsidies for facilities that adopt environmentally friendly waste management technologies.
- Create recognition programs for compliant industries, promoting them as environmentally responsible entities.

Establish Collaborative Forums

- Organize regular forums for industries, government bodies, and environmental experts to discuss challenges and solutions.
- Foster knowledge-sharing sessions where successful waste management practices are highlighted.

Sources of Information for Evaluation

- Expert Interviews: Insights from environmental protection experts regarding the effectiveness of fines and educational campaigns.
- Policy Reviews: Analysis of existing regulations and their enforcement gaps, including case studies of selective application.
- Case Studies: Examples of similar challenges faced by other regions and their approaches to resolving them.

Brainstormed Ideas

The Process

The ideation process began during the phase of our research when the group was conducting interviews and visiting the river. The actual brainstorming occurred after completing thorough stakeholder interviews and assessing the various, both large and small, affecting the river's condition. Once the interviews and observations were concluded, we organized a brainstorming session that incorporated both divergent and convergent thinking techniques. By aiming to generate ideas in a large quantity, we generated over 20 potential solutions.

Steps:

- Each team wrote down every idea they could think of on sticky notes and placed them on the table.
- Criticisms were withheld until everyone was done writing their ideas.
- Then, the session was open to constructive criticism and feedback, building up on every potential solution.
- The solutions were grouped according to their specific goals and focus areas
- The group converged solutions that complemented each other into a broader concept.

Figure 16

Images From Group Brainstorming Session

<insert Figure 17: Images From Group Brainstorming Session; Appendix A>

Summary Table of Brainstormed Ideas

Table 4

Summary Table of All Brainstormed Ideas

<insert Table 4: Summary Table of All Brainstormed Ideas; Appendix B>

Criteria Used to Narrow Down Brainstormed Ideas

1. Community/Stakeholder Engagement (Design thinking)

Drawing from our design thinking framework , we identified community engagement as a core component of our solution. By engaging the target audience in the decision-making process, we can ensure that the solution aligns with the needs of the community and promotes inclusivity . Our most impactful idea, *Community-Centric Integrated Water Resource Management Awareness Program*, is an example for this approach by directly including the stakeholders in the solution process.

2. Sustainability

The selected solutions are sustainable in terms of resource use. Sustainability becomes critical for solutions when we think of scaling up in the future. Our most impactful solution utilizes sustainable human resources, particularly youth, to maintain its long-term impact. Additionally, our most feasible solution uses easily accessible, sustainable materials to build small-scale plants, making it adaptable in different locations.

3. Cost

Emphasizing the rural and low-income background of the community, we prioritized cost-effectiveness of our solutions. Most of the ideas we selected can be implemented using locally available resources, with the exception of the wildest solution. At this time, given the current high levels of unemployment, human resources are plentiful, which reduces implementation costs. The use of sustainable materials and resources further reduces costs, ensuring the solution is economically suitable for the community.

4. Scalability

When evaluating the solutions, we considered their potential for scalability. We looked at resources that could be gathered from within the community and how they could be used for future expansion. We narrowed down our choices to those that could be scaled effectively over time.

5. Immediate Impact

All stakeholders need a solution that could immediately satisfy their urgent needs. We focused on solutions that could show improvements in a short time. Our selected solutions engage a large

population, resulting in an immediate impact. Moreover, address the root problem, stopping the problem before it starts and reducing time-consuming remediation measures.

Most Impactful, Most Feasible, and Wildest Ideas

Table 5

Summary of Most Impactful, Most Feasible, and Wildest Ideas

<insert Table 5: Summary of Most Impactful, Most Feasible, and Wildest Ideas; Appendix B>

The Most Impactful Idea

Community-Centric Integrated Water Resource Management Awareness Program

Description

A public driven program that empowers local communities to actively participate in protecting and managing the Beresa River.

The Target Audience

- Local communities residing in Debre Berhan, mainly those around the Beresa River
- Government agencies (Debre Birhan Water and Sewage Office, Debre Berhan Environmental Protection Authority, Debre Birhan Health Bureau)
- Private companies and industries in Debre Birhan (Debre Berhan Blanket Factory, Habesha Beer Factory, etc)

Key Implementation Strategies

- The establishment of community-based water user associations to promote fair and equitable water allocation.
- Advocacy for action with local high school students and unemployed youth to clean trash around and inside the river.
 - This could be made a Service Learning Program in schools like Haile Manas Academy (HMA)
- Delegating a specific day in a year to raise awareness and honor the cause. The program could include fundraisers and other events to promote a collaborative action towards protecting the Beresa River.

Stakeholder Needs Addressed

- Improved water security for domestic, agricultural, and industrial uses
- Enhanced ecosystem health and biodiversity conservation of the Beresa River
- Reduced vulnerability to water borne, water related, and water shortage diseases

Difference From Existing Solutions

- Prioritizes community engagement and ownership throughout the planning and implementation process.
- Leverages traditional knowledge and local practices to complement modern scientific techniques.

Justification for Potential Impact

- By empowering communities, this approach ensures long-term sustainability and resilience.
- Nature-based solutions offer cost-effective and environmentally friendly solutions to water challenges.
- Integrated water resource management can optimize water allocation and reduce conflicts among different water users.

The Most Feasible Idea

Construction of Small-Scale Wastewater Treatment Plants

Description

Includes building decentralized wastewater treatment plants in key urban and rural areas along the Beresa River. These plants would use appropriate technologies, such as biological treatment or UV treatment to treat domestic wastewater before discharge.

Target Audience

- Urban and rural communities in the Beresa River basin
- Local government authorities

Stakeholder Needs Addressed

- Improved water quality in the river
- Reduced public health risks associated with waterborne diseases
- Enhanced environmental sanitation

Feasibility Considerations

- It requires relatively lower initial investment and operational costs compared to large-scale centralized treatment plants.
- Can be implemented in a phased manner, starting with high-priority areas.
- Can be integrated with other infrastructure projects, such as road construction or urban development.
- Proven technology with a track record of success in similar contexts and has been proven to be scalable in some industries and institutions that are in Debre Berhan.

The Wildest Idea

Bioremediation Using Indigenous Microorganisms

Description

It is identifying and cultivating indigenous microorganisms with the ability to degrade specific pollutants in the Beresa River. These microorganisms would be introduced into the river to naturally break down contaminants and improve water quality.

Target Audience

- Environmental scientists and researchers
- Government agencies responsible for environmental protection (Debre Berhan Environmental Protection Authority)

Stakeholder Needs Addressed

- Innovative and sustainable solution for water pollution
- Reduced reliance on chemical treatments

Rationale for Calling it the 'Wildest Idea'

- Requires extensive scientific research and experimentation.
- Uncertainties about the effectiveness and long-term impacts of bioremediation techniques.
- Potential challenges in scaling up the technology and ensuring its widespread application.

Strengths and Limitations

Evaluation of Strengths

- The project successfully gathered diverse perspectives, resulting in a well-rounded understanding of the issues.
- Despite challenges, we managed our time efficiently and adapted to constraints.
- The final project effectively highlights key themes, including public health, environmental and engineering impacts and pollution sources.

Evaluation of Limitations

Time Constraints

- Our progress was limited by boarding school curfew requirements, which often cut interviews short. Despite this, we managed to use our time effectively.
- The demanding schedule of our boarding school further restricted the time available for the project.

Field Trip Limitations

- Organizing a field trip within the constraints of a boarding school environment was particularly difficult.
- Although Debre Birhan is not in active turmoil, its status as a war zone meant certain areas were off-limits which limited the scope of our investigation.

Challenges Faced

- Some stakeholders, such as local residents, were not available or unwilling to participate.
- Certain organizations, like the environmental protection bureau, restricted recording, which limited the ability to fully document responses.
- Accessing reliable research and data on the topic proved to be challenging which required extra effort and resourcefulness to fill knowledge gaps such as accessing unpublished project reports from the Debre Birhan University Resources Center.
- Consolidating all the information into a comprehensive and organized written report was particularly demanding.

Lessons Learned and Next Steps

Our Understanding of Systems-Thinking and Design-Thinking

Learning about Systems-Thinking and Design-Thinking was an adventurous individual and team journey. Having taken Design-Thinking as a class at our boarding school, we all thought we would relearn what we already know. To our surprise, our experience was quite different from what we expected. Below are quick reflections from each team member:

“The further we went through the process, the problem kept getting broader and clearer, but more complex. It's almost like zooming out, having a drone look at a big forest; the further you go upwards, the clearer the border of the forest gets but the more complex looking at the individual trees becomes because of their increasing number. Systems thinking in real life is just simply fascinating!” – **Tsion, the Traveler**

“Systems thinking for me was like breaking down a car. Each component has its own function which works with other parts to make the whole system, which is the car in this case. Similarly, breaking down all the components of our problem was an important process we went through to deeply understand the problem. Going back to the car analogy, empathy and design thinking were like listening to and observing the condition each part is in and how it operates. Design thinking was an important tool we used to find solutions that fit the problem well.” —**Simon, the Engineer**

“Throughout my journey during our research, I began to see systems thinking as a river—deep, winding, and interconnected—where every decision upstream affects the flow downstream. Initially, I only noticed the surface, but as I went deeper, I uncovered hidden currents: social, economic, and environmental factors shaping the problem. Design thinking became the bridge I built across this river, connecting fragmented ideas into actionable, human-centered solutions. Together, these approaches transformed my perspective, teaching me to navigate complexity with purpose and compassion.”
—**Etsehiwot, the Swimmer**

“Systems thinking feels like looking at a symphony where every instrument is playing its role in making this music. The violins may carry the melody, the drums the rhythm, and brass the power. Every single one is essential; taken together, they make harmony-or chaos if out of tune. Breaking down our problem felt like analyzing the score to this symphony, to understand how each note and every player contributed to the overall piece.”—Nathan, the Happy-go-lucky musician

“In the process of carrying out this research and seeking solutions, I felt like I was a part of a big play. This play is the system we were assessing, and as a systems thinker in this story, I was able to do my part in shaping the plot for the better. Most importantly, I had castmates—the stakeholders. I am grateful to meet all of them for they are the main characters in the play. Even though I had such a short stage time, I have faith that my character will continue to influence the system and inspire other characters as well.”—Annabel, the Actress

“Systems thinking for me is like a garden while design thinking is represented by each plant and their needs. Each plant represents a different element within a system, and their growth depends on various factors such as soil quality, sunlight, and water. Just as a gardener must understand the needs of each plant and how they interact, systems thinking requires recognizing the interconnectedness and dynamics among different components. In a garden, if one plant is thriving while another struggles, it can affect the overall health of the ecosystem. Similarly, in systems thinking, changes in one part of a system can influence others, which shows the importance of balance and harmony. Gardening also involves nurturing relationships. This is a reflection of how collaboration and communication are vital in a system.” —Mariamawit, the Elegant Gardner

This art of looking at our problem identification journey like a river, a forest, a music piece, a car, a stage, and a garden is what enabled us to see how complex the problem is in our own ways. The combination of these views helped us brainstorm solutions that incorporated as many aspects of the problem as possible and diverged from ‘typical’ solutions in our country.

Recommendations for Future Work

Community-Centric Integrated Water Resource Management Awareness Program

Description: A public driven program that empowers local communities to actively participate in protecting and managing the Beresa River.

Empathy

- Local communities residing in Debre Berhan, mainly those around the Beresa River

Define

- The pollution of the Beresa River is partly due to limited education, awareness, and engagement from residents and stakeholders. This is why interventions that foster ownership and responsibility within the community are needed.

Ideate

- Establish Community-Based Water User Associations (CBWUAs):
 - Promote fair and equitable water allocation through community-led governance.
 - Empower residents to monitor and report pollution sources, ensuring accountability.
 - Partner with experts to provide education on water resource management practices.
- Youth Engagement and Action Advocacy:
 - Collaborate with local high schools and unemployed youth to organize regular river clean-up drives.
 - Pilot a Service Learning Program in schools such as Haile Manas Academy (HMA), integrating environmental education and practical action.
- Annual Awareness Day for the Beresa River:
 - Designate an official day for raising awareness about the river's importance.

Prototype/ Implementation

1. Select one or two local neighborhoods as pilot areas to establish CBWUAs.
2. Facilitate quarterly community workshops to assess progress and adjust strategies.

3. Partner with HMA to develop a curriculum combining environmental education and civic engagement.
4. Schedule bi-annual river clean-ups with students and youth groups.
5. Conduct surveys or focus groups with local residents to gather input on CBWUAs and awareness events.
6. Build partnerships with NGOs or local universities for technical and logistical support.
7. Start with small-scale prototypes for clean-ups and awareness events.

Scaling Up

- Expand successful programs to more neighborhoods, schools, and stakeholder groups.
- Lobby local governments to integrate these initiatives into policy frameworks for long-term sustainability.

Our Team

Meet our team!

Annabel | Etsehiwot | Mariamawit | Nathan | Simon | Tsion



Adventurous 12 Weeks!





Hard Work + Fun = Our Team!



Reference

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<https://www.ssiaeration.com/systems/conventional-activated-sludge-wastewater-systems/#gref>

Additional Materials:

Link to a short video of a glimpse to our journey:

<https://drive.google.com/file/d/1cHsr0zbBzlGJS9JCe3hMAgU-3k0k6w1W/view?usp=drivesdk>

Link to our presentation slide:

https://www.canva.com/design/DAGYnqkJ_xw/iSerB3THD_EXCOR0Z1fXOg/view?utm_content=DAGYnqkJ_xw&utm_campaign=designshare&utm_medium=link2&utm_source=uniquelinks&utm_id=h8b95caff1f

Appendix A

List of Figures

Figure 6

Visit to Debre Birhan City Health Department Bureau



Figure 8

Visit to Debre Birhan Town Water Supply and Sewerage Service Office



Figure 10

Visit to Debre Birhan University



Figure 11

Visit to Environmental Protection Bureau



Figure 12

Visit to Debre Birhan Blanket Factory PLC



Figure 13

Observation Field Trip to Beressa River

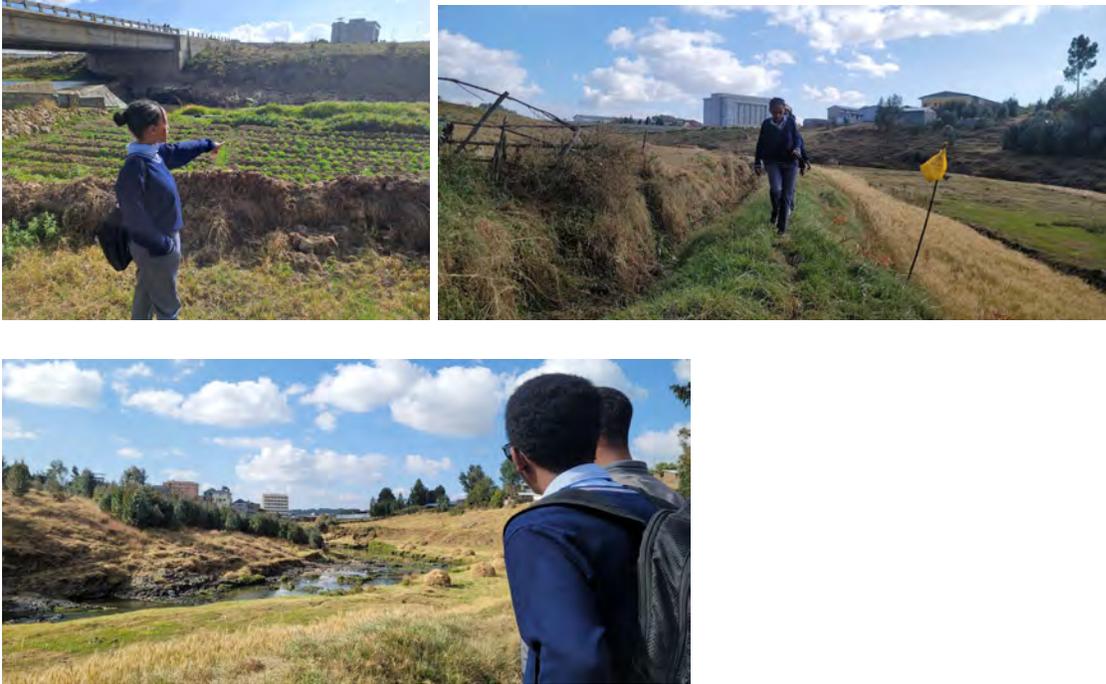


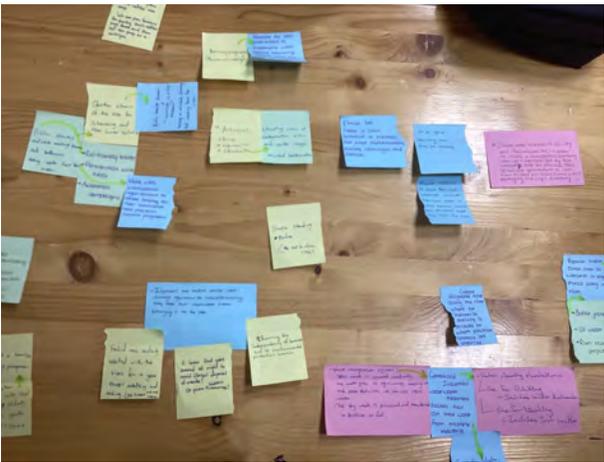
Figure 15

Images of the Debre Birhan University Filtration Plant



Figure 16

Images From Group Brainstorming Session



Appendix B

List of Tables

Table 1

Summary Table of HMW Statements

HMW STATEMENTS		
N ō	Disciplinary focus	Statement
1	Geo-chemistry, Engineering	<i>How might/can we help the residents around Beresa river get uncontaminated and clean water from the Beresa river on which their lives rely?</i>
2	Public Health	<i>How might we ensure that the communities surrounding Beresa river have access to safe and uncontaminated water that doesn't pose a risk to their health and wellbeing?</i>
3	Public health	<i>How can we address the health issues faced by residents around the Beresa River due to contamination, ensuring they have access to clean and safe water for their well-being?</i>
4	Economic status	<i>How might we ensure that the low-income residents living near the Beresa River have access to clean and uncontaminated water essential for their daily lives and well being, without any additional cost?</i>
5	Design thinking and all three disciplines	<i>How might we collaborate with government agencies, industries, local residents, and other stakeholders to restore and maintain the Beressa River as a safe, reliable water source for daily use and livestock?</i>

Table 2*Alternative Matrix*

Identified Needs	Existing Solution: CAS System	Existing Solution: Pump Replacement & Maintenance	Existing Solution: Alternative Filtration Technologies
Reliable Wastewater Treatment	Achieves 75% filtration efficiency but does not meet higher filtration demands.	Restores functionality but does not address efficiency limitations.	Advanced systems like MBR achieve 90%+ efficiency.
Cost-Effectiveness	Operational costs are moderate but dependent on pump reliability.	Requires significant investment for pump repair and ongoing maintenance.	High upfront cost; lower long-term operating costs (e.g., constructed wetlands).
System Redundancy	Lacks redundancy; failure of the pump halts operations.	Can include spare pumps to minimize downtime.	Reduces dependency on single points of failure with some systems.
Ease of Maintenance	Requires skilled technicians and regular servicing.	Preventive maintenance helps but increases operating workload.	Constructed wetlands require less maintenance but need space.
Adaptability to New Regulations or Needs	Limited adaptability due to technology constraints.	Restores current system but does not enhance flexibility.	MBR and other technologies are more

			adaptable to stricter standards.
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Table 3

Alternative Matrix

Identified Needs	Existing Solution: Imposing Fines	Existing Solution: Educational Campaigns	Existing Solution: Collaboration with Stakeholders
Fair and Uniform Enforcement	Selective enforcement undermines effectiveness.	Does not address enforcement; focuses on voluntary behavior.	Collaboration lacks consistent support or monitoring mechanisms.
Effective Pollution Deterrence	Fines provide a deterrent but lack fairness and proper enforcement.	Raises awareness but has limited impact without accompanying penalties.	Collaboration encourages compliance but is voluntary and slow.
Stakeholder Education and Awareness	Limited to punitive actions with little focus on education.	Directly addresses this need through campaigns.	Partially addresses this need by sharing best practices.
Incentives for Sustainable Practices	No incentives offered, only penalties.	Does not address this need.	Encourages sustainable practices but without financial incentives.

Transparency and Community Advocacy	Selective application creates mistrust among stakeholders.	Does not directly involve the community in accountability efforts.	Collaboration forums can address transparency but are underutilized.
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Table 4

Summary Table of All Brainstormed Ideas

Brainstormed Ideas			
Prevention		Remediation	
Engineering	Policy, Law and Advocacy	Engineering	Policy, Law and Advocacy
<p>Synthetic</p> <ul style="list-style-type: none"> • Plastic waste reduction • Riparian buffer zones, such as wetlands or vegetated zones along the river. • Centralized industrial wastewater treatment facilities that can treat 	<p>Industries</p> <ul style="list-style-type: none"> • Driving more investors to the city and businesses too, in order to create a competitive economy that isn't monopolized by a few facilities that are polluters. • Implement and enforce strict waste discharge regulations for industries, ensuring they treat their wastewater before discharging it into the river. • Create designated zones along the river where no industrial activity is 	<p>Microbial Polluters</p> <ul style="list-style-type: none"> • UV water purifier • Wastewater management system that separates organic matter immediately to make fertilizer and uses the excess water for irrigation 	<ul style="list-style-type: none"> • Advocacy for action with local high school students and unemployed youth to clean (pick up) trash around and inside the river. • This could be made a Service Learning Program in

<p>water from multiple industries.</p> <p>Organic</p> <ul style="list-style-type: none"> Wastewater management system that separates organic matter immediately to make fertilizer and uses the excess water for irrigation and other uses. Public showers and cloth washing stations. Eco-friendly toilets in a protected and designated area. 	<p>allowed or where pollution controls are enforced.</p> <ul style="list-style-type: none"> Provide tax breaks for other incentives to industries that adopt environmentally friendly technologies and practices. Set up regular monitoring and fines for industries. Mandate industries to build their own advanced wastewater treatment plants to treat harmful chemicals and pollutants before they enter the river. <p>River- related Activities</p> <ul style="list-style-type: none"> Forbid any activity related with the river for a year or more except activities that do not input anything into the river. (Let it wash out the chemicals naturally) A team that goes around at night to avoid illegal disposal of waste. <p>Governmental Offices</p> <ul style="list-style-type: none"> Ensuring the independence of bureaus such as 	<p>and other uses.</p> <p>Physical Polluters</p> <ul style="list-style-type: none"> Simple standing purifier from simple materials like rocks and pebbles and supply of packets of water treatment chemicals. <p>Chemical Polluters</p> <ul style="list-style-type: none"> Water treatment plants; one for drinking and one for washing River restoration projects 	<p>schools like Haile Manas Academy (HMA)</p> <ul style="list-style-type: none"> Partnerships with NGOs to monitor and clean up the river. Working with international organisations to secure funding for river restoration and pollution control programs.
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	<p>environmental protection bureaus.</p> <ul style="list-style-type: none"> ● Forming a committee composed of professionals from each government bureau we interviewed which is solely focused on Beresa river <p>Information related</p> <ul style="list-style-type: none"> ● Advocate for local governments to implement water quality monitoring stations along the river and to make pollution data publicly available. ● Awareness campaigns. ● Forming a team dedicated to working on testing the water frequently. ● Creating a research and qualified data collecting workforce to aid the government bureaus and stakeholders from our interview. 		
<p>Looking for other options :</p> <ul style="list-style-type: none"> ● Rainwater harvesting 			

Table 5*Summary of Most Impactful, Most Feasible, and Wildest Ideas*

Solution Approach	Key Features	Target Audience	Stakeholder Needs Addressed	Feasibility	Impact Potential
Community-Centric Integrated Water Resource Management Awareness Program	Community empowerment and participation	Local communities and government agencies	Improved water security and reduced disease risk	High	High
Construction of Small-Scale Wastewater Treatment Plants	Decentralized wastewater treatment technology implementation	Urban and rural communities and local government	Improved water quality, reduced health risks, enhanced sanitation	Medium-High	Medium-High
Bioremediation Using Indigenous Microorganisms	Innovative biological solution, scientific research	Government agencies, environmental scientists	Sustainable pollution reduction, reduced chemical reliance	Low	High (potential)