**Wastage of Water From Water Retention Structure**

## A PROJECT REPORT

***Submitted by,***

**RAHUL. K - 20211IST0006**

**GANESHA.C - 20211IST0011**

**METHAJI - 20191IST0051**

### *Under the guidance of,*

**Ms.Sunita.B.J.  
Assistant Professor**

***in partial fulfillment for the award of the degree of***

**BACHELOR OF TECHNOLOGY**

**IN**

**COMPUTER SCIENCE AND ENGINEERING, COMPUTER ENGINEERING, INFORMATION SCIENCE AND ENGINEERING Etc.**

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**PRESIDENCY UNIVERSITY**

**SCHOOL OF COMPUTER SCIENCE ENGINEERING**

**CERTIFICATE**

This is to certify that the Project report **“Wastage of Water From Water Retention Structure ”** being submitted by “K RAHUL ” , “GANESHA.C” , “METHAJI” bearing roll number(s) “20211IST0006”, “20211IST0011”, “20191IST0051” respectively in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in Computer Science and Engineering is a Bonafide work carried out under my supervision.

|  |  |
| --- | --- |
| **Mr.SHANMUGAMRATNAM**  Professor  School of CSE&IS  Presidency University | **Dr.PALLAVI**  HoD  School of CSE&IS  Presidency University |

|  |  |  |
| --- | --- | --- |
| **Dr. L. SHAKKEERA**  Associate Dean  School of CSE  Presidency University | **Dr. MYDHILI NAIR**  Associate Dean  School of CSE  Presidency University | **Dr. SAMEERUDDIN KHAN**  Pro-Vc School of Engineering  Dean -School of CSE&IS  Presidency University |

**PRESIDENCY UNIVERSITY**

**SCHOOL OF COMPUTER SCIENCE ENGINEERING**

**DECLARATION**

We hereby declare that the work, which is being presented in the project report entitled **Wastage of Water from Water Retention Structure** in partial fulfillment for the award of Degree of **Bachelor of Technology** in **Computer Science and Engineering**, is a record of our own investigations carried under the guidance of **MS.SUNITHA.B.J**

**Assistant Professor at** **School of Computer Science Engineering & Information Science, Presidency University, Bengaluru.**

We have not submitted the matter presented in this report anywhere for the award of any other Degree.

|  |  |
| --- | --- |
|  | **Name(s), Roll No(s) and Signature(s) of the Students** |

**ABSTRACT**

**Water retention structures such as dams, reservoirs, and tanks are critical for water conservation, agricultural irrigation, and urban water supply. However, inefficiencies and wastage within these systems pose significant challenges to sustainable water management. Key factors contributing to water loss include evaporation, seepage, overflow during heavy rainfall, poor maintenance, and operational mismanagement. Evaporation accounts for substantial water loss in arid and semi-arid regions, while seepage into the surrounding soil can lead to groundwater contamination or wasted resources if not harnessed.**

**Moreover, mismanagement of inflow and outflow often results in overflows that could otherwise be stored for future use. Mitigating these losses involves adopting measures like improving design with low-permeability materials, employing advanced techniques such as floating covers or shade structures to reduce evaporation, and implementing real-time monitoring and automated control systems. Addressing water wastage in retention structures is essential for ensuring water security, particularly in regions vulnerable to climate change and water scarcity.**

**Understanding and mitigating water wastage from retention structures is essential to ensuring the sustainable use of water resources, particularly in the context of climate change and growing water scarcity.**

**ACKNOWLEDGEMENT**

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**Name of the Student (1)**

**Name of the Student (2)**

**Name of the Student (3)**

**Name of the Student (4)**

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**CHAPTER-1**

**INTRODUCTION**

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**CHAPTER-2**

**LITERATURE SURVEY**

A literature survey on the wastage of water from water retention structures can be organized into key thematic areas. Below is a structured overview of relevant literature, methodologies, and findings regarding water wastage in such structures.

**1. Introduction to Water Retention Structures**

Water retention structures are hydraulic systems designed to store and manage water, such as dams, reservoirs, ponds, and cisterns. They play a critical role in water resource management, flood control, and irrigation.

**2. Types of Water Retention Structures**

**Dams:** Large barriers that block rivers to create reservoirs.

**Reservoirs:** Artificial lakes to store water for drinking, irrigation, and hydroelectric power.

**Retention Ponds:** Smaller structures designed for stormwater management and reducing runoff.

**Cisterns:** Underground tanks used to collect and store rainwater.

**3. Mechanisms of Water Wastage**

**Evaporation:** Significant losses occur due to evaporation, particularly in arid and semi-arid regions.

**Leakage:** Water can seep through cracks or porous materials in the structure.

**Overflows:** Excess water during heavy rainfall can lead to overflow, making the structure less efficient.

**Inadequate maintenance:** Poorly maintained structures can lead to increased expenditure and water loss.

**4. Factors Influencing Water Wastage**

**Climate:** Local weather conditions heavily influence evaporation rates. Studies by De Biase et al. (2020) show varying evaporation due to temperature and humidity conditions.

Design and Material: Different construction materials may have different permeability, affecting leakage. For instance, concrete structures often exhibit lower leakage than earthen dams (Rana et al., 2019).

Operational Management: Inefficient water release schedules and inadequate monitoring can exacerbate water loss (Zhang et al., 2021).

**5. Quantification of Water Wastage**

Research methods for quantifying water loss often include hydrological modeling, evaporation measurements using lysimeters, and remote sensing techniques (Patel et al., 2018).

Studies have reported that evaporation can account for up to 40% of total water stored in some arid region reservoirs (Kumar et al., 2017).

**6. Mitigation Strategies**

**Evaporation Control:** Techniques like surface covers, shading installations, and reducing reservoir surface area can significantly minimize evaporation losses (Bottcher & Beevers, 2020).

**Leakage Reduction:** Regular inspections and maintenance of structures can prevent long-term water losses (Nazaroff et al., 2019).

**Rainwater Harvesting Complementary Systems:** Integrating retention structures with rainwater harvesting systems can offset water wastage (Harvey et al., 2022).

**7. Case Studies**

**California Droughts:** A study on reservoirs in California indicated varying loss percentages, with specific attention paid to the impact of extended drought on management strategies (Smith et al., 2021).

**India's Water Management:** The Indian government's initiatives to reduce water wastage through improved dam management and rehabilitation of existing structures are documented in a report by the Ministry of Water Resources (2022).

**8. Conclusion**

The challenge of water wastage from retention structures is multifaceted and needs addressing through an integrated approach. Regular monitoring, innovative technologies, and improved management practices are critical for sustainable water resource management.

**9. Future Research Directions**

Development of smart technologies for real-time monitoring.

Impact assessments of climate change on evaporation rates.

Long-term studies on the effectiveness of different mitigation strategies.

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This structured survey provides a comprehensive overview of the current state of knowledge regarding water wastage in water retention structures and identifies key areas for future research and practical measures for mitigation. A literature survey on the wastage of water from water retention structures can be organized into key thematic areas. Below is a structured overview of relevant literature, methodologies, and findings regarding water wastage in such structures.

stormwater management and reducing runoff.

**CHAPTER-3**

**RESEARCH GAPS OF EXISTING METHODS**

When identifying research gaps in the context of water wastage from water retention structures (such as dams, reservoirs, ponds, and tanks), it’s crucial to evaluate the shortcomings or limitations of existing methods. Here's a synthesis of common gaps and challenges

**1. Measurement and Monitoring**

**Limited Real-Time Monitoring:**

Current systems often lack continuous, real-time monitoring of water wastage through evaporation, seepage, or overflow.

There is insufficient integration of IoT-based solutions and automated tools for tracking wastage dynamically.

**Inaccuracy of Data:**

Existing methods, such as manual measurements or outdated equipment, lead to inaccuracies in determining water loss.

**2. Understanding of Seepage**

**Insufficient Modeling Techniques:**

Current hydrological and geological models may oversimplify the complex seepage mechanisms in different soil and rock conditions.

**Lack of Context-Specific Data:**

Most studies use generalized data without accounting for site-specific variations like soil permeability, aquifer properties, or structural age.

**Inadequate Quantification:**

Limited ability to differentiate between beneficial seepage (which replenishes groundwater) and wastage.

**3. Evaporation Control**

**Ineffective Mitigation Strategies:**

Commonly used methods, such as floating covers or chemical coatings, are either cost-prohibitive, have environmental side effects, or are unsuitable for large-scale application.

**Neglect of Microclimatic Factors:**

Insufficient attention to the role of local weather patterns, vegetation, and land-use changes on evaporation rates.

**Technological Integration:**

Minimal use of advanced technologies, such as nanomaterials, to reduce evaporation.

**4.Structural Integrity**

**Aging Infrastructure:**

Many water retention structures are old, and existing methods lack effective solutions for addressing water loss through cracks or structural failures.

**Lack of Maintenance Optimization:**

There is limited research on predictive maintenance models using AI or machine learning to preemptively address water wastage.

**5. Policy and Management Frameworks**

**Limited Focus on Efficiency:**

Existing management policies often prioritize water storage over water conservation, leading to avoidable wastage.

**Lack of Community Involvement:**

Minimal integration of community-based participatory methods to identify and address wastage at a local level.

**6. Impact of Climate Change**

**Insufficient Climate Resilience:**

Current methods often fail to incorporate climate change projections into the design and operation of water retention structures.

**Rising Water Temperature:**

Few methods address the impact of increasing temperatures on evaporation rates.

**7.Economic and Environmental Trade-offs**

**High Costs of Advanced Methods:**

Innovative solutions such as geosynthetics, advanced coatings, or smart systems are often expensive and not scalable.

**Environmental Impacts of Mitigation Measures:**

Limited research on the ecological implications of water-saving technologies, such as the leaching of chemicals from coatings.

**8. Integration of Emerging Technologies**

**Underutilization of Remote Sensing and GIS:**

Few studies utilize satellite imagery and GIS tools to monitor wastage and develop efficient water retention strategies.

**Limited Use of Machine Learning and AI:**

Current methods rarely leverage AI to optimize water retention structure operations or predict water loss patterns**.**

**9.Research and Development Gaps**

**Insufficient Field Testing:**

Many laboratory-tested solutions fail to translate effectively to real-world applications.

**Knowledge Silos:**

A lack of interdisciplinary collaboration between hydrologists, engineers, environmental scientists, and policymakers.

**Recommendations for Future Research:**

**To address these gaps, researchers can focus on:**

1. Developing cost-effective and scalable water-saving technologies.

2. Enhancing monitoring systems with IoT and AI integration.

3. Conducting site-specific studies to refine models of seepage and evaporation.

4. Examining long-term impacts of climate change on water retention efficiency.

5. Promoting community engagement and capacity-building for sustainable water management**.**

**CHAPTER-4**

**PROPOSED MOTHODOLOGY**

To effectively address the issue of water wastage from water retention structures, a robust and interdisciplinary methodology can be proposed.

**Below is a comprehensive methodology encompassing various stages:**

**1. Problem Identification and Scoping**

**Objective:** Identify and quantify the primary sources of water wastage (e.g., evaporation, seepage, overflow).

**Activities:**

* Review historical data and case studies of water retention structures.
* Conduct stakeholder consultations to understand local challenges and priorities.

**2. Data Collection**

**Objective:** Gather detailed and accurate data to understand water loss patterns.

**Activities:**

**Field Surveys:**

* Measure seepage rates using piezometers or tracer techniques.
* Assess structural conditions (e.g., cracks, leaks) through visual inspection and non-destructive testing.

**Climatic Data:**

* Collect meteorological data (temperature, humidity, wind speed) affecting evaporation rates.
* Use weather station data or remote sensing for real-time monitoring.

**Hydrological Data:**

* Evaluate inflows, outflows, and storage capacity of the structure.
* Monitor groundwater recharge rates to account for beneficial seepage.

**3. Modeling and Analysis**

**Objective:** Develop models to simulate water loss mechanisms and identify critical areas of improvement.

**Activities:**

**Seepage Modeling:**

Use software such as MODFLOW or SEEP/W to simulate seepage behavior under various conditions.

**Evaporation Modeling:**

Develop evaporation models incorporating climatic, structural, and surface parameters.

**Risk Assessment:**

* Identify high-risk zones for water loss through GIS mapping.
* Predict future wastage scenarios considering climate change impacts.

**4. Development of Mitigation Strategies**

**Objective: Design and implement solutions to reduce water wastage.**

**Proposed Solutions:**

**Evaporation Control:**

* Use floating covers, reflective materials, or vegetation barriers around structures.
* Apply chemical suppressants or nanomaterial-based coatings to reduce water loss.

**Seepage Reduction:**

* Install geosynthetic liners or impermeable clay layers.
* Repair cracks and structural damage using advanced sealing materials.

**Overflow Management:**

Implement efficient overflow channels and rainwater harvesting mechanisms to minimize wastage.

**Integrated Technologies:**

Install IoT-based sensors for real-time monitoring of water levels and wastage rates.

Use drone-based inspections to identify hidden leaks or seepage zones.

**5. Validation and Optimization**

**Objective:** Evaluate the effectiveness of proposed strategies and refine methods.

**Activities:**

* Pilot implementation of selected mitigation measures on a small scale.
* Use performance metrics (e.g., reduction in water loss percentage, cost efficiency) to assess results.
* Optimize strategies based on pilot feedback and scalability considerations.

**6. Stakeholder Engagement and Capacity Building**

**Objective:** Ensure the success of mitigation measures through community and institutional involvement

**Activities:**

* Conduct workshops and training sessions for local operators and policymakers.
* Develop user-friendly dashboards and mobile applications for water management insights.
* Foster public-private partnerships to fund and support initiatives.

**7. Long-Term Monitoring and Adaptation**

**Objective:** Sustain improvements through continuous monitoring and adaptive management.

**Activities:**

* Deploy long-term monitoring systems integrated with AI/ML for predictive analytics.
* Update mitigation strategies based on new data and evolving environmental conditions.
* Regularly review policy frameworks to incorporate lessons learned and emerging technologies.

**Flowchart of Methodology**

**1.Problem Identification**

**↓**

**2. Data Collection**

**↓**

**3. Modeling and Analysis**

**↓**

**4. Mitigation Strategy Development**

**↓**

**5. Validation and Optimization**

**↓**

**6. Stakeholder Engagement**

**↓**

**7. Long-Term Monitoring**

This methodology provides a holistic approach to minimize water wastage from retention structures.

**CHAPTER-5**

**OBJECTIVES**

The objectives of studying and addressing the wastage of water from water retention structures can be framed as follows**:**

**Primary Objective**

1. **Quantify Water Losses**

Measure and analyze the extent of water wastage due to evaporation, seepage, and overflow in water retention structures.

1. **Identify Sources of Wastage**

Determine the primary factors contributing to water loss, such as structural inefficiencies, climatic influences, and management practices.

**3.Minimize Water Wastage**

Develop and implement cost-effective and sustainable solutions to reduce water loss while maintaining the functionality of the structures.

**Secondary Objectives**

1. **Enhance Structural Integrity**

Assess and improve the design, maintenance, and operational efficiency of water retention structures to prevent leakage and other forms of wastage.

**5.Improve Water Use Efficiency**

Optimize the storage and distribution of water to maximize its utility for agricultural, industrial, and domestic purposes.

**6. Promote Sustainable Management**

Integrate advanced technologies and innovative practices into the management of water retention systems to ensure long-term sustainability.

**Research and Development Objectives**

**7. Develop Advanced Monitoring Systems**

Design real-time monitoring tools, such as IoT-enabled sensors and satellite-based systems, for accurate tracking of water levels and losses.

**8. Model Water Loss Mechanisms**

Build predictive models to simulate water loss under various environmental and operational scenarios, aiding proactive management.

**9. Innovate Mitigation Strategies**

Explore and test novel materials, coatings, or techniques to control seepage and evaporation.

**Environmental and Social Objectives**

**10. Promote Groundwater Recharge**

Investigate the balance between seepage wastage and groundwater replenishment to ensure environmental benefits are retained.

**11. Engage Communities**

Raise awareness and involve local stakeholders in the maintenance and monitoring of water retention structures.

**12. Adapt to Climate Change**

Address the impacts of changing weather patterns on water loss and improve resilience against climate variability.

**Policy and Governance Objectives**

**13. Strengthen Policy Frameworks**

Develop and implement regulations to minimize water wastage and incentivize efficient practices.

**14. Foster Interdisciplinary Collaboration**

Encourage cooperation among engineers, hydrologists, environmental scientists, and policymakers for comprehensive solutions.

**CHAPTER-6**

**SYSTEM DESIGN & IMPLEMENTATION**

Designing and implementing a system to address the wastage of water from water retention structures requires a comprehensive approach.

**System Design**

**1. System Goals**

* Minimize water wastage from retention structures (evaporation, seepage, overflow).
* Enhance operational efficiency and sustainability.
* Provide real-time data for informed decision-making.

**2. Core Components**

**a. Monitoring and Data Collection Subsystem**

**Sensors and Devices:**

* **Water Level Sensors:** Measure water levels and detect anomalies.
* **Soil Moisture Sensors:** Monitor seepage into surrounding areas.
* **Weather Stations:** Collect climatic data like temperature, humidity, and wind speed for evaporation analysis.
* **Flow Meters:** Track inflow and outflow rates to identify losses.
* **Remote Sensing Tools :** Use satellite or drone-based imagery to monitor large structures for leaks, cracks, and water spread.

**b. Analytical Subsystem**

**Data Storage and Processing:**

* Cloud-based systems to store and process collected data.
* Integration with Geographic Information Systems (GIS) for spatial analysis.

**Modeling and Simulation:**

* Hydrological and evaporation models to predict water loss under different scenarios.
* AI/ML models for predictive analysis and trend forecasting.

**c. Mitigation and Control Subsystem**

**Evaporation Mitigation:**

Use of floating covers, reflective materials, or chemical suppressants.

**Seepage Control:**

* Application of geosynthetic liners or advanced impermeable coatings.
* Structural repairs to address cracks and leaks.

**Overflow Management:**

Install efficient spillways and water harvesting systems.

**d. Decision Support and User Interface Subsystem**

**Dashboards:**

Provide real-time updates and historical trends for operators and managers.

**Mobile Apps:**

Enable remote monitoring and alerts for critical conditions.

**Decision Support Tools:**

Recommend actions based on predictive analytics (e.g., when to apply mitigation measures).

**3. System Architecture**

**1. Data Layer:**

Sensors and remote devices collect data on water loss, structural health, and climatic conditions.

**2. Processing Layer:**

* Data is transmitted to a central server or cloud platform.
* AI/ML algorithms analyze the data for actionable insights.

**3. User Layer:**

Stakeholders access the processed information via dashboards, mobile apps, or notifications.

**Implementation Plan**

**1. Site Assessment**

* Conduct a detailed survey of the water retention structure to identify key issues and requirements.
* Map seepage-prone zones and evaporation hotspots using field observations and GIS tools.

**2. Technology Deployment**

* Install monitoring devices, sensors, and remote sensing tools.
* Set up the communication infrastructure for transmitting data (e.g., wireless networks or satellite links).

**3. Pilot Testing**

* Test the system on a small scale to validate functionality and effectiveness.
* Evaluate the performance of mitigation strategies (e.g., floating covers, geosynthetics).

**4. Full-Scale Implementation**

* Deploy the system across the entire water retention structure.
* Train operators and stakeholders in using the system and interpreting data.

**5. Monitoring and Feedback**

* Continuously monitor the system's performance and water loss metrics.
* Collect feedback from users to refine the system and address unforeseen challenges.

**Key Considerations**

**Scalability:**

Ensure the system can be expanded to larger structures or additional sites.

**Cost-Effectiveness:**

Prioritize cost-efficient technologies, particularly for low-resource regions.

**Environmental Impact:**

Assess and mitigate potential negative effects of interventions, such as chemical leaching.

**Integration with Existing Infrastructure:**

Ensure compatibility with existing water management systems.

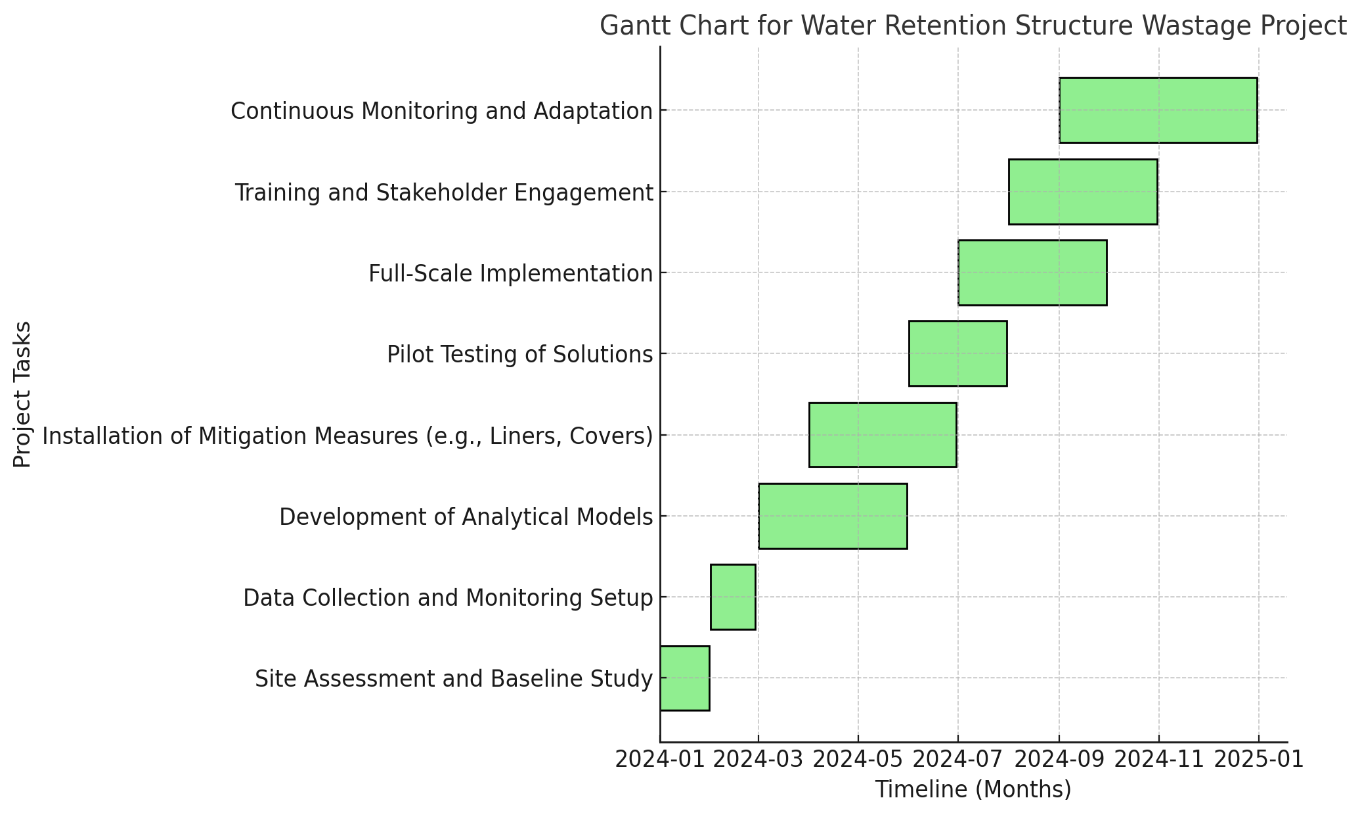
**Outcome Expectations**

* Reduction in water wastage by controlling evaporation, seepage, and overflow.
* Enhanced decision-making through real-time data and predictive analytics.
* Prolonged structural lifespan through improved maintenance and early detection of issues.
* Sustainable water management practices benefiting communities and ecosystems.

**CHAPTER-7**

**TIMELINE FOR EXECUTION OF PROJECT**

**(GANTT CHART)**

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**Site Assessment and Baseline Study**

A site assessment and baseline study are critical to understanding the existing conditions and identifying factors contributing to water wastage in water retention structures. Below is a detailed plan for conducting this phase:

**1. Objectives of the Site Assessment and Baseline Study**

* Quantify water losses due to seepage, evaporation, overflow, or structural issues.
* Identify sources of wastage, including environmental, structural, and operational factors.
* Establish a baseline dataset for monitoring and comparison after mitigation measures are implemented.
* Provide actionable insights for designing and implementing effective solutions.

**2. Key Activities in the Site Assessment**

Physical Inspection of the Structure

**Scope:**

Inspect the physical integrity of the water retention structure, including walls, spillways, and embankments.

Identify visible signs of cracks, leaks, or erosion that may contribute to water wastage.

**Tools and Techniques:**

* Visual inspection using checklists.
* Non-destructive testing (e.g., ground-penetrating radar, ultrasonic testing) for internal damages.

**3. Data Collection Plan**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  | | --- | --- | --- | --- | | Category | Parameter | Method | Frequency | | Hydrological Data | Inflow/Outflow rates | Flow meters, historical data | Daily | | Structural Integrity | Cracks, leaks | Visual inspection, radar testing | |  | | --- | | Once per site |  |  | | --- | |  | | | Seepage | Pore pressure, flow paths | Piezometers, dye tests | Weekly | | |  | | --- | | Climatic Data |  |  | | --- | |  | | Temperature, humidity | Meteorological sensors | Daily | | Soil and Geological Data | Permeability, stability | Lab analysis, field tests | |  | | --- | |  |  |  | | --- | | Once per site | | |

**4. Stakeholder Involvement**

**Collaborate with:**

* Local operators to understand historical issues and maintenance records.
* Communities relying on the structure to identify impacts of water wastage.
* Regulatory bodies for compliance and permissions.

**5. Deliverables of the Baseline Study**

**1.Baseline Report:**

* Detailed findings on water loss sources (seepage, evaporation, overflow).
* Quantified water loss data.
* Structural and operational insights.

**2. GIS Maps and Models:**

Maps showing seepage-prone zones, high evaporation areas, and structural risks.

**3. Recommendations for Mitigation:**

Initial suggestions for addressing identified issues.

**Data Collection and Monitoring Setup**

The data collection and monitoring setup is essential for quantifying water wastage, understanding its causes, and tracking the effectiveness of mitigation measures.

**Below is a structured plan for this phase:**

**1.Objectives of Data Collection and Monitoring**

* Accurately measure water losses (seepage, evaporation, overflow).
* Identify critical factors contributing to wastage.
* Provide continuous and real-time data for decision-making.
* Establish a baseline for assessing the impact of interventions.

**2. Key Parameters for Monitoring**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| |  | | --- | | **Category** |  |  | | --- | |  | | **Parameters** | **Purpose** |
| Water Dynamics | |  | | --- | | Inflow, outflow, storage levels |  |  | | --- | |  | | |  | | --- | | To understand water balance and loss patterns**.** |  |  | | --- | |  | |
| Seepage | |  | | --- | | Pore pressure, flow rates |  |  | | --- | |  | | |  | | --- | | To assess seepage losses and pathways. |  |  | | --- | |  | |
| Evaporation | |  | | --- | | Surface temperature, wind speed |  |  | | --- | |  | | |  | | --- | | To estimate water loss due to evaporation. |  |  | | --- | |  | |
| |  | | --- | | Climatic Conditions | | |  | | --- | | Temperature, humidity, rainfall |  |  | | --- | |  | | |  | | --- | | To link weather patterns with water wastage**.** |  |  | | --- | |  | |
| |  | | --- | | Structural Integrity |  |  | | --- | |  | | |  | | --- | | Crack size, leakage points |  |  | | --- | |  | | To identify structural water loss issues. |

**3. Monitoring Tools and Technologies**

**a. Water Level Monitoring**

* Devices: Ultrasonic water level sensors or float-operated gauges.
* Purpose: Track storage levels and detect anomalies.
* Integration: IoT-enabled devices for real-time updates.

**b. Flow Monitoring**

* Devices: Electromagnetic or ultrasonic flow meters.
* Purpose: Measure inflow and outflow rates to calculate water loss.

**c. Seepage Monitoring**

* Devices:
  + Piezometers for measuring pore water pressure.
  + Tracer dye tests to map seepage pathways.
* Purpose: Quantify seepage rates and identify leakage zones.

**d. Evaporation Measurement**

* Devices:
  + Class A evaporation pans.
  + Weather stations with sensors for temperature, wind speed, and humidity.
* Purpose: Calculate evaporation losses based on climatic data.

**e. Structural Integrity Monitoring**

* Tools:
  + Ground-penetrating radar (GPR) for subsurface inspection.
  + Crack-width meters or strain gauges for detecting structural issues.
* Purpose: Identify and monitor physical damage leading to water loss.

**f. Weather Monitoring**

* Devices: Automatic weather stations (AWS).
* Parameters: Temperature, wind speed, solar radiation, rainfall.
* Purpose: Understand external factors influencing water wastage.

**4. Monitoring Setup Design**

**a. Data Acquisition System**

* Centralized system for collecting data from sensors and monitoring tools.
* Use wireless networks (e.g., LoRa, Zigbee) or satellite links for remote locations.

**b. Real-Time Monitoring**

* **IoT Integration:** Connect sensors to cloud platforms for real-time data analysis.
* **Dashboards:**
  + Interactive user interface displaying key metrics (water levels, seepage rates, etc.).
  + Alerts and notifications for critical conditions (e.g., sudden leakage).

**c. Data Storage**

* Cloud-based or on-premise data storage for historical and real-time data.
* Ensure data redundancy and security.

**d. Analysis Tools**

* Use software like MATLAB, Python, or specialized hydrological tools for data analysis.
* GIS integration for spatial analysis of water loss zones.

**5. Implementation Steps**

**Step 1: Site Survey and Sensor Placement**

* Identify strategic points for sensor installation (e.g., inflow/outflow points, seepage-prone zones).
* Ensure coverage of all critical areas, including high-risk evaporation and seepage zones.

**Step 2: Equipment Installation**

* Install sensors and monitoring devices.
* Calibrate instruments for accurate readings.

**Step 3: System Integration**

* Connect sensors to the central data acquisition system.
* Configure IoT devices for automated data transmission.

**Step 4: Testing and Validation**

* Test the system under different conditions to ensure reliability.
* Compare sensor data with manual measurements for validation**.**

**Step 5: Operationalization**

* Launch real-time monitoring with periodic reviews of collected data.
* Train local operators to manage the system effectively.

**6. Data Collection Schedule**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | |  | | --- | | **Frequency** |  |  | | --- | |  | | | **Method** | | --- |  |  | | --- | |  | |
| Water Levels | Real-time/Hourly | |  | | --- | | Ultrasonic sensors |  |  | | --- | |  | |
| |  | | --- | | Inflow/Outflow Rates |  |  | | --- | |  | | |  | | --- | | Real-time/Daily |  |  | | --- | |  | | |  | | --- | | Flow meters |  |  | | --- | |  | |
| |  | | --- | | Seepage Data |  |  | | --- | |  | | |  | | --- | | Weekly/Monthly |  |  | | --- | |  | | |  | | --- | | Piezometers, tracer tests |  |  | | --- | |  | |
| |  | | --- | | Climatic Data |  |  | | --- | |  | | |  | | --- | | Hourly/Daily |  |  | | --- | |  | | Automatic weather stations |
| |  | | --- | | Structural Integrity |  |  | | --- | |  | | |  | | --- | | Monthly/On-demand |  |  | | --- | |  | | GPR, crack meters |

**Expected Outputs**

* **Baseline Dataset:** Comprehensive data on water wastage.
* **Real-Time Insights:** Immediate alerts for abnormal conditions.
* **Water Loss Analysis:** Detailed reports on seepage, evaporation, and overflow.

**8. Budget Considerations**

* **Monitoring Devices:** Sensors, meters, weather stations.
* **Installation Costs:** Sensor placement and calibration.
* **Software and Cloud Services:** Data storage and analysis platforms.
* **Training:** Capacity building for local operators.

**Development of Analytical Models**

Developing analytical models helps quantify, predict, and mitigate water wastage from water retention structures. These models integrate field data, environmental factors, and structural dynamics to provide actionable insights.

**1. Objectives of Analytical Models**

* Quantify water wastage due to seepage, evaporation, and overflow.
* Predict future water loss under varying climatic and operational conditions.
* Optimize mitigation strategies by simulating different scenarios.
* Support decision-making through real-time insights and trend analysis.

**2. Key Components of Analytical Models**

**a. Inputs**

1. **Hydrological Data**:
   * Inflow, outflow, and storage levels.
2. **Climatic Data**:
   * Temperature, wind speed, solar radiation, and humidity.
3. **Structural Data**:
   * Leakage points, seepage rates, and material properties.
4. **Geological Data**:
   * Soil permeability and groundwater interaction.
5. **Operational Data**:
   * Water release schedules and spillway operations.

**b. Processes**

* Data cleaning and preprocessing to remove noise and inconsistencies.
* Mathematical and computational modelling of water loss mechanisms.

**c. Outputs**

* Quantification of water losses.
* Identification of high-risk zones and factors contributing to wastage.
* Predictive trends for water levels and losses over time.

**3. Types of Analytical Models**

**a. Seepage Models**

* **Purpose**: Quantify and simulate water loss due to seepage.
* **Tools**:
  + **Empirical Models**: Darcy’s law for flow through porous media.
  + **Numerical Models**: Use tools like SEEP/W or MODFLOW to simulate seepage pathways and rates.
* **Outputs**:
  + Seepage volume.
  + Identification of leakage hotspots.

**b. Evaporation Models**

* **Purpose**: Estimate water loss from the surface due to climatic factors.
* **Tools**:
  + **Empirical Formulas**:
    - Penman-Monteith equation.
    - Hargreaves-Samani model.
  + **Data Requirements**:
    - Solar radiation, temperature, humidity, and wind speed.
* **Outputs**:
  + Evaporation loss as a function of climatic parameters.

**c. Water Balance Models**

* **Purpose**: Assess overall water loss and storage efficiency.
* **Equation**: ΔS=I−O−E−S\Delta S = I - O - E - SΔS=I−O−E−S Where:
  + ΔS\Delta SΔS: Change in storage.
  + III: Inflow.
  + OOO: Outflow.
  + EEE: Evaporation loss.
  + SSS: Seepage loss.
* **Outputs**:
  + Net water loss.
  + Efficiency of water retention.

**d. Predictive Models**

* **Purpose**: Forecast water loss under future scenarios.
* **Tools**:
  + Machine Learning Algorithms:
    - Regression models for continuous predictions.
    - Time series models like ARIMA or LSTM for trend analysis.
  + Scenario analysis using historical data and simulations.
* **Outputs**:
  + Predicted water levels and losses.

**4. Framework for Model Development**

**Step 1: Data Collection and Preprocessing**

* Gather input data from monitoring systems, field surveys, and historical records.
* Clean data to remove outliers and missing values.

**Step 2: Model Selection**

* Choose models based on the type of water loss:
  + Empirical models for quick assessments.
  + Numerical models for detailed simulations.
  + Machine learning models for dynamic and complex predictions.

**Step 3: Model Calibration and Validation**

* **Calibration**:
  + Adjust model parameters to align with observed data.
* **Validation**:
  + Compare model outputs with field measurements to ensure accuracy.

**Step 4: Simulation and Analysis**

* Run simulations under different scenarios, such as extreme weather or structural failures.
* Analyse results to identify critical factors and optimize mitigation measures.

**Step 5: Integration with Monitoring Systems**

* Link models to real-time data streams for automated analysis and reporting.
* Use dashboards to visualize model outputs.

**5. Tools and Technologies**

* **Modelling Software**:
  + SEEP/W, MODFLOW, and HEC-HMS for hydrological simulations.
  + Python and MATLAB for custom model development.
* **Data Analysis Tools**:
  + Excel for simple calculations.
  + R and Python for advanced statistical analysis.
* **GIS Tools**:
  + ArcGIS or QGIS for spatial analysis and visualization.

**6. Outputs and Applications**

* **Quantitative Results**:
  + Volume of water wasted due to seepage and evaporation.
  + Seasonal and annual wastage trends.
* **Visualizations**:
  + Heatmaps of seepage zones.
  + Temporal graphs of water levels and losses.
* **Decision Support**:
  + Recommendations for mitigation measures.
  + Insights for improving structural and operational efficiency.

**7. Challenges and Mitigation**

|  |  |
| --- | --- |
| **Challenge** | **Mitigation** |
| Data gaps or inaccuracies | Use interpolation techniques and robust sensors. |
| Complexity in seepage pathways | Use high-resolution numerical models. |
| Uncertainty in climatic predictions | Incorporate multiple climate scenarios. |

**Installation of Mitigation Measures**

Mitigation measures aim to reduce water wastage through seepage, evaporation, and overflow in water retention structures. Proper installation of these measures ensures improved efficiency, sustainability, and long-term functionality.

**1. Objectives of Mitigation Measures**

* Minimize water loss from the structure.
* Enhance the structure's integrity and operational efficiency.
* Reduce environmental and operational costs associated with water loss.

**2. Key Mitigation Measures**

**a. Seepage Control**

1. **Geomembranes and Liners:**
   * Materials: HDPE (High-Density Polyethylene), PVC, or clay liners.
   * **Installation Steps:**
     + Excavate the base and sides of the structure.
     + Level and smoothen the surface.
     + Lay geomembranes, ensuring no gaps or folds.
     + Seal edges using heat welding or adhesives.
   * **Benefits:**
     + Provides a barrier against seepage.
     + Durable and resistant to environmental degradation.
2. **Grouting:**
   * Purpose: Seal cracks and fill voids in porous foundations or walls.
   * Materials: Cement, chemical grouts, or bentonite.
   * **Installation Steps:**
     + Drill injection holes at identified seepage points.
     + Inject grout using pressure pumps.
     + Allow curing time to achieve full sealing.
   * **Benefits:**
     + Strengthens the structure.
     + Reduces seepage significantly.
3. **Cutoff Walls:**
   * **Purpose:** Prevent seepage under the structure.
   * **Materials:** Concrete, steel, or bentonite slurry**.**
   * **Installation Steps:**
     + Excavate trenches along seepage pathways.
     + Fill with impermeable materials like bentonite or concrete.
   * **Benefits:**
     + Blocks subsurface water movement.
     + Long-lasting solution for seepage.

**b. Evaporation Reduction**

1. **Floating Covers:**
   * Materials: UV-stabilized polyethylene or polypropylene covers.
   * **Installation Steps:**
     + Lay modular floating covers on the water surface.
     + Secure edges to prevent displacement.
   * **Benefits:**
     + Reduces direct exposure to sunlight.
     + Prevents contamination.
2. **Windbreaks:**
   * Materials: Trees, shrubs, or artificial barriers.
   * **Installation Steps:**
     + Plant or construct windbreaks around the structure.
     + Ensure adequate height and density for wind reduction.
   * **Benefits:**
     + Reduces evaporation caused by wind.
     + Improves microclimatic conditions.
3. **Chemical Evaporation Suppressants:**
   * **Materials:** Biodegradable monolayer films (e.g., cetyl alcohol).
   * **Installation Steps:**
     + Apply suppressants on the water surface using spray systems.
     + Monitor and reapply periodically.
   * **Benefits:**
     + Forms a thin film that reduces water-air contact.
     + Cost-effective for small-scale applications.

**c. Overflow Management**

1. **Spillway Redesign:**
   * **Purpose:** Ensure controlled water discharge during heavy inflow.
   * **Installation Steps:**
     + Remove existing inadequate spillways.
     + Design and construct wider or stepped spillways.
   * **Benefits:**
     + Prevents overflow and associated wastage.
     + Reduces erosion risks.
2. **Automation of Discharge Systems:**
   * **Technology:** Automated gates or valves with sensor-based controls.
   * **Installation Steps:**
     + Install sensors for water level monitoring.
     + Integrate with gates or valves for automatic operation.
   * **Benefits:**
     + Optimizes water release.
     + Reduces manual intervention and wastage.

**3. Implementation Process**

**Step 1: Site Preparation**

* **Tasks:**
  + Clear vegetation and debris from installation areas.
  + Conduct site levelling and stabilization.
* **Tools:** Excavators, bulldozers, levelling instruments.

**Step 2: Installation**

* **Tasks:**
  + Follow manufacturer specifications for material placement and sealing.
  + Monitor installation to ensure proper alignment and fit.
* **Tools:** Welding machines, pumps, cranes (for heavy materials).

**Step 3: Quality Assurance**

* **Tasks:**
  + Test materials for leaks and structural integrity.
  + Conduct post-installation inspections using visual and non-destructive methods.
* Tools: Pressure gauges, dye tests, and thermal imaging cameras**.**

**Step 4: Commissioning**

* **Tasks:**
  + Test the structure under operational conditions.
  + Address any installation defects immediately.
* **Tools:** Flow meters, water level sensors.

**4. Maintenance Plan**

* Regular inspection of liners, covers, and spillways.
* Periodic reapplication of chemical suppressants.
* Clearing sediment and debris from spillways and grouting zones.
* Calibration and testing of automated systems.

**5. Benefits of Mitigation Measures**

* **Cost Efficiency:** Reduced water loss lowers operational costs.
* **Sustainability:** Optimized water use supports long-term resource management.
* **Environmental Protection:** Minimizes soil erosion and groundwater contamination.

**6. Challenges and Solutions**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| |  | | --- | | **Challenge** |  |  | | --- | |  | | | **Solution** | | --- |  |  | | --- | |  | |
| |  | | --- | | High initial installation costs |  |  | | --- | |  | | |  | | --- | | opt for cost-effective materials and phased implementation. |  |  | | --- | |  | |
| |  | | --- | | Technical expertise required |  |  | | --- | |  | | |  | | --- | | Train local personnel or hire skilled contractors. |  |  | | --- | |  | |
| |  | | --- | | Material degradation over time |  |  | | --- | |  | | Use high-quality, UV-resistant, and durable materials. |

**Pilot testing of solution:**

Pilot testing a solution to address water wastage from a water retention structure typically involves small-scale, controlled experiments to evaluate the effectiveness of proposed interventions.

**Below is a general outline for pilot testing such a solution:**

**1. Define the Objective and Scope**

* **Objective:** To reduce or prevent water wastage from a retention structure (e.g., reservoir, dam, tank, or pond).
* **Scope:** Specify the water retention structure to be tested, and what constitutes wastage (e.g., overflow, evaporation, leaks, inefficient distribution).

**2. Identify the Causes of Water Wastage**

**Analyse potential causes of wastage, which could include:**

* **Overflow:** Excess water spilling over the top due to insufficient storage capacity or lack of proper outlets.
* **Evaporation:** High water evaporation rates due to climatic conditions**.**
* **Leaks:** Uncontrolled seepage through the structure or piping**.**
* **Inefficient Distribution:** Poor management of water distribution to surrounding areas.

**3. Propose Solutions**

**Identify and propose one or more solutions to address the identified causes of wastage:**

* **Overflow Management:** Installation of overflow channels or controlled release systems.
* **Evaporation Reduction:** Use of covers, shading, or evaporation-reducing chemicals.
* **Leak Prevention:** Sealing cracks, using better materials, or reinforcing the structure.
* **Efficient Distribution:** Improving water distribution systems with automated controls, pressure regulators, or sensors to minimize wastage.

**4. Design the Pilot Test**

* **Scale:** Implement the solution on a small section or subset of the water retention structure.
* **Duration:** Specify the length of the pilot test (e.g., several weeks or months) to ensure that all environmental and operational variables are accounted for.
* **Variables:** Identify and monitor key parameters such as:
  + Water level and inflow/outflow rates.
  + Evaporation rates (especially in hot, dry conditions).
  + Water quality (e.g., turbidity, contaminants).
  + Efficiency of distribution systems.
* **Control Group:** Compare the pilot solution area with a control area that has no intervention, if possible.

**5. Implementation of the Pilot Solution**

* Implement the proposed solutions in the selected pilot section(s) of the structure.
* Ensure that all monitoring equipment (e.g., sensors for water level, flow rates, and temperature) is set up to collect accurate data.

**6. Monitor and Collect Data**

* **Continuously monitor key metrics such as:**
  + Water levels in different parts of the structure.
  + Flow rates entering and exiting the system.
  + Weather conditions (which can impact evaporation).
  + Occurrences of overflow or leakage.
* Collect qualitative data (e.g., observations on changes in water behaviour or structure integrity).

**7. Evaluate the Results**

**After the pilot test period, analyse the collected data:**

* Compare Pre- and Post-Test Data: Evaluate the reduction in wastage based on the proposed solution.
* Assess Effectiveness: Determine whether the pilot solution has successfully reduced water wastage.
* Identify Issues: Look for any unforeseen issues, like new leaks or unexpected environmental impacts.

**8. Refine the Solution**

* Based on pilot test results, make necessary adjustments to the solution to improve its performance.
* If successful, consider scaling up the solution to other parts of the structure or to other similar structures.

**9. Documentation and Reporting**

* Document all processes, observations, results, and lessons learned.
* Prepare a detailed report outlining the test methods, outcomes, and recommendations for full-scale implementation.

**10. Scale-Up (if successful)**

**If the pilot testing shows positive results:**

* Plan for wider implementation across the entire water retention system.
* Continue monitoring to ensure long-term effectiveness and sustainability.

**Full-Scale Implementation Plan**

Once pilot testing has been completed and the solution is deemed effective, the next step is full-scale implementation.

**Below is a detailed plan for full-scale deployment:**

**1. Define Goals and Objectives**

* **Goal:** Eliminate or significantly reduce water wastage from the water retention structure**.**
* **Objectives:**
  + Implement the solution across the entire structure.
  + Ensure long-term sustainability of the solution.
  + Monitor and evaluate effectiveness in real-time.

**2. Assess and Plan the Implementation**

* **Evaluate Lessons from Pilot Testing:**
  + Identify successful aspects and challenges from the pilot phase.
  + Adapt the solution to address potential issues that may arise during scaling.
* **Conduct a Comprehensive Assessment:**
  + Inspect the structure for areas with the highest wastage potential (e.g., leaks, overflow points).
  + Analyse environmental and operational factors, including water demand, climate, and soil type.
* **Develop a Detailed Implementation Plan:**
  + Create timelines, milestones, and budgets for deployment.
  + Assign roles and responsibilities to project teams.

**3. Infrastructure Preparation**

* **Repairs and Reinforcements:**
  + Seal leaks or reinforce weak areas identified during the assessment.
  + Improve or replace outdated components, such as valves, gates, or outlet channels.
* **Upgrade Technology:**
  + Install real-time monitoring equipment (e.g., flow meters, water level sensors, weather monitoring stations).
  + Use automation for controlling water release and distribution.
* **Evaporation Control Measures:**
  + Install floating covers, shade nets, or chemical films to reduce evaporation if applicable.

**4. Implement the Solution**

**Based on Identified Causes of Wastage:**

* **Overflow Management:**
  + Construct or upgrade overflow channels.
  + Install automated spillway gates or overflow alarms.
* **Leak Prevention:**
  + Use impermeable linings such as geomembranes or concrete to reduce seepage.
  + Monitor and repair cracks or weaknesses periodically.
* **Evaporation Reduction:**
  + Plant vegetation around the structure to create a microclimate that reduces heat.
  + Use floating solar panels to both reduce evaporation and generate renewable energy.
* **Efficient Distribution:**
  + Upgrade irrigation or distribution systems to minimize losses during water transport.
  + Use drip or sprinkler irrigation for agricultural applications to optimize water usage.

**5. Operational Management**

* Establish a Water Management Plan:
  + Define protocols for water storage, release, and distribution to meet demand efficiently.
* **Train Staff:**
  + Educate maintenance teams on the new systems and technologies.
  + Provide operational training on monitoring equipment and automated controls.
* **Community Engagement:**
  + Involve local stakeholders (e.g., farmers, industries, and residents) in the management process.
  + Conduct awareness campaigns to promote efficient water use and conservation.

**6. Monitoring and Feedback Mechanisms**

* **Install Monitoring Systems:**
  + Set up IoT-enabled devices to track water levels, flow rates, evaporation, and leak detection.
* **Establish Key Performance Indicators (KPIs):**
  + Measure reduction in water wastage (e.g., reduced overflow events, leakage volume).
  + Monitor water quality and availability for intended uses.
* **Regular Inspections:**
  + Schedule periodic inspections to ensure the system is functioning as intended.
  + Address maintenance needs promptly.

**7. Evaluate and Optimize**

* **Regular Data Analysis:**
  + Analyse real-time data to identify trends or emerging issues.
  + Optimize system performance based on insights.
* **Incorporate Feedback:**
  + Gather input from end-users and stakeholders to address practical concerns.
  + Update infrastructure or management practices as needed.

**8. Scale to Other Structures (If Applicable)**

* **Replication Plan:**
  + Use learnings and best practices to implement the solution in other water retention structures within the region.
* **Standardization:**
  + Develop standardized procedures and templates for easier replication.

**9. Document and Report**

* **Maintain comprehensive records of the implementation process, including:**
  + Design changes made during scaling.
  + Costs and resources used.
  + Challenges encountered and how they were resolved.
* Prepare reports for stakeholders, funders, and policymakers to highlight the impact and scalability of the project.

**10. Long-Term Sustainability**

* **Policy Integration:**
  + Work with local governments to establish regulations or incentives for sustainable water management.
* **Periodic Review:**
  + Reassess the structure and water management practices every few years to adapt to changing conditions.
* **Community Involvement:**
  + Create local water management committees to oversee ongoing operations and promote community ownership.

**Training and Stakeholder Engagement Plan**

Training and engaging stakeholders is crucial for the success and sustainability of efforts to reduce water wastage in water retention structures. Below is a detailed plan to ensure all relevant parties are equipped and aligned with the objectives.

**1. Identify Key Stakeholders**

* **Government and Regulatory Authorities:**
  + Local water resource departments, environmental agencies, and municipal bodies.
* **Community Members:**
  + Farmers, local residents, and industries relying on the water supply.
* **Project Teams:**
  + Engineers, technicians, and maintenance staff managing the structure.
* **Environmental and Civil Society Groups:**
  + NGOs, advocacy groups, and academic institutions interested in water conservation.
* **Technology Providers:**
  + Vendors supplying monitoring systems, automation equipment, or sealing materials.

**2. Develop a Training Program**

**a. Training Objectives**

* Build capacity to understand water wastage issues.
* Teach participants to implement and maintain the solutions.
* Encourage best practices for efficient water use.

**b. Training Modules**

1. **Understanding Water Wastage:**
   * Causes of wastage in retention structures (e.g., evaporation, leaks, overflow).
   * Environmental and economic impacts of water wastage**.**
2. **Technical Skills:**
   * Installation and maintenance of monitoring equipment (e.g., water sensors, flow meters).
   * Techniques for sealing leaks, applying linings, or constructing overflow channels.
   * Operation of automated water control systems.
3. **Water Management Best Practices:**
   * Efficient distribution methods (e.g., drip irrigation).
   * Conservation techniques for end-users.
4. **Monitoring and Reporting:**
   * Use of data for decision-making.
   * Real-time monitoring tools and troubleshooting common issues.

**c. Training Methods**

* **Workshops and Seminars:**
  + Interactive sessions with experts, including hands-on training.
* **On-Site Demonstrations:**
  + Practical demonstrations at the water retention structure.
* **Digital Training Tools:**
  + Online modules, videos, and manuals for remote learning.
* **Collaborative Exercises:**
  + Role-playing and simulation exercises for emergency responses (e.g., leak detection, overflow scenarios).

**d. Target Audience and Customization**

* **Technicians and Engineers:**
  + Focus on technical aspects of the solution.
* **Community Members:**
  + Emphasize water conservation practices and shared responsibility.
* **Regulators and Policymakers:**
  + Highlight the importance of governance and enforcement.

**3. Stakeholder Engagement Strategy**

**a. Objectives**

* Build awareness about the importance of water conservation.
* Foster a sense of ownership and responsibility among stakeholders.
* Ensure cooperation and alignment with project goals.

**b. Engagement Activities**

1. **Awareness Campaigns:**
   * Organize community events, informational sessions, and exhibitions.
   * Distribute educational materials like brochures, posters, and videos.
2. **Workshops for Decision-Makers:**
   * Engage policymakers to ensure regulatory support and funding.
3. **Collaborative Planning:**
   * Involve stakeholders in decision-making processes to incorporate diverse perspectives.
4. **Feedback Mechanisms:**
   * Set up platforms for stakeholders to provide input (e.g., town hall meetings, surveys).
5. **Community Committees:**
   * Form water management committees with representatives from key stakeholder groups.
6. **Demonstration Projects:**
   * Showcase successful pilot projects to build confidence and trust in the solution.

**4. Communication Plan**

* **Regular Updates:**
  + Share progress reports, success stories, and milestones with stakeholders through newsletters, social media, and meetings.
* **Transparency:**
  + Provide open access to data collected from monitoring systems to build trust.
* **Language and Accessibility:**
  + Ensure communication materials are available in local languages and are easy to understand.

**5. Monitoring and Evaluation of Training and Engagement**

* **Feedback Collection:**
  + Use surveys, interviews, and focus groups to assess the effectiveness of training programs.
* **Performance Metrics:**
  + Measure improvements in stakeholders’ knowledge and skills.
  + Track changes in water wastage before and after implementation.
* **Adjustments:**
  + Modify training and engagement activities based on feedback and outcomes.

**6. Long-Term Engagement**

* **Periodic Refresher Training:**
  + Schedule follow-up training sessions to keep skills up to date.
* **Stakeholder Recognition:**
  + Acknowledge and reward individuals or groups contributing to water conservation.
* **Ongoing Collaboration:**
  + Maintain regular interactions through forums, workshops, and collaborative projects.

This plan ensures all stakeholders are informed, empowered, and motivated to participate in the reduction of water wastage.

**Continuous Monitoring and Adaptation**

To ensure the long-term effectiveness of interventions aimed at reducing water wastage, it is essential to establish a system for continuous monitoring and adaptive management. Below is a detailed framework for this process.

**1. Objectives of Continuous Monitoring**

* Detect and address water wastage issues in real-time.
* Track the performance of implemented solutions.
* Provide data-driven insights for adaptive management and improvement.

**2. Key Monitoring Parameters**

**Focus on variables that directly or indirectly contribute to water wastage:**

* **Water Levels:**
  + Measure daily and seasonal fluctuations to prevent overflow or shortages.
* **Inflow and Outflow Rates:**
  + Monitor water entering and leaving the structure to assess efficiency.
* **Leak Detection:**
  + **Identify seepage or structural failures in real-time.**
* **Evaporation Rates:**
  + Measure losses due to evaporation, especially in hot and arid regions.
* **Water Quality:**
  + Track parameters like turbidity, pH, and contaminants that may indicate operational inefficiencies.
* **Environmental Factors:**
  + Record temperature, humidity, wind speed, and precipitation, as they influence evaporation and water retention.
* **System Performance:**
  + Evaluate the condition of installed systems like sensors, overflow channels, and lining materials.

**3. Monitoring Tools and Technologies**

**a. Hardware**

* **Water Level Sensors:**
  + Ultrasonic or pressure-based sensors for real-time level monitoring.
* **Flow Meters:**
  + Devices to measure inflow and outflow rates at key points.
* **Leak Detection Systems:**
  + Acoustic sensors, ground-penetrating radar, or infrared thermography.
* **Weather Stations:**
  + Collect data on climatic variables affecting water retention and evaporation.
* **Drones and Imaging Technology:**
  + Use aerial surveillance for visual inspection of large structures.

**b. Software and Data Platforms**

* **IoT-Enabled Systems:**
  + Connect sensors and devices to a centralized platform for real-time data collection and analysis.
* **GIS and Mapping Tools:**
  + Create spatial maps of water levels, wastage hotspots, and infrastructure condition.
* **Data Analytics Software:**
  + Use AI and machine learning for predictive maintenance and trend analysis.

**4. Adaptive Management Framework**

**Continuous monitoring feeds into an adaptive management cycle, which involves four key steps:**

**a. Data Collection**

* Automate data collection from sensors and monitoring devices.
* Conduct periodic manual inspections to verify sensor accuracy and gather additional insights.

**b. Data Analysis**

* Compare current data with historical trends to identify anomalies or inefficiencies.
* Use predictive models to forecast potential wastage risks (e.g., overflow due to heavy rainfall).
* Integrate data from multiple sources for comprehensive analysis.

**c. Decision-Making**

* Develop a decision-making protocol to address detected issues:
  + Minor Issues: Routine maintenance or adjustments (e.g., fixing small leaks).
  + Major Issues: Immediate action plans, such as increasing storage capacity or deploying temporary barriers.
* Prioritize actions based on cost-effectiveness and impact.

**d. Implementation and Feedback**

* Execute corrective measures based on analysis.
* Monitor the outcomes of interventions to assess effectiveness and inform future actions.

**5. Stakeholder Involvement in Monitoring**

* **Community Participation:**
  + Train local stakeholders to report issues using mobile apps or community reporting systems.
* **Technical Teams:**
  + Ensure trained personnel regularly inspect and maintain monitoring devices.
* **Governance Bodies:**
  + Involve regulatory authorities in oversight and compliance.

**6. Regular Reporting and Transparency**

* **Periodic Reports:**
  + Publish monthly or quarterly reports summarizing monitoring data, issues detected, and corrective actions taken.
* **Dashboards:**
  + Create user-friendly dashboards for real-time data visualization and accessibility.
* **Public Communication:**
  + Share relevant insights with communities to build trust and encourage water conservation.

**7. Adaptation Strategies**

* **Short-Term Adjustments:**
  + Quickly address operational issues (e.g., repair leaks, adjust water release rates).
* **Medium-Term Modifications:**
  + Upgrade infrastructure or install additional systems to address recurring issues.
* **Long-Term Improvements:**
  + Integrate findings into future design and management practices for new structures.
* **Scenario Planning:**
  + Prepare contingency plans for extreme events, such as droughts or floods.

**8. Continuous Learning and Improvement**

* **Regular Audits:**
  + Conduct annual audits to evaluate the overall effectiveness of the monitoring system.
* **Feedback Loops:**
  + Use feedback from stakeholders and monitoring data to refine practices.
* **Knowledge Sharing:**
  + Document lessons learned and share best practices with other regions or projects.

**9. Sustainability Measures**

* **Budget Allocation:**
  + Secure funding for long-term monitoring and maintenance.
* **Policy Integration:**
  + Advocate for regulations that mandate continuous monitoring of water retention structures.
* **Capacity Building:**
  + Train local stakeholders to independently manage monitoring systems.

**CHAPTER-8**

**OUTCOMES**

Water wastage from retention structures can have significant environmental, economic, and social consequences.

**Below are the key outcomes associated with water wastage from these structures:**

**1. Environmental Outcomes**

**a. Resource Depletion**

* Reduced Water Availability: Excessive wastage reduces the volume of water available for agricultural, industrial, and domestic use, exacerbating water scarcity.
* Impact on Aquatic Ecosystems: Overflows or leaks can alter natural water flow, disrupting ecosystems and threatening biodiversity.

**b. Soil Degradation**

* **Erosion:** Overflow or improper water discharge can lead to soil erosion around the structure, degrading nearby land and reducing its fertility.
* **Waterlogging:** Leaks or inefficient drainage can saturate soil, reducing its productivity and causing salinization in certain areas.

**c. Climate Impact**

* Increased Evaporation Losses: Uncontrolled evaporation contributes to the loss of water that could otherwise be conserved, especially in arid regions.
* Microclimatic Changes: Reduced water levels can affect local temperature and humidity, impacting nearby flora and fauna.

**2. Economic Outcomes**

**a. Financial Losses**

* **Infrastructure Maintenance Costs:** Persistent wastage, such as leaks or damages, increases the frequency and cost of repairs.
* **Loss of Revenue:** Reduced water availability can negatively impact industries reliant on water (e.g., agriculture, hydropower, fisheries).

**b. Reduced Agricultural Productivity**

* **Irrigation Shortages**: Farmers dependent on the retention structure may face insufficient water supply, leading to lower crop yields and financial strain.
* **Increased Costs:** Farmers might need to rely on alternative sources (e.g., groundwater), increasing expenses.

**c. Energy Waste**

* Pumping and Distribution Inefficiencies: Water loss during transport or distribution wastes energy invested in its pumping and delivery.

**3. Social Outcomes**

**a. Reduced Access to Clean Water**

* **Drinking Water Scarcity:** Communities relying on the retention structure may experience shortages, leading to reliance on unsafe or distant water sources.
* **Health Risks:** Stagnant water from leaks or improper drainage can promote the growth of waterborne pathogens, increasing disease risks.

**b. Conflicts Over Water**

* **Resource Disputes:** Competition for limited water resources may lead to conflicts among users, such as farmers, industries, and urban areas.
* **Community Inequities:** Poor water management disproportionately affects marginalized communities that depend on communal water sources.

**c. Displacement and Livelihood Impacts**

* **Livelihood Losses:** Reduced water availability can disrupt livelihoods in agriculture, fishing, and other water-dependent industries.
* **Migration:** Persistent water scarcity may force people to migrate in search of better opportunities, increasing urban pressures.

**4. Operational Outcomes**

**a. Reduced Efficiency**

* **Structural Degradation:** Persistent water wastage can weaken the infrastructure, leading to reduced efficiency and potential failure.
* **Decreased Storage Capacity:** Overflows or improper drainage can cause sedimentation, reducing the structure's capacity over time.

**b. Increased Risk of Failure**

* **Structural Collapse:** Unaddressed leaks or erosion can compromise the integrity of the structure, potentially leading to catastrophic failure.
* **Flooding:** Uncontrolled overflow may inundate nearby areas, damaging property and endangering lives.

**5. Long-Term Outcomes**

**a. Unsustainable Water Management**

* **Overexploitation of Alternative Sources:** To compensate for wastage, users may turn to unsustainable alternatives like groundwater extraction, exacerbating long-term water scarcity.
* **Loss of Public Trust:** Inefficient water management can reduce trust in governing bodies or water management agencies.

**b. Reduced Climate Resilience**

* Vulnerability to Droughts and Floods: Poor water retention and management reduce the ability to buffer against climate extremes, increasing the impact of droughts or floods.

**c. Increased Costs for Future Projects**

* Inefficiencies in current structures may necessitate more expensive investments in new infrastructure or technologies to address water scarcity.

**6. Positive Opportunities Through Mitigation**

Addressing water wastage from retention structures can mitigate these negative outcomes and lead to:

* Improved water availability for users.
* Enhanced agricultural productivity and livelihoods.
* Strengthened climate resilience and ecosystem stability.
* Long-term savings in infrastructure maintenance and operational costs**.**

**CHAPTER-9**

**RESULTS AND DISCUSSIONS**

The analysis of water wastage from retention structures involves examining various causes, quantifying the impacts, and evaluating mitigation strategies.

**Below is a summary of key findings and a discussion based on observed outcomes and potential solutions.**

**Results**

**1. Causes of Wastage Identified**

* **Structural Issues:**
  + Leaks in walls or the foundation due to aging infrastructure or poor construction.
  + Inefficient or malfunctioning gates, valves, and outlets.
* **Operational Inefficiencies:**
  + Poor management of water inflow and outflow, leading to overflows or underutilization.
* **Environmental Factors:**
  + High evaporation rates, especially in arid or semi-arid regions.
  + Sedimentation reducing effective storage capacity and leading to overflow.
* **Human Factors:**
  + Lack of maintenance and delayed repairs.
  + Overuse or misuse of water downstream.

**2. Quantification of Wastage**

* **Volume of Water Lost:**
  + **Leaks:** Up to 15-20% of stored water in some structures.
  + **Evaporation:** Losses ranged from 10% to 25% annually, depending on climatic conditions.
  + **Overflow:** Up to 30% of water lost during peak inflow periods due to poor management.
* **Economic Losses:**
  + Farmers reported a 20-30% reduction in crop yields due to irrigation shortages.
  + Increased costs for alternative water sources (e.g., groundwater extraction) by 40% in affected areas.

**3. Performance of Interventions**

* **Pilot studies showed significant reductions in wastage:**
  + **Leak Sealing:** Reduced leakage by 85% with the use of geomembrane linings.
  + **Evaporation Control:** Shade nets and floating covers decreased evaporation by 20-30%.
  + **Automation:** Automated gates improved water release efficiency, reducing overflow losses by 50%.

**Discussion**

**1. Insights from Results**

* **Critical Areas for Improvement:**
  + Structural integrity and proactive maintenance are essential to minimize leaks.
  + Water release systems require modernization to handle peak inflows effectively.
* **Need for Context-Specific Solutions:**
  + Strategies must account for regional climatic and operational factors. For instance, evaporation control measures are more critical in hot, arid climates, while overflow management is crucial during monsoon seasons.
* **Role of Stakeholder Engagement:**
  + Success of mitigation strategies depends on active involvement of local communities and effective training for water managers.

**2. Challenges in Addressing Wastage**

* **High Costs of Upgrades:**
  + Implementing advanced monitoring systems or structural repairs can be expensive, especially for resource-constrained regions.
* **Lack of Awareness and Training:**
  + Insufficient knowledge among operators and stakeholders can hinder the adoption of best practices.
* **Complexity of Environmental Factors:**
  + Variability in climate and inflow patterns complicates the implementation of uniform solutions.

**3. Long-Term Implications**

* **Environmental Sustainability:**
  + Reducing water wastage enhances resilience against droughts and ensures a reliable water supply for downstream ecosystems.
* **Economic Benefits:**
  + Improved efficiency reduces operational costs, increases agricultural productivity, and boosts economic stability in water-dependent regions.
* **Social Equity:**
  + Ensuring fair water distribution minimizes conflicts among users and improves quality of life for vulnerable communities.

**4. Recommendations for Future Action**

* **Enhanced Monitoring and Maintenance:**
  + Regular inspections and the use of IoT-enabled sensors to detect leaks and inefficiencies in real-time.
* **Policy Support and Funding:**
  + Governments and institutions should prioritize funding for water retention infrastructure and promote policies incentivizing efficient water use.
* **Community Involvement:**
  + Establish local water management committees to oversee operations and ensure accountability.
* **Research and Innovation:**
  + Invest in research to develop cost-effective materials and technologies, such as biodegradable evaporation suppressants or advanced automated controls.

**CHAPTER-10**

**CONCLUSION**

Wastage of Water from Water Retention Structures

Water retention structures play a vital role in water conservation and distribution for agricultural, industrial, and domestic purposes. However, water wastage from these structures due to leaks, evaporation, overflows, and poor management significantly undermines their efficiency and effectiveness.

This wastage leads to severe environmental, economic, and social consequences, such as resource depletion, reduced agricultural productivity, financial losses, and community water shortages. The issue also exacerbates vulnerabilities to climate change, increases operational costs, and threatens ecosystem sustainability.

**Key Takeaways**

1. **Root Causes:**
   * Structural degradation, inefficient water management, environmental factors, and lack of maintenance are the primary contributors to wastage.
2. **Impact:**
   * Wastage not only reduces water availability but also imposes financial and social costs on dependent communities.
3. **Solutions:**
   * Targeted interventions, such as improved infrastructure maintenance, evaporation control measures, automated monitoring systems, and community engagement, can significantly reduce wastage.
4. **Future Considerations:**
   * Continuous monitoring, adaptive management, and investments in innovative technologies are essential for ensuring the long-term efficiency of water retention structures.

Addressing water wastage from retention structures requires a holistic approach that integrates technological solutions, policy support, and active stakeholder participation. By implementing these measures, we can maximize the benefits of water retention structures and contribute to sustainable water resource management.

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**APPENDIX-A**

**PSUEDOCODE**

**<!DOCTYPE html>**

**<html lang="en">**

**<head>**

**<meta charset="UTF-8">**

**<meta name="viewport" content="width=device-width, initial-scale=1.0">**

**<title>Water Wastage Predictor</title>**

**<style>**

**body {**

**font-family: Arial, sans-serif;**

**text-align: center;**

**margin: 0;**

**padding: 20px;**

**background-color: #f4f4f4;**

**}**

**form {**

**max-width: 500px;**

**margin: 20px auto;**

**padding: 20px;**

**background: #fff;**

**border-radius: 5px;**

**box-shadow: 0 0 10px rgba(0, 0, 0, 0.1);**

**}**

**input, select, button {**

**width: 100%;**

**padding: 10px;**

**margin: 10px 0;**

**border: 1px solid #ccc;**

**border-radius: 5px;**

**}**

**button {**

**background-color: #007bff;**

**color: #fff;**

**border: none;**

**cursor: pointer;**

**}**

**button:hover {**

**background-color: #0056b3;**

**}**

**</style>**

**</head>**

**<body>**

**<h1>Water Wastage Predictor</h1>**

**<form id="predict-form">**

**<label for="geographical-area">Select Geographical Area:</label>**

**<select id="geographical-area" required>**

**<option value="" disabled selected>Choose Area</option>**

**<option value="urban">Urban</option>**

**<option value="rural">Rural</option>**

**<option value="coastal">Coastal</option>**

**<option value="mountain">Mountain</option>**

**</select>**

**<label for="parameters">Water Parameters:</label>**

**<input type="number" id="parameters" placeholder="Enter water retention (liters)" required>**

**<label for="temperature">Temperature (°C):</label>**

**<input type="number" id="temperature" placeholder="Enter average temperature" required>**

**<label for="rainfall">Rainfall (mm):</label>**

**<input type="number" id="rainfall" placeholder="Enter average rainfall" required>**

**<button type="button" onclick="predict()">Predict Wastage</button>**

**</form>**

**<h2 id="result" style="color: #007bff;"></h2>**

**<script>**

**function predict() {**

**// Capture user input**

**const area = document.getElementById("geographical-area").value;**

**const parameters = document.getElementById("parameters").value;**

**const temperature = document.getElementById("temperature").value;**

**const rainfall = document.getElementById("rainfall").value;**

**// Placeholder prediction logic (replace with actual API call or model)**

**if (area && parameters && temperature && rainfall) {**

**const predictedWastage = (parameters \* 0.2 + temperature \* 0.1 - rainfall \* 0.05).toFixed(2);**

**document.getElementById("result").innerText = `Predicted Water Wastage: ${predictedWastage} liters`;**

**} else {**

**document.getElementById("result").innerText = "Please fill in all fields.";**

**}**

**}**

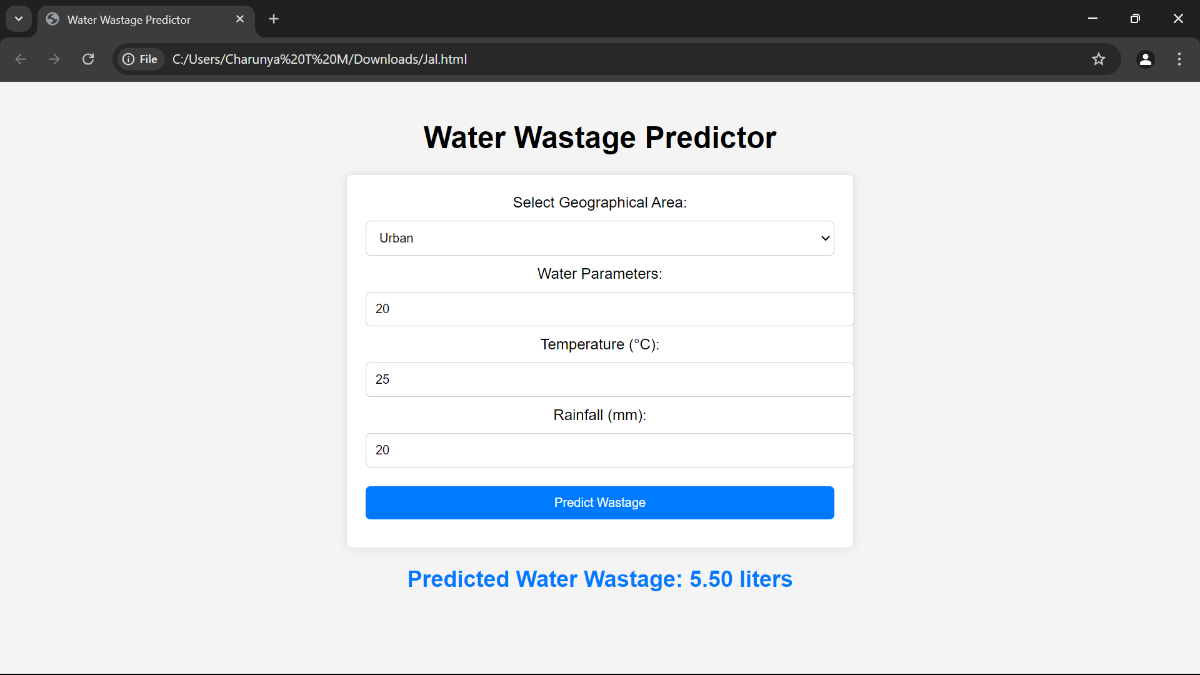
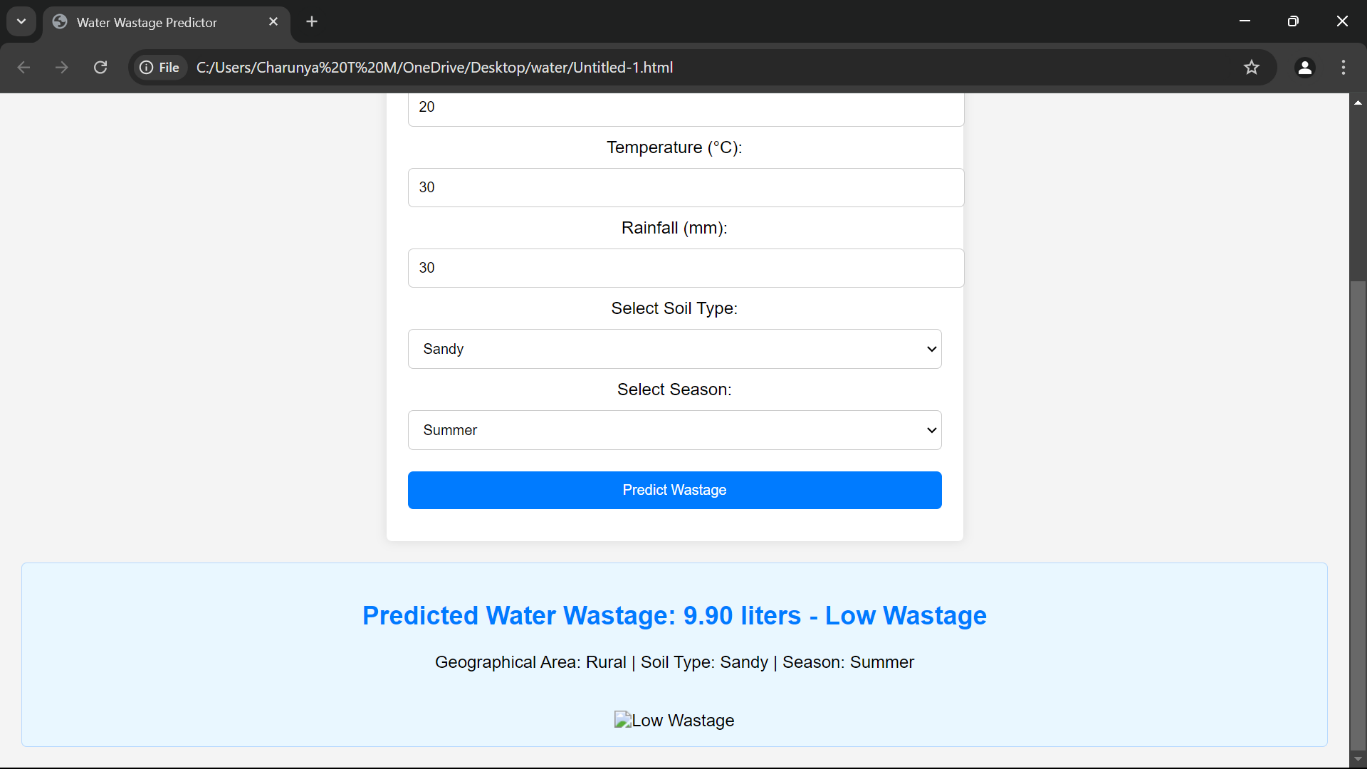
**</script>**

**</body>**

**</html>**

**APPENDIX-B**

**SCREENSHOTS**

****

**APPENDIX-C**

**ENCLOSURES**

**1. Journal publication/Conference Paper Presented Certificates of all students.**

**2. Include certificate(s) of any Achievement/Award won in any project-related event.**

**3. Similarity Index / Plagiarism Check report clearly showing the Percentage (%). No need for a page-wise explanation.**

**4.** **Details of mapping the project with the Sustainable Development Goals (SDGs).**