



World Water Challenge²⁰²⁵

PROGRAM BOOK



Ministry of Climate, Energy
and Environment



KOREA
WATER FORUM



World Water Challenge²⁰²⁵

PROGRAM BOOK





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Garuda WaterGuard: An integrated Smart Ecosystem for Water Quality Restoration and Monitoring in Degraded Freshwater Bodies

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1. Executive Overview & Introduction (Geographic Content & Area Assessment)

Executive Overview & Introduction

Background Problems

Indonesia is facing an acute water pollution crisis. As of 2020, government monitoring at 4,660 locations on 1,460 rivers found **26.7% water polluted**—only 63.4% of river areas now meet clean water standards. Major rivers like the Citarum, Ciliwung, and Cawas are vital for drinking water, irrigation, and fisheries, but are classified as “critically polluted,” with nearly all urban rivers failing basic tests.

- Root Causes: Rapid urbanization, unregulated industrial waste, intensive agriculture, and untreated sewage from interconnected river systems.
- Consequences: Unsafe drinking water, lost biodiversity, food safety issues, and major public health threats.
- Scale: With the majority of Indonesia's 250,000 rivers in jeopardy, which directly affects 10+ million people, the water crisis is not only one of environmental degradation but also threatens economic stability and national food security.



▪ Reason for Selection: The Ciliwung River area is the most manageable and smallest of the four pilot zones, with a defined geographic boundary and existing infrastructure.

- Why is this a discrete test for environmental preservation technology?
- The pollution is complex—a mix of heavy metals, nutrients, pesticides, and pathogens—making conventional single-solution treatments ineffective or too expensive.
- Centralized wastewater plants can't reach scattered or rural settlements. New, integrated technological solutions are urgently needed that can innovate, track, and adapt in real-time across diverse and degraded environments.

Targeted Pilot Area - Geographic Context

Ciliwung River Overview

- The Ciliwung River is the longest and one of the most important rivers in West Java, Indonesia, stretching approximately 210 km with an average width of 50 meters. It serves as a vital water source for about 15 million people, providing water for domestic, agricultural, and industrial use.
- Unfortunately, it is severely polluted by domestic sewage, industrial discharges (especially textile dye effluents), and agricultural runoff.

Division of River Areas

- Upper Zone - Headwaters: Having textile industry pollution, high BOD and COD levels.
- Middle Zone - Ciliwung: Urban and domestic sources, treated nutrients like ammonium and phosphate.
- Regulang Dam Zone (Selected Target Pilot Zone): Smaller manageable area dominated by mixed agricultural and industrial pollution, ideal for pilot tests.
- Lower Zone - Below: Extremely high pollution levels from dense population and industrial runoff, including heavy metals.

Parameter	Value
Area	2.1 km ² (210 hectares)
Average Depth	15 m
Estimated Water Volume	37,000,000 m ³
Pollution Severity	Moderate to High
Key Pollutants	Nitrates, Heavy Metals

Field Test Data Overview

Field Test and Technology Readiness Overview - Karsanga Lake, University of Indonesia

Parameter	Description / Value	Notes
Location	Central University of Indonesia Campus, Depok, West Java (6.942°S, 106.837°E)	Receives inflow from the Ciliwung sub-basin and on-campus storm drains.
Surface Area	≈ 2 hectares (0.00 km ²)	Approx. 30,000 m ³
Average Depth	≈ 5 m	Based on field and hydraulic estimations
Maximum Depth	≈ 15 m	Observed near the center and western depression zone
Estimated Water Volume	≈ 150,000 m ³	Calculated as area × avg. depth
Water Source / Catchment	Ciliwung sub-basin inflow + campus stormwater	High suspended solids and nutrient load after rainfall.
Key Pollutants	Nutrients (N, P), heavy metals (Fe, Pb), organic contaminants (COD/BOD), microplastics, detergents	Major contributions from domestic runoff and nearby drainage.
Pollution Severity (Qualitative)	Moderate-High	Periodic eutrophication and odor events reported.
Dominant Hydrological Behavior	Semi-estuarine with low flushing rate	Potential for controlled remediation pilot tests.
Ecological Notes	Presence of duckweed, algae, and rooted macrophytes	Indicates nutrient loading suitable for FTW-based phylogenetics.

- Field technology validation study area: designated as Karsanga Lake, University of Indonesia, serving as a controlled environment for system testing and performance verification prior to large-scale implementation in diverse ecosystems such as the Ciliwung sub-basin.

- Pilot configuration includes:
 - 1 Autonomous Surface Vehicle (ASV) for high-resolution monitoring and automated sampling.
 - 2 modular Phytolysis Treatment Units (PTW) (30 m² coverage) paired with Biomass Ecosystems (Wetland Hydron) and Biomass Aquatics (Wetland Sprout).
 - 1 Photocatalytic Treatment Reactor (pro-PTW) for advanced polishing treatment, with solar-powered TiO₂ catalyst panels.
 - 1 portable aeration module integrated with dissolved oxygen sensors for active mixing and regeneration.





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2. Integrated Technology (Workflow & Operational Phases)



Operation Stages & Key Components

- 1st Component – Autonomous Surface Vehicles (ASVs) as the mobile sensory nervous system of the operation, providing real-time, high-resolution water quality data across vast areas



Technological Specifications

- Platform – Compact solar-electric submarine with 420 Wh Li-ion battery > 100 W solar module for 8 hr autonomy.
- Sensors – 10+ multi-parameter array (pH, DO, EC, turbidity, ammonia, nitrate, phosphate, and light-harvesting probes).
- AI System – Executes simplified PPO policy for adaptive routing—utilizes automatically upon-pollutant spike detection.
- Compute Unit – Raspberry Pi 4 – Jetson Nano for edge AI processing and GPS-based navigation.
- Communication – 4G/LTE + LoRaWAN link to the Cloud AI Hub.
- Data Harvesting – All readings geo-tagged and timestamped for spatial-temporal mapping.

Layer	Function	Algorithm
Input Layer	ASV mapping (pH, DO, EC, NH_4^+ , NO_3^- , turbidity, heavy metals, ammonia, heavy metals).	Federated anomaly detection (z-scores).
Computation Layer	Cloud-based clustering & horizon mapping.	K-Means, DBSCAN.
Decision Layer	Route & PMPR scheduling optimization.	PPD + Adaptive FL Model.

Specialized Intelligence Subsystem

1. Command: "Survey Zone C for nutrient plumes."
2. Sensor Spots: Nitrate levels from 2.0 to 9.5 mg/L.
3. Edge AI: Initiates optimal path to map plumes.
4. Data Output: Nutrient map, DO, EC, pH, turbidity: 26 NTU; – Contaminant cluster coordinates sent to PMPR deployment team.
5. Result: Horizon flagged + PMPR deployment recommendation.

Phase

Phase	Description
Phase 1 – Intelligence & Monitoring	1 ASV + 5 fixed-sensor buoys across Zones A-E. Deploy 3-4 hr pattern. Buoy provides continuous telemetry (10 min intervals).
Phase 2 – Federated Adaptation	ASV uploads local updates to the AI hub during tracking. Cloud model refines global detection patterns.
Phase 3 – Data-Integration & Decision Support	Integrated dashboard identifies high-risk nutrient zones for PMPR placement and PMPR route setting.

Operation Stages & Key Components

- 2nd Component – Floating Treatment Wetlands (FTWs)

Aspect	Specification
Structure & Materials	Modular 1 x 1 m frames made from recycled HDPE pipes with PET bottle flotation and biodegradable coir mats as planting media.
Plant Species	Native macrophytes – <i>Eichornia crassipes</i> (Water Hyacinth) & <i>Ipomoea aquatica</i> (Water Spinach) – selected for high-nutrient and metal uptake.
Construction Process	1. Assemble HDPE frame + PET bottle flotation. 2. Lay coir mat and plant 20-25 seedlings/m ² . 3. Cure in calm water (2-3 weeks) for root establishment. 4. Deploy to ADV identified pollution hotspots.
Enhancements (Optional)	Solar-powerederation units (integrated into select modules) improve DO levels and enhance microbial nutrient cycling.
Phyto-Remediation Process	<ul style="list-style-type: none"> Root uptake: Plants absorb nitrates, phosphates, ammonia, and trace metals. Phosphorus Biotiny: Microbes degrade organic pollutants. Aerobic-Anaerobic Zones: Enable nitrification/denitrification for nitrogen removal.
Performance Metrics	Nitrate 90%, Phosphate 83.2%, Ammonia 89.5%, P/Ca > 90% (total & lab tests).
Life Cycle & Maintenance	<ul style="list-style-type: none"> Month 1-12: Root establishment. Month 1-12: Plant rehabs. Annual harvesting: remove biomass to extract pollutants. HDPE frame lifespan = 7 years.
Budget Allocation (Bdt.)	FTW module fabrication & deployment = Bdt 14 million (27% of total). Covers 12-15 m ² prototype coverage with integrated DO sensor nodes.



FTW 2 – Targeted Remediation Execution (Dense & prioritized)	
<ul style="list-style-type: none"> FTWs are modular and heterogeneous. The AI recommends FTW placement in Zones A and C initially (offices and residential cluster zones) and may instruct dense deployment in Zone C for load balancing. Because ASV count = 1, deployment of FTW modules is performed by a single boat (low cost). ASV selects by mapping access lines and recording anchor positions. 	ASV "Effective Treatment Volume"
<ul style="list-style-type: none"> ASV deployment & deployment: Comparative post-assumption: 1 m² FTW treats ~1.0 m³/day of the adjacent water column, for measurable nutrient/TOC reduction (load-area specific, time-of-month for dense inclusion FTW). Total FTW area = 2 m² = ~2 m³/day approximate influences (removal zone). Removal is primarily for nutrients, TOC, and supporting DO recovery via biotin-action. 	ASV Deployment

FTW 3 – Targeted Remediation Execution (Dense & prioritized)	
<ul style="list-style-type: none"> ASV deployment & deployment: Comparative post-assumption: 1 m² FTW treats ~1.0 m³/day of the adjacent water column, for measurable nutrient/TOC reduction (load-area specific, time-of-month for dense inclusion FTW). Total FTW area = 2 m² = ~2 m³/day approximate influences (removal zone). Removal is primarily for nutrients, TOC, and supporting DO recovery via biotin-action. 	ASV Deployment

Operation Stages & Key Components

- 3rd Component – Photocatalytic/Nanofiltration-Reactor (PMPR)

Aspect	Specification
Purpose	Post-treatment unit for semi-treated or runoff water containing pesticides, pharmaceuticals, and microplastics.
Design	Compact hollow-fiber ceramic membrane integrated with TiO ₂ /B2H5 photocatalysis, responsive to solar and UV-visible light.
Structure	Includes pre-filter (100 µm), low-pressure diaphragm pump, and dual solvents for permeate (clean) and concentrate (reject).
Operation Principle	Solar-assisted photocatalysis + nanofiltration light activates TiO ₂ /B2H5 to produce hydrogen radicals (OH [•]), breaking down organic pollutants while the membrane filters fine particles.
Performance	<ul style="list-style-type: none"> Microplastic removal > 90%. Pesticide removal (e.g., phosphates, chlorophenols) > 87%. Water recovery > 95%.
Processing Rate	>20 L/h per module; 8-12 h/day (4 scheduled cycles) (aligned with sunlight).
Energy Source	Primarily solar-assisted; reducing grid dependency; low-mall UV-LEDs used during low-light conditions.
React Management	5% concentrate stream stored in a sealed tank, transported periodically for evaporation or sludge-cogeneration treatment.
Integration with FTWs	Receives partially clarified water from upstream FTW zones to increase turbidity and extend membrane lifespan.
Feed Setup	Placed downstream near lake edge on stable foundation, intake pipe connected from FTW outlet zone.
Budget Allocation (Bdt.)	PMPR unit + pump + UV-LED + sensors = Bdt 21 million (43% of total budget).



PMPR 2 – Targeted Remediation Execution (Dense & prioritized)	
<ul style="list-style-type: none"> PMPR execution & scheduling: ASV operates on an AS schedule determined by continuous busy = ASV measurements. Typical rate for PMPR at highest throughput during late morning to mid-afternoon when solar intensity peaks and pollutant concentrations at the intake exceed threshold. With a single ASV, PMPR intake monitoring relies on (1) fixed buoy monitoring (pre-PMPR), (2) ASV utilization monitoring, and (3) manual site checks for membrane fouling indicators. 	ASV "Effective Treatment Volume"
<ul style="list-style-type: none"> A solar-assisted nanofiltration reactor that combines TiO₂/B2H5 photocatalysis and membrane filtration to remove residual pesticides and microplastics. It complements PMPR by providing clean, reusable water for small-scale environmental restoration. 	PMPR Deployment

PMPR 3 – Targeted Remediation Execution (Dense & prioritized)	
<ul style="list-style-type: none"> Chambers + High-turbidity flow membranes and scanning sensors: UV light, turbidity reducing efficiency. Solution: The PMPR is deployed as a post-treatment unit. The upstream FTW acts as a highly effective pre-filter, significantly reducing turbidity and organic load, protecting the PMPR and ensuring optimal performance. Cleaning & Maintenance – periodic backwash, TiO₂-re-activating as scheduled (every 8-12 months for plants, membrane change annually depending on fouling). 	PMPR Operational Schedule and Capacity Metrics
<ul style="list-style-type: none"> Typical day schedule: operate PMPR 8-12 hours during day to leverage solar-assisted photocatalysis and UV light. Plus 4 maintenance areas: For hollow-fiber pre-membrane, 40000 L low-pressure operation (0.2-0.8 bar) and permeate flux in the order of 2-10 L/m²/h depending on membrane and feed quality; membrane area must be scaled to produce the 20 L/h target. Action: ASV schedules PMPR start at 09:00, ends at 17:00 by default; can override for surge protection if needed. 	PMPR Operational Schedule and Capacity Metrics



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Operation Stages & Key Components

- 4th Components – Closed-Loop AI Optimization & Feedback

Aspect	Specification
Architecture	Hybrid-edge-cloud system integrating data from sensors, FTWs, PHFs, and a single ASV.
AI Model	Reinforcement Learning (RL) algorithm that optimizes operations based on live water quality data.
Function	Continuously learns and updates the best placement for FTWs and operation schedule for PHFs according to pollution dynamics and hydrological patterns.
Data Flow	ASVs collect post-treatment data (e.g., nutrient levels, turbidity, dissolved oxygen) and send it to the cloud for analysis.
Optimization Loop	Observe: ASV measures treated zones – Analyze: AI evaluates pollution reduction – Decide: Adjust FTW/PHF deployment and ASV patrol routes – Act: Updated commands sent automatically to field units.
Validation Phase	After each operation cycle, the ASV performs a focused resurvey mission to measure improvement (e.g., BOD, COD, nitrate) for feedback calibration.
Automation Level	Semi-autonomous; human input limited to supervision and maintenance.
Decision Latency	▪ Route & placement update: every few hours ▪ On-field response (ASV): within seconds
Cost Allocation (€m)	AI controller (single device, sensors, software integration): 0.5 million (€100k).

Phase 4 – Validation & Closed-Loop Feedback (single ASV workflow)

Resurveying for validation:

- After a remediation action (FTW redeployment or PHF operation window), the ASV is dispatched for a focused validation mission to survey the treated area. Because only one ASV is available, the AI prioritizes validation targets to expected marginal improvements.

Validation:

- Validation includes in-situ sensor logging and photography; a subset of water samples are taken for lab confirmation (BOD/COD, nitrate) to validate remote sensor readings.

Feedback & policy update:

- Validation results feed the central AI system. Policy updates (route priorities, FTW placement heuristics, PHF runtime rules) are transmitted to the ASV during its treated data mission.
- Over sequential cycles, the AI agent learns which remediation priorities produce measurable improvements for given environmental signatures.

Closed-Loop Feedback & AI Optimization

3. Field Tested Outcomes

System Overview Diagram

- System Overview Diagram: The "Smart Ecosystem" (ASVs, FTW, PHF, AI feedback)

Before vs **After (3 Months)**

Field Tested Outcomes

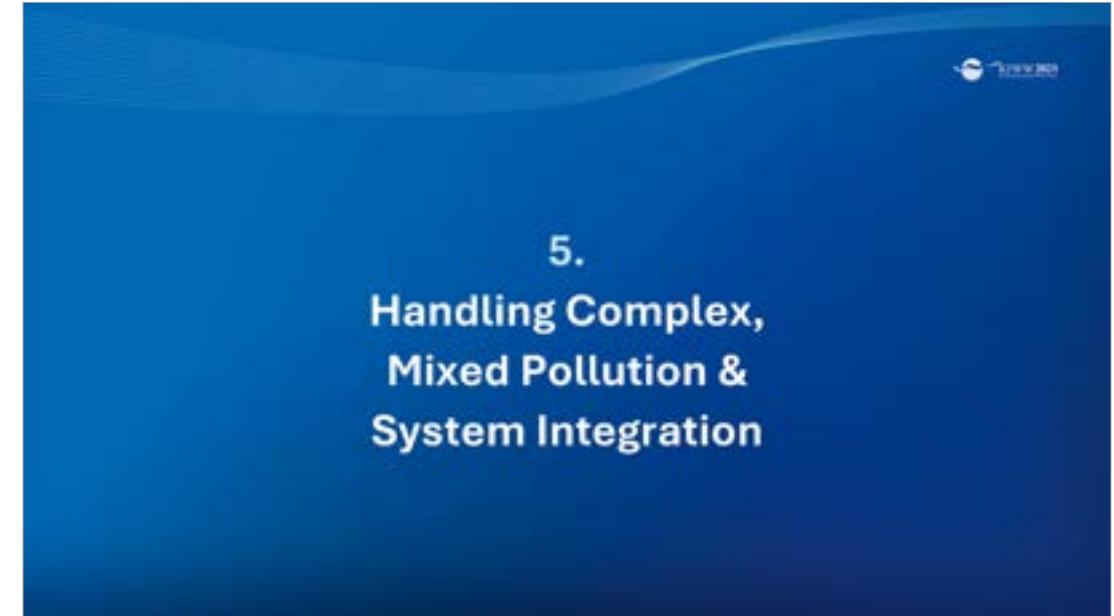
- System Effectiveness & Quantitative Results
- Impact Assessment

Parameter	Pre-Treatment (Baseline)	Post-Treatment (30 Days)	Efficiency (%)	Remarks
Heavy Metals	0.00 mg/L	0.025 mg/L	50%	Restored to neutral stability
Dissolved Oxygen (DO)	2.1 mg/L	4.3 mg/L	210%	Improved through aeration
Biological Oxygen Demand (BOD ₅)	30 mg/L	9 mg/L	74%	Bioremediation via FTW was baseline
Chemical Oxygen Demand (COD)	80 mg/L	18 mg/L	72%	PHF photocatalytic oxidation effective
Total Nitrogen (TN)	8.5 mg/L	2.1 mg/L	64%	Nutrient uptake by wetland plants
Total Phosphorus (TP)	1.3 mg/L	0.8 mg/L	60%	Phytoplankton bloom
Turbidity	85 NTU	18 NTU	78%	Reduced by filtration & biofiltration
Total Coliform	8200 CFU/100mL	640 CFU/100mL	92%	UV sterilization + microbial competition

Impact Dimension	Indicator / Parameter	Observed or Projected Result	Quantitative / Qualitative Metrics	Remarks
Environmental	Nutrient & Organic Load Reduction	70-75% pollutant reduction (COD, BOD, TN, TP)	DO + from 2.1 + 6.8 mg/L	Substantial ecosystem mitigation
	Biodiversity Recovery	Reappearance of plant and animal life	DO + from 2.1 + 6.8 mg/L	Improved aquatic life resilience
	Carbon Footprint	Low-carbon operation via solar PHFs	<0.21 kWh/m ²	50% lower energy vs. conventional aeration
	Water Quality Upgrade	Class IV → Class II (within 1 year)	EN-738-2008 standard alignment	Suitable for recreational and educational use
Social/Community	Student & Research Engagement	Involvement of ~10 students across Engineering	Cross-department (Chemical, Environmental, Electrical Eng.)	Promotes interdisciplinary innovation
	Academic Demonstration & Training	On-site demos and short training sessions	Conducted periodically for coursework or research methodology classes	Coordinated with Chemical Engineering Lab
	Campus Sustainability Alignment	Contributes to internal sustainability training	Data shared with PTU's sustainability reporting unit	Aligns with GreenMetric environmental performance indicators



4. Competitive Landscape & Decisive Advantages



5. Handling Complex, Mixed Pollution & System Integration

Competitive Landscape & Decisive Advantages

Superiority of Garuda WaterGuard		Risk Mitigation		
Feature	Garuda WaterGuard System Advantage	Risk Category	Potential Issue	Mitigation Protocol
Integrated Modular Architecture	Combines ADV + FTW + PWR into one adaptive and interconnected platform. Each module is physically independent yet logically connected, enabling scalable, field-ready deployment.	System Integration Risk	Hardware-software misalignment between ADV, FTW, and PWR modules.	Standardized communication protocol (HQ211 - REST API), hardware modularity-validation, pre-deployment system tests.
Adaptive AI Management	Employs Federated Learning + Reinforcement Learning (RL) to autonomously adapt operations based on real-time pollution data, ensuring higher efficiency with minimal human intervention.	Single-Point-of-Failure (SPoF)	Failure in main control node or AI command center.	Redundant microcontrollers on ADV; distributed edge intelligence allows autonomous failover operation.
Decentralized Intelligence	Every ADV is an independent node with on-board computation; only model insights are shared to preserve bandwidth and enable distributed decision-making.	Hardware Durability	Damage from floating debris, corrosion, or UV degradation.	Marine-grade coatings, waterproofing (IP67), shock-resistant casings.
Reduced System Reliability	Operates as a single-vendor system, minimizing incompatibility risks across software and hardware layers. All components are developed under one cohesive control logic.	Sensor Reliability	Calibration drift and data inconsistency over long-term use.	Automated calibration algorithms, dual-sensor redundancy for critical parameters.
Local Manufacturing & Cost Efficiency	Designed and fabricated using local materials and Indonesian engineering capacity, cutting costs by up to 80% compared to imported systems while improving sustainability and responsibility.	Environmental Conditions	Flooding, algae overgrowth, or extreme weather.	Dynamic buoyancy adjustment in FTW, real-time route adaptation for ADVs, emergency shutdown protocols.
Circular & Green Engineering	Employs recycled HDPE/PVC materials for FTW and solar-driven PWR systems, embracing low-carbon and circular economy principles aligned with Indonesia's Net Zero 2060 agenda.	Cybersecurity	Data (re)processing or communication劫持 (Mitigation: End-to-end encryption with circuit-level access control, continuous AI model integrity checks)	

Handling Complex & Mixed Pollution - A Case Study

Scenario	Observed/Simulated Condition	Adaptive System Response	Expected Outcome
High Seawater Concentration Peaks	High evaporation, elevated pollutant concentrations (DO < 5 mg/L, N, P reduced by 40-50%)	AI prioritizes FTW redeployment to increaseluent zone density; PWR operates intermittently during high evaporation.	Stabilized DO > 5 mg/L, N, P reduced by 40-50%
Rainy Season Inflow Surge	Sudden inflow of turbid, low-DO water from flooding runoff	ADV swarm upstream, map inflow-contamination, and guide FTW anchoring at inflow points.	Reduced inflow pollutant impact; improved water clarity (turbidity < 50%)
Mixed Contaminant Pulse (Nutrients + Heavy Metals)	Detected P, Cd > threshold + phosphate surge	PWR priority activation with simultaneous FTW repositioning; adaptive pH balancing every 15 min.	Pb < 0.5 mg/L, phosphate < 40% after 48-hour operation
High Organic Load (Algal Bloom)	Dense microalgae and low oxygen	AI triggers aeration mode on ADV propellers, increases FTW surface aeration.	Organic load reduced; oxygen recovery > 100% of baseline
Equipment Degradation/ Sensor Drift	Prolonged use, calibration drift	AI detects data drift pattern; system triggers self-calibration or redundant sensor check.	Retains data integrity >90% accuracy

Case Study Scenario: Mixed Seawater Events

The Garuda WaterGuard system employs an AI-driven decision-making that prioritizes remediation actions dynamically based on sensor-detected pollution profiles. The logic integrates data from the ADV sensor suite (real-time pH, DO, turbidity, nitrate, phosphate, Pb, Cd, Cd:water) and feeds into a hierarchical controller for optimized responses.

Scenario 1: A simultaneous increase in nutrients (N, P) and heavy metals (Pb, Cd) detected at Zone 3 (Kemangga Lake) inflow channels.

AI DECISION LOGIC (Step 1):

- Data Detection Layer (0-30 sec):
 - ADV sensors detect abnormal turbidity, phosphate > 2 mg/L, Pb > 0.2 mg/L.
 - AI assigns a pollution index score for each contaminant type based on severity weighting:
 - Nutrient Load Index = 0.68
 - Heavy Metal Index = 0.72
- Federated Local Decision Layer (within 60 sec):
 - ADV sends a [Zone 3 ADV module] to intervention priority:
 - If Nutrient Load Index > Heavy Metal Index, = prioritize FTW activation.
 - If Nutrient Load Index < Heavy Metal Index, = prioritize PWR activation.
 - Concurrently, the ADV transmits aggregated severity data to the cloud for multi-agent reinforcement learning.
- The RL-HPO Controller evaluates historical treatment efficiency curves for each module type:
 - ADV optimizes command.
 - FTW re-deploys to monitor historical parameters:
 - PWR activated downstream for isolating heavy metals and residual organics.
- Execution Layer (real-time):
 - FTW initiates phytoremediation and microbial degradation (nutrients).
 - PWR operates in parallel for phosphate reduction of metal complexes.
 - ADV performs continuous ventilation scanning, feeding new data for Adaptive AI learning.

Logistics & Advanced Tools:

- High Processing Delay < 1 second per 100 m²
- Cloud Computing Cycle: < 2 minutes for real-time AI-to-end
- FTW Redeployment Adjustment: < 20 minutes for 10 m² module intercalibration aware
- PWR Activation Response: instant system UV-on-demand system

This hybrid decision framework ensures that mixed pollution events are handled synergistically, maximizing pollutant reduction while minimizing operational redundancy.



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System Integration, Sensor Technology & Field Robustness

- Durability Solutions**
 - Autonomous Propulsion** – All submerged components—including sensor casings and PTW root modules—are coated with non-toxic, hydrophobic fluoropolymer layers to prevent algal or bacterial buildup. Self-cleaning sensor housings use micro-vibration pulses every 12 hours to dislodge sediment accumulation without chemical intervention.
 - Anti-Corrosion Coating** – Plastic elements (casing, frame, AUV propeller housings) are anodized or made from marine-grade aluminum with epoxy sealing to resist oxidation and corrosion from marine-scale water.
- Calibration & Maintenance Protocols**
 - To ensure continuous data reliability and operational accuracy:
 - Automated Calibration – ADVs feature onboard reference solutions allowing in-situ calibration for DO, pH, and conductivity sensors every 48 hours.
 - Scheduled Human Checks – Human maintenance is performed quarterly for cross-validation against laboratory standards and cleaning of PTW sampling points.
 - Sensor Replacement Cycle

Sensor Type	Expected Lifespan	Replacement Cycle
DO Sensor	12 months	Annually
pH/CRP Sensor	18 months	Every 1.5 years
Turbidity Sensor	34 months	Every 2 years
Heavy Metal/TOC Sensor	38 months	Every 2 years

- Local Repair & Rapid Recovery Strategy**
 - To minimize downtime and reduce dependency on regional components:
 - Local Manufacturing – Most structural and electronic components are sourced from domestic suppliers, ensuring quick replacement within 72 hours.
 - Product Architecture – Each subsystem (AOV, PTW, PWF) can be swapped for non-operational repair without halting the entire operation.
 - Fault Detection & Recovery – The central AI continuously monitors sensor health via self-diagnostic indicators. Fault trigger consequences recoding—ADVs in standby automatically cover failed units until maintenance is complete.
- Integrated Operational Resilience**
 - The robust integration of mechanical, electronic, and digital components ensures the Savana WaterGuard system can maintain high fidelity and continuity in complex, mixed-pollutant aquatic environments. The combination of biotesting resistance, modular redundancy, and adaptive edge intelligence makes it a fully field-ready, self-sustaining smart ecosystem suitable for long-term deployment in lakes and riverine systems.

- Edge Computing & Battery Management**
 - Each ADV is powered by a hybrid solar-LiFePO₄ battery pack providing 48 hours of continuous operation. Intelligent edge computing allows local AI inference to minimize data transmission load, enabling autonomous operation even under weak connectivity. Power allocation dynamically prioritizes propulsion, sensing, or computation depending on the mission phase, with automatic docking for solar recharge at the station hub.

Cost Calculation

- Cost Breakdown**

Category	Component	Qty	Unit Cost (IDR)	Total (IDR)	Notes
A. Autonomous Surface Vehicle (ASV)	Body & Propulsion	1 unit	12,000,000	12,000,000	Local fabrication using HDPE and PVC
	Sensor Suite	1 set	6,000,000	6,000,000	Calibrated monthly
	Microcontroller & Telemetry	1 set	2,000,000	2,000,000	Connected to cloud platform
Subtotal ASV			20,000,000 (USD 1,200)		
B. Floating Treatment Wetlands (PTW)	Frame & Panels	2 modules	4,500,000	9,000,000	Local materials
	Plant Media	2 sets	750	1,500,000	Native species from UI nursery
Subtotal PTW			10,500,000 (USD 632)		
C. Mini Photocatalytic Nanofiltration Reactor (PWF)	Reactor Shell	1 unit	7,500,000	7,500,000	WRF-20-L capacity
	Catalyst & Membrane	1 set	3,500,000	3,500,000	Solar/UV driven
	Control & Solar Panel	1 set	2,000,000	2,000,000	Self-integrated
Subtotal PWF			13,000,000 (USD 762)		
D. Labor, Logistics & Installation	Field deployment & Setup	Lump sum	5,000,000	5,000,000	2-day setup
E. Cloud & AI System Setup	Cloud server, dashboard & initial training		5,000,000	5,000,000	IPD = data dashboard
TOTAL FIELD PHASE			451,000,000 IDR (USD 3,676)		

6.

Economic Viability, Cost Calculation, and Resource Planning

Economic Viability

- Full Scale-Up Scenarios**

Item (per treated zone)	Qty	Unit price (USD)	Subtotal (USD)	Notes / assumptions
ASV (field-ready, modular)	3	2	6	Small catamaran ADVs (modest sensors & propulsion) → 3 per zone for coverage
PTW modules (1 m ² kits)	50	40	200	Modular recycled-HDPE/PEI (under 50 m ² total footprint per zone)
Plant modules (giant-scale)	4	1.5	6.0	20 L/m ² ceramic + TiO ₂ /ZnO modules (parallel for throughput)
Edge & comm. gateway	1	2	2	LoRaWAN gateway + local edge server + local dashboard
Read sensor buoys	4	250	1000	Simple pH/DO/turbidity/EC nodes

- Unit Economics**

Parameter	Smart Ecosystem	Legacy Treatment (Conventional)
Cost per m ³ treated	~IDR 1,000-2,000 (USD 0.065 - 0.13)	IDR 3,000-4,500 (USD 0.2 - 0.3)
Energy Source	Solar-driven	Grid electricity
Operation Mode	Autonomous, adaptive	Manual, scheduled
Maintenance Frequency	Monthly calibration	Bi-annually
Data Value	Real-time environmental data	None

- Local Sourcing & Supply Chain**
 - PTW Components: 100% locally sourced (HDPE, HDI epoxy from West Java suppliers)
 - ADV Hardware: Electronics via UMI Instrumentation Lab & local auto suppliers
 - Plant: 100% Indonesian soil, TiO₂/ZnO catalyst (negotiated co-innovation with PT UI Chemistry Engineering Lab)
- Notes**
 - Supply chain latency 2-3 months for integrated 1st milestones.
 - UV degradation of polymer hosts—longevity → coating with UV-resistant paint.



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Annual Operational Cost					
Annual Operational/Replacement Costs – Sensors, Wastewater, routine maintenance, labor					
Component / Technology	Description	Estimated Lifespan	Maintenance Frequency	Annual Cost (USD)	Notes
Autonomous Surface Vehicle (ASV)	Battery-powered mobile unit for data collection, mapping, and monitoring.	5 years (unit & frame)	Battery replaced every 2 years; calibration every 6 months.	5,000,000 (USD 361)	Includes motor and sensor cleaning, firmware updates.
Battery Module (Unit)	Power source for ASV and sensors.	2 years	Replace every 2 years	1,000,000 (USD 90)	Degradation after ~400 cycles.
Flowing Treatment Workcells (FTW)	Modular floating platforms with aquatic plants and root mass.	8-12 years	Monthly inspection, partial replacement annually.	3,000,000 (USD 181)	Plant replacement (15-20% per year).
Photocatalytic Membrane Reactor (PMFR)	Solar-driven reactor for advanced oxidation and incineration.	3-4 years	Filter membranes replaced annually; photocatalyst refreshed every 2 years.	6,000,000 (USD 387)	TiO ₂ coating and membrane maintenance cost included.
Water Quality Sensors (pH, TDS, Turbidity, Conductivity, BOD)	Smart multi-parameter sensor array integrated with ASV & PMFR.	2 years	Calibration every 6 months; sensor replacement every 2 years.	4,000,000 (USD 341)	Includes calibration fluid and spare probes.
Microcontroller & Edge Computing Unit	Onboard AI edge unit for autonomous operation and data ingestion.	3-4 years	Firmware updates every 6 months.	2,000,000 (USD 125)	Maintenance includes data syncing and diagnostics.
Solar Panels & Power Electronics	Provides power to PMFR and FTWs auxiliary systems.	5-10 years	Cleaning every 1 month; inverter replaced every 5 years.	1,000,000 (USD 90)	Assumes tropical sunlight exposure.
Aeration System	Provides oxygenation for biological activity under FTWs.	5 years	Routine cleaning quarterly.	2,500,000 (USD 155)	Replacement of tubing and diffusers as needed.
Network & Data Transmission (Cell/Gateway)	Data transfer via cellular or LoRaWAN to the dashboard.	5 years	Replace SIM and service annually.	1,000,000 (USD 60)	Includes cloud storage fee.
Labor & Field Technicians	On-site monitoring, maintenance, sample testing, and reporting.	—	Monthly (2-person team)	12,000,000 (USD 720)	Covers training, site visits, safety gear.
Miscellaneous (spare parts, logistics, calibration tools)	Spare margin for operational continuity.	—	—	2,000,000 (USD 139)	Contingency 10-15% of total cost.

Cost Projection								
5 Year Operational Cost Projection (in USD)								
Category	Initial (Year 0)	Year 1	Year 2	Year 3	Year 4	Year 5	Replacement Cycle	Depreciation (%)
ASV Unit (1 unit)	1,161	129	129	129	129	129	Every 5 yrs (battery, frame unit)	10%
FTW System (Large Module)	374	65	65	129	65	129	Every 5 yrs (bio-reactor, 10 yrs (frame))	10%
PMFR Module	645	65	65	65	65	65	Every 5 yrs (membrane & catalyst)	20%
Sensors & Electronics	298	65	65	129	65	65	Every 2-3 yrs	25%
Labor & Field Ops	—	367	367	367	367	367	Annual recurring	—
Data Platform & AI Processing	129	65	65	65	65	65	Annual subscription & cloud fee	—
Consumables (Nutrients, Cleaning)	—	65	65	65	65	65	Annual recurring	—
Total (Annual)	4,661	841	841	1,694	841	841	—	—
Cumulative Total	3,833	3,871	4,712	5,748	6,687	7,628	—	—

Feasibility Note & Resource Planning																					
Value To Society																					
Impact Dimension																					
<ul style="list-style-type: none"> Total Estimated Annual Operational Cost: <ul style="list-style-type: none"> Per annum budget = USD 22,400 Capital (4 years) = USD 80,000 + O&M 1.34x initial Initial cost: 2025, FTW, PMFR, local materials, tool, tools, maintenance, training, 10% contingency Not included long-term capital cost (beyond 12 months), large cap works (roads), assumed self-funding contributions beyond initial investment. 																					
<ul style="list-style-type: none"> Operational Highlights <ul style="list-style-type: none"> Autonomous lifespan = Average 2 years replacement aligned with ASV calibration cycles. FTW Components = 10-20% of replacement replacing yearly ensures nutrient update performance stability. PMFR Reactors = Catalyst re-coating duration remains 10x pursuant degradation efficiency. Membrane Storage = Predictive-based system—predictive diagnosis via AI data trends, removes uncertainty. Local Repair Network = AI-based technical team handles first-line maintenance, minimizing external costs. 																					
<ul style="list-style-type: none"> Feasibility Note & Pilot Scale Adjustment <ul style="list-style-type: none"> This is a 1:1 solution (USD 207k), budget covers only a functional prototype, not a full-scale deployment. Focus = integration of data integration, small-scale pilot-scale validation, and community involvement. Final-scale implementation would need 3-5x higher capital for durable components, larger FTWs, and multi-ASV setup. Pilot data will be used to support scaling and funding processes (e.g., GreenPower, FTW, ESG, R&D research grants). 																					
<ul style="list-style-type: none"> Impact Dimension Quantified Benefit Illustration 																					
<table border="1"> <thead> <tr> <th>Impact Dimension</th> <th>Quantified Benefit</th> <th>Illustration</th> </tr> </thead> <tbody> <tr> <td>Health Impact</td> <td>30-50% reduction in bacterial load and nutrient concentration</td> <td>Lower waterborne disease risks for surrounding communities.</td> </tr> <tr> <td>Regulatory Compliance</td> <td>Supports SDG 6 (Clean water), 9 (Innovation), 13 (Climate Action)</td> <td>FTW serves as green-tech demonstration.</td> </tr> <tr> <td>Economic Multiplier</td> <td>Job creation + research & manufacturing ecosystem</td> <td>Estimated multiples >2.5 (local fabrication)</td> </tr> </tbody> </table>						Impact Dimension	Quantified Benefit	Illustration	Health Impact	30-50% reduction in bacterial load and nutrient concentration	Lower waterborne disease risks for surrounding communities.	Regulatory Compliance	Supports SDG 6 (Clean water), 9 (Innovation), 13 (Climate Action)	FTW serves as green-tech demonstration.	Economic Multiplier	Job creation + research & manufacturing ecosystem	Estimated multiples >2.5 (local fabrication)				
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Timeline Implementation					
12-Week Phased Deployment & Testing Schedule					
Phase	Week	Key Activities	Deliverables	Risk Points & Mitigation	
Phase 1 - Concept Refinement & Design (2 weeks)	Week 1-2	<ul style="list-style-type: none"> Finalize 3D CAD design for ASV hull & high-rail. Define service auto & IoT architecture. Select local materials for FTW structure & plants. Validate water system sizing. 	<ul style="list-style-type: none"> Final design documents. Procurement list. 	<ul style="list-style-type: none"> Risk: Delay in material confirmation. Mitigation: One-month local supplier (Alumina & Deposit) and reuse local inventory for prototyping. 	
Phase 2 - Procurement & Fabrication (2 weeks)	Week 3-4	<ul style="list-style-type: none"> Procure ASV body & PMFR unit. Assemble FTW modules (2 units). Purchase sensors, microcontroller, batteries. Design local power management & microcontroller logic. 	Functional ASV chassis - PMFR filtration assembly - local power system.	<ul style="list-style-type: none"> Risk: Delivery delay or subcontractor issues. Mitigation: monitor local vendor and select alternative local subcontractors (e.g., Ondoku, Tokopedia). 	
Phase 3 - Integration & Software Development (2 weeks)	Week 5-6	<ul style="list-style-type: none"> Integrate IoT sensors to ASV - Develop AI-based control (navigation & cleaning path). Calibrate FTW flow & UV intensity. Conduct planned-kick test in lab-scale. 	Pilot assembled and integrated system. Initial data stream validation.	<ul style="list-style-type: none"> Risk: Software delay. Mitigation: modular coding; follow-up to semi-autonomous manual override mode for ASV. 	
Phase 4 - Field Deployment & Testing (3 weeks)	Week 7-10	<ul style="list-style-type: none"> Install prototype at Pilot Field. Operate system under controlled observation. Collect baseline and operational WQ data. Adjust flow rate, FTW buoyancy, and solar charge. 	<ul style="list-style-type: none"> Performance log (DO, COD, TDS, pH). Visual and quantitative performance data. 	<ul style="list-style-type: none"> Risk: Weather or durability issues. Mitigation: flexible deployment window & backup test sites. 	
Phase 5 - Evaluation, Documentation, and Handover (2 weeks)	Week 11-12	<ul style="list-style-type: none"> Analysis data (baseline vs. after deployment). Prepare technical report & impact summary. Conduct handover to customer (training, operation + maintenance). Establish online data dashboard & remote support. 	Pilot evaluation report. Simplified SOP & user manual. Trained customer operations.	<ul style="list-style-type: none"> Risk: Limited user adoption. Mitigation: visual, infographic-based training materials & 2-week onboarding by core team. 	



7.

Risks, Challenges, and Mitigation

7. Risks, Challenges, and Mitigation

Risks, Challenges & Mitigation

Long-Term Maintenance

Category	Key Risk	Impact Level	Mitigation Strategy	Responsible Entity
Local Technical Resources	Limited local expertise for high-hazard system maintenance.	High	Develop on-call training programs with contractors for maintenance personnel.	Project Management Unit (PMU), Maintenance Facility
Supply Parts Availability	Delay in importing or procuring key components (e.g., sensors, batteries, actuators).	Medium	Establish partnerships with component manufacturers; maintain a minimum stock of critical parts.	Procurement & Supply Chain Team
Sensor Calibration & Degradation	Sensor drift or degradation over time reduces data accuracy.	High	Implement quarterly calibration schedules; adopt modular sensor replacement design.	Field Operations Team
Manufacturing & System Risk	Delays in initial test equipment acquisition for PTW and PdT modules.	Medium	Require extensive pre-assembly validation of PTW and PdT modules.	Field Technicians
Data System Transparency	Issues in data storage, backup, passing, monitoring, and interruptions.	Medium	Cloud-based redundancy, automatic data synchronization.	Data Management Division
Resilience of Operations	Deviating operational budget over time.	Medium	Develop hybrid funding paths (granted model and other take-on-in-service subscription).	Financial & Policy Team

Open-Source Value & Competition Risk

Category	Key Risk	Impact Level	Mitigation Strategy	Responsible Entity
Open-Source Exposure	Excessive sharing of designs, AI algorithms, or software frameworks leading to imitation.	High	Use modular code between open proprietary algorithms (e.g., closed-source).	Encourage academic collaboration while retaining proprietary code.
Competition Risk	Entry of competing systems with cheaper, but less reliable hardware.	High	Emphasize integrated performance, local adaptability, and data security as differentiators.	Develop exclusive partnership programs with local governments.
Intellectual Property (IP) Protection	Lack of clear patent or IP filing for unique components.	Medium	Register proprietary modules (IP, patents, design, PdT design) under "Grace Patent".	Build technology licensing and identify under "Grace Patent".
Market Sustainability	Short-term competition with unsustainable cost metrics.	Medium	Focus on long-term cost efficiency and long-term environmental value.	Strengthen social impact and ESG-based funding eligibility.
Knowledge Diffusion	Open-training model to transfer of operational know-how.	Medium	License-based access for advanced operational know-how and training tools.	Develop licenses from certification and training programs.

Risks, Challenges & Mitigation

Technical Risks

Category	Specific Risk / Challenge	Impact	Mitigation Strategy
Technical Risks	Hardware Import Volatility – Delays or cost spikes in sensors, control boards, or microchips; membranes sourced internationally.	Medium-High	<ul style="list-style-type: none"> Prioritize local component fabrication (e.g., sensors, mem, casings). Establish dual-sourcing agreements and maintain a small inventory buffer. Utilize modular electronics for easy substitution.
	Reliance on Local Supply Chain Maturity – Limited domestic vendors for precision sensors or AI hardware.	Medium	<ul style="list-style-type: none"> Partner with universities and local startups for co-development. Implement component certification program to assure quality. Gradually locate manufacturing through government-supported programs (e.g., NEDO).
	Regulatory Delays – Extended approval time for permits or environmental assessments.	Medium	<ul style="list-style-type: none"> Conduct early stakeholder engagement with BOMS, OSHA, EPA, and local administration. Prepare template documentation for OSHA-CPL and safety submissions. Include a buffer timeline in-project Gantt chart (min. +3 months).
	Force Exposure & Physical Damage – Floods, debris impact, or vandalism.	High	<ul style="list-style-type: none"> Design weather-resistant (dust, moisture, shock-absorbing) cases. Install protective booms and debris screens near PTWs. Implement CCTV or AI-based surveillance integrated with ADG telemetry. Community engagement for shared guardianship.

8. Conclusion & Next Steps



World Water Challenge 2025

Conclusion

■ Summary of Key Innovations and Outcomes

The Damai WaterGuard System demonstrates a transformative, data-driven approach to water quality restoration—integrating Autonomous Surface Vehicles (ASVs), Floating Treatment Wetlands (FTWs), and Photocatalytic Hydrodissolution Reactors (PHRs) within an AI-driven, closed-loop ecosystem. The Kuningan pilot has validated the operational feasibility and data reliability of this hybrid platform, achieving measurable reductions in nutrient and heavy metal concentrations, while maintaining cost efficiency and real-time monitoring capacity.

- Key technological outcomes include:
 - Immediate Impact – Rapidly improves Water Quality Index (WQI) and pollutant levels through synchronized ASV-FTW-PHHR operations.
 - Scalable by Design – Modular architecture allows replication across multiple polluted zones – from Banua, Kuningan to the Citarum watershed and beyond.
 - Data-Centric Resilience – AI-based monitoring and adaptive algorithms enable predictive responses, ensuring long-term water health.
 - Circular Sustainability – Minimizes waste, reduces energy demand, and respects natural balances for regenerative outcomes.
 - Community Engagement – Engages volunteers and local communities with accessible insights and simple operational protocols.

■ Roadmap to Scale and Commercialization

Focus Area	Objective	Planned Outcome
All Network Expansion	Scale from single-unit to multi-ASV coordinated swarm	Full-spectrum monitoring of Saguling's inflow zones
FTW Deployment	Large-scale (co-)remediation module integration	>80% nutrient and organic pollutant reduction
PHHR System	Continuous-flow polishing and advanced filtration	High-quality treated water suitable for ecosystem recovery
Community & Policy Engagement	Collaborate with local authorities and researchers	Establish Citarum as a national model of smart water governance

Global Vision

- From Indonesia to the World
 - What begins in Damai Kuningan becomes a blueprint for sustainable smart water management adoption in polluted rivers, lakes, and coastal regions worldwide.
- Cross-Sector Collaboration – Encourages joint innovation between academia, industry, and local governments to create measurable environmental returns.
- Future-Proof Infrastructure – Builds the foundation for an era where clean water access is not a privilege – but a right powered by technology.

Damai WaterGuard is not just a prototype, it's a testament towards an intelligent, circular, and data-driven water remediation ecosystem. It reshapes how we restore water – autonomous, adaptive, and accessible for all. It truly represents a future where technology, data, and humanity converge – to restore ecosystems, empower humanity.

Damai WaterGuard – From a water crisis to a global movement.

MEMO

Korea International Water Week 2025

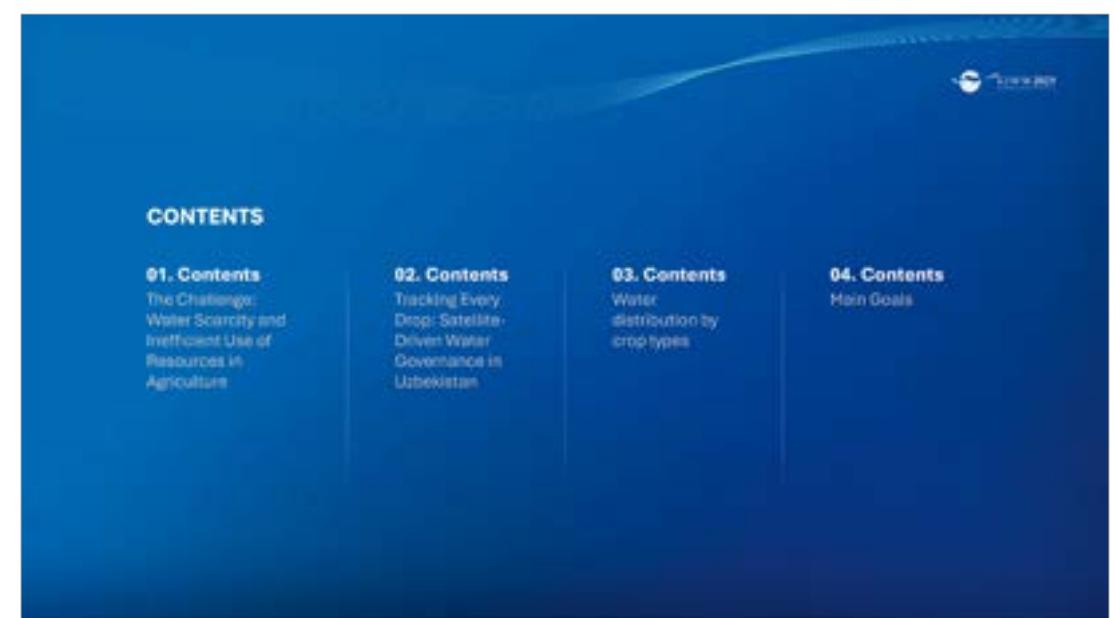
THANK YOU

Oryza Sativa Afra Iftikar | University of Indonesia

Ministry of Environment, Republic of Korea | Korea Water Resources Corporation | K-water | Korea Water Week

Monitoring of Water Consumption and Water Productivity in irrigated Lands of the Fergana

Jakhongir Iskhakov
(Uzcosmos)





The Challenge: Water Scarcity and Inefficient Use of Resources in Agriculture

Context

- Central Asia faces increasing water scarcity due to climate change, population growth, and intensive irrigation.
- Over 80% of Uzbekistan's freshwater resources originate from neighboring countries, making national water management highly vulnerable to regional dynamics.
- Agriculture consumes more than 80% of available water, yet a significant portion is lost through inefficient irrigation and distribution systems.
- Existing monitoring methods rely on manual data collection and outdated reporting, which lack accuracy and timeliness.

Core Problem

- No precise and up-to-date data on actual water consumption at the field level.
- Limited ability to detect water stress zones and inefficiencies in real time.
- Insufficient analytical tools for evidence-based decision-making at national and regional levels.

Why It Matters

- Unsustainable water use threatens food security, ecosystem health, and climate resilience.
- There is an urgent need for data-driven management systems to optimize water use and strengthen regional water security.

“THE LAST MILE” IN WATER MEASUREMENT

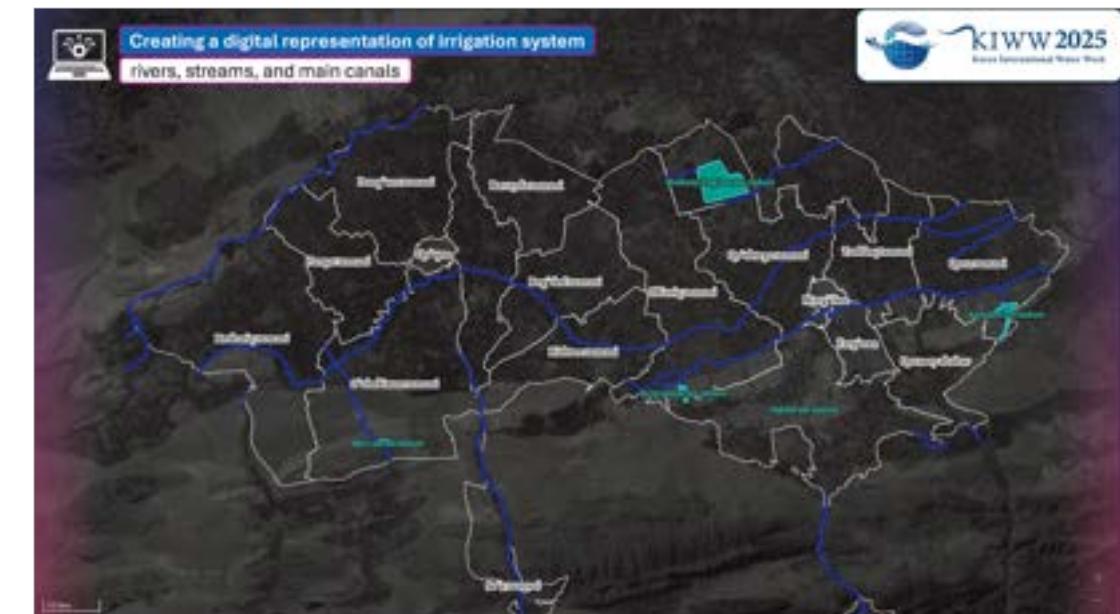
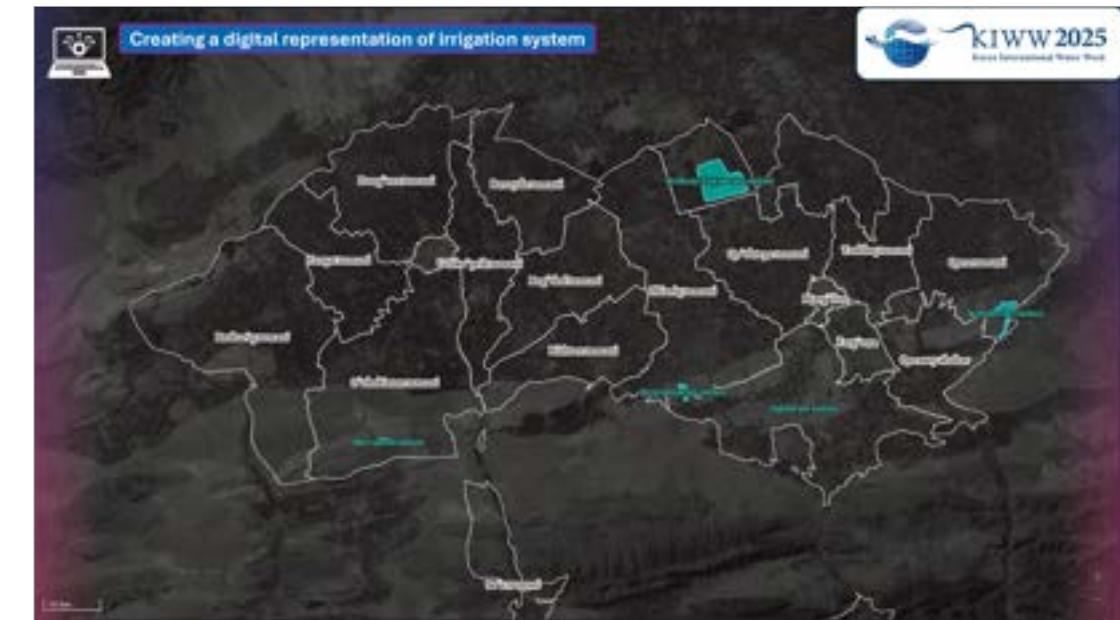
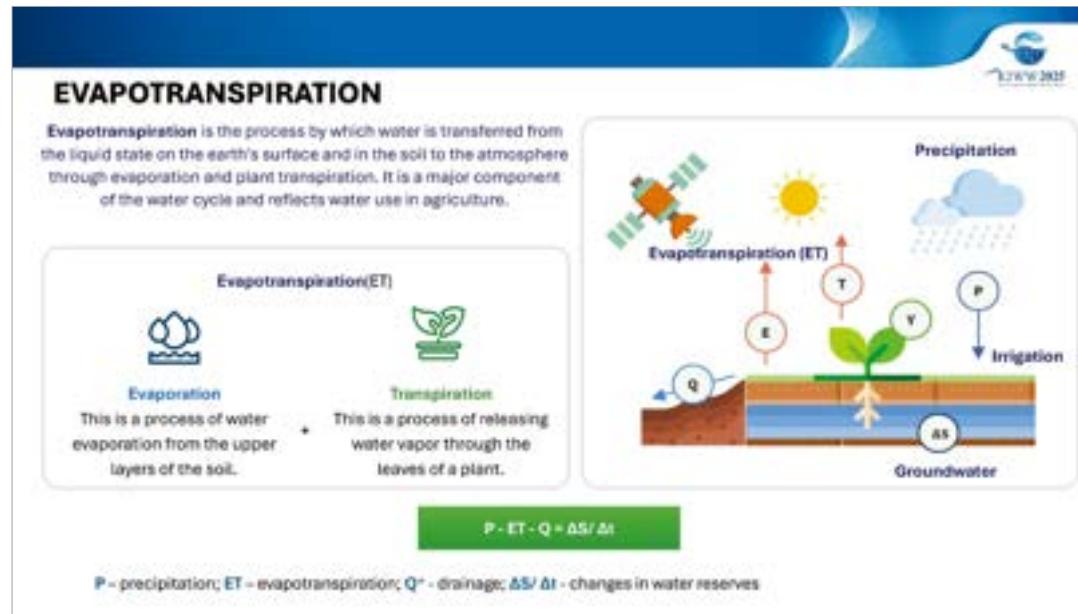
Rivers and reservoirs → Channels → Irrigated fields

Hydrological stations → Sensors → ???

Satellite technologies help to track the dynamics and volumes of water consumption to the so-called “last mile” – to the level of an individual field

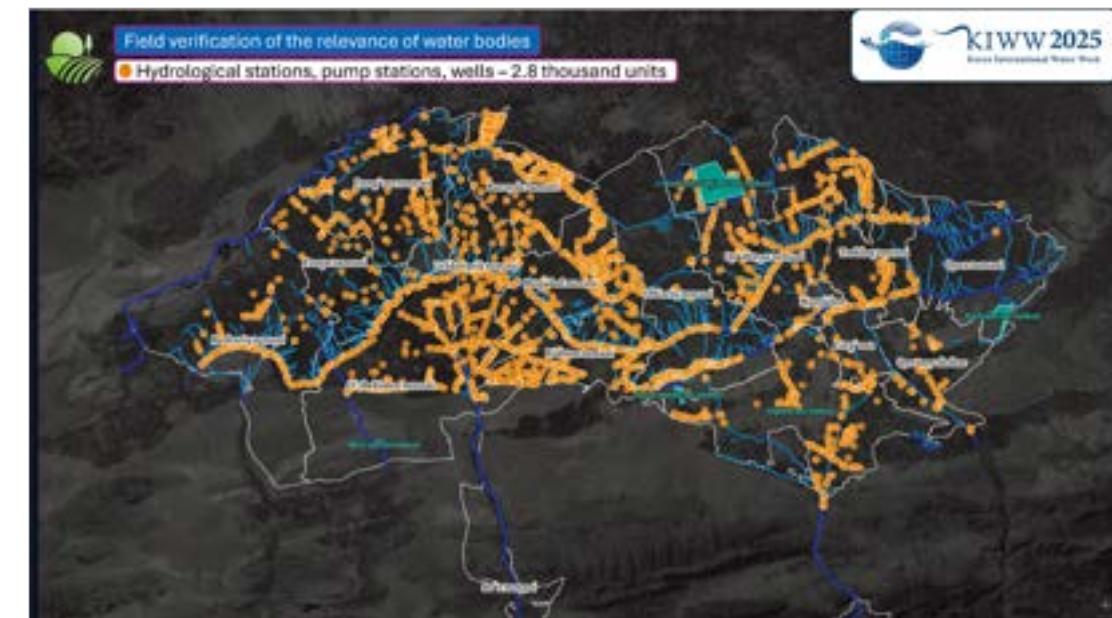
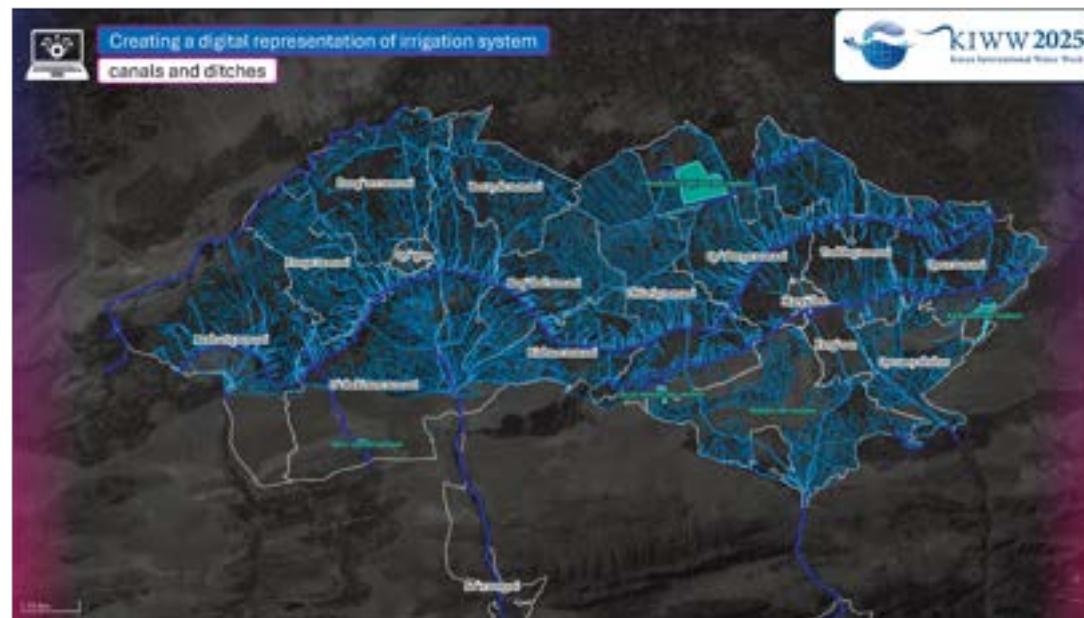
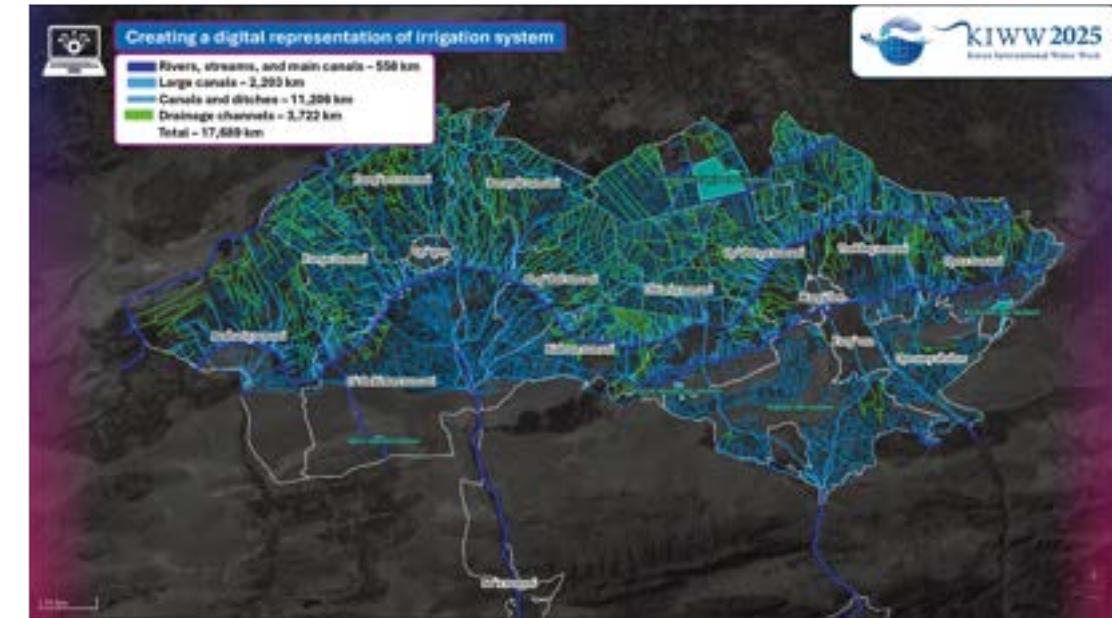


World Water Challenge 2025



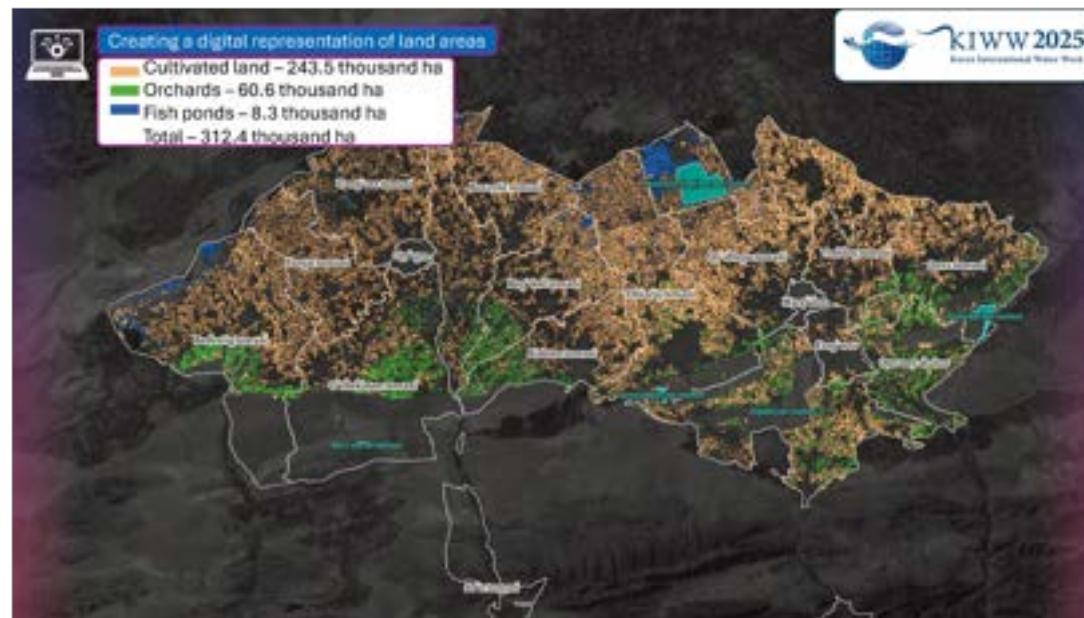
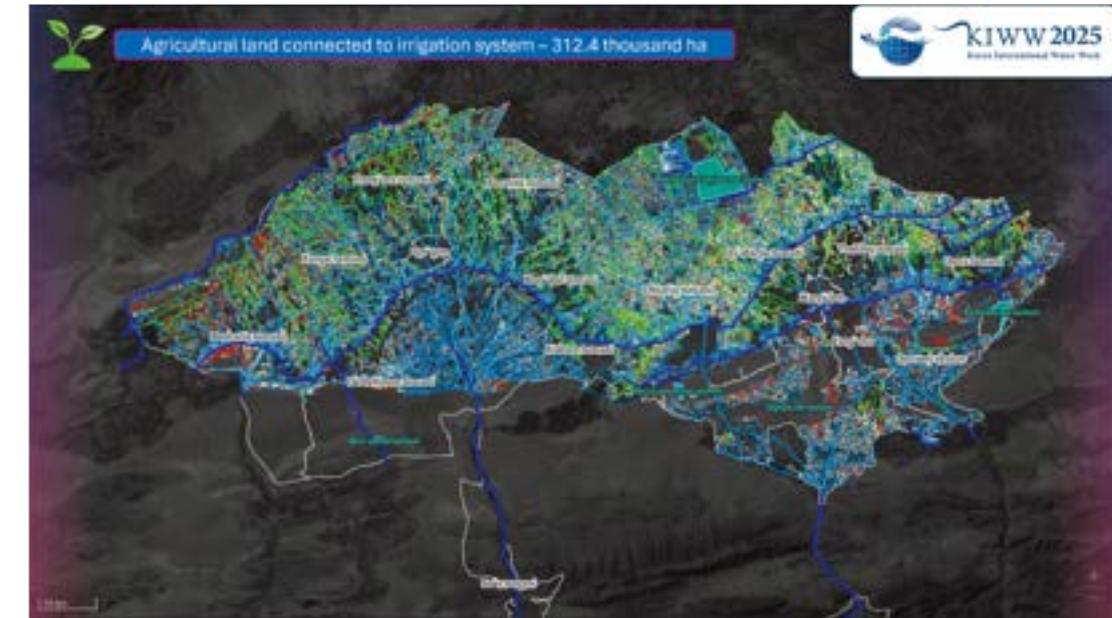


World Water Challenge 2025



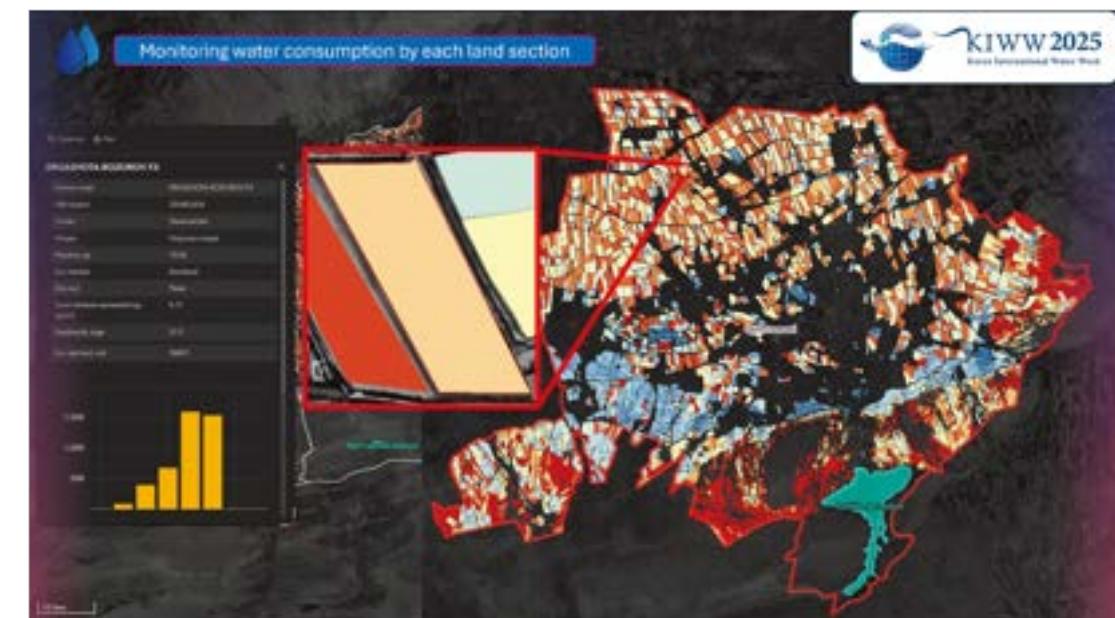
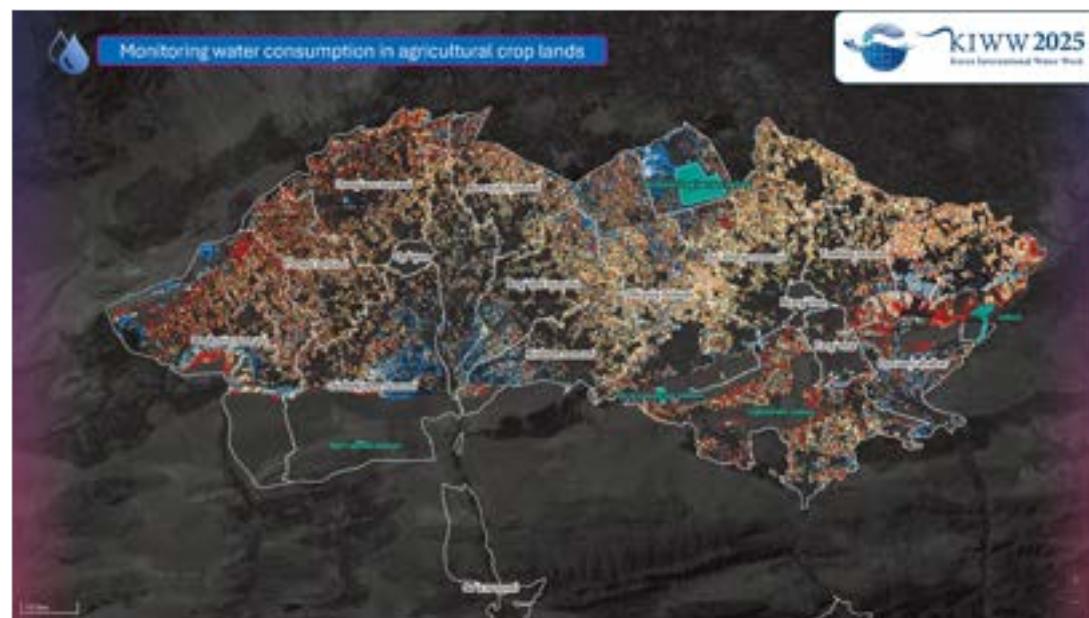
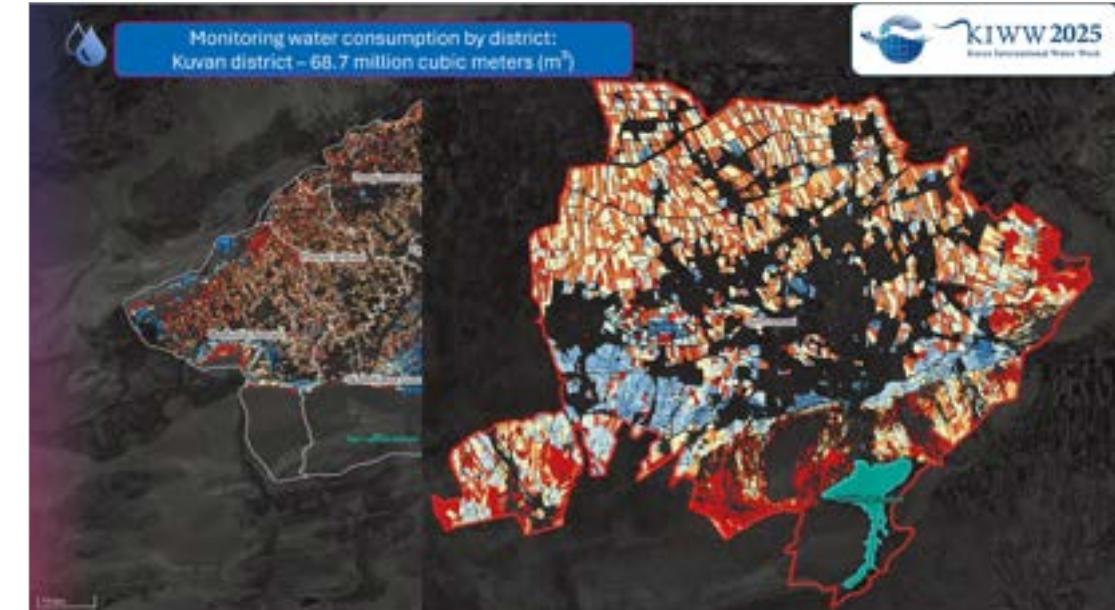
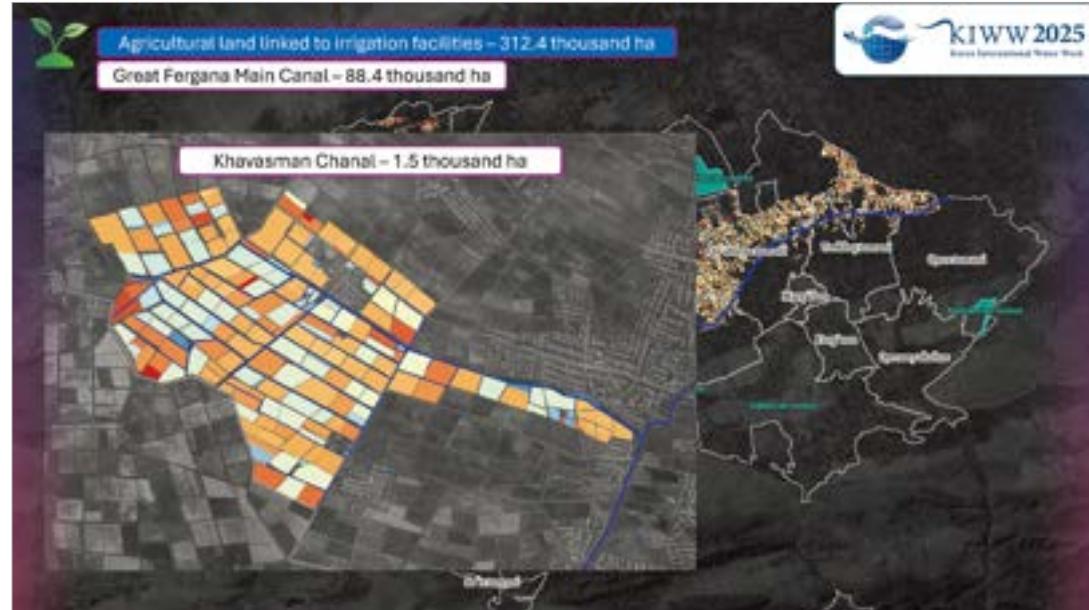


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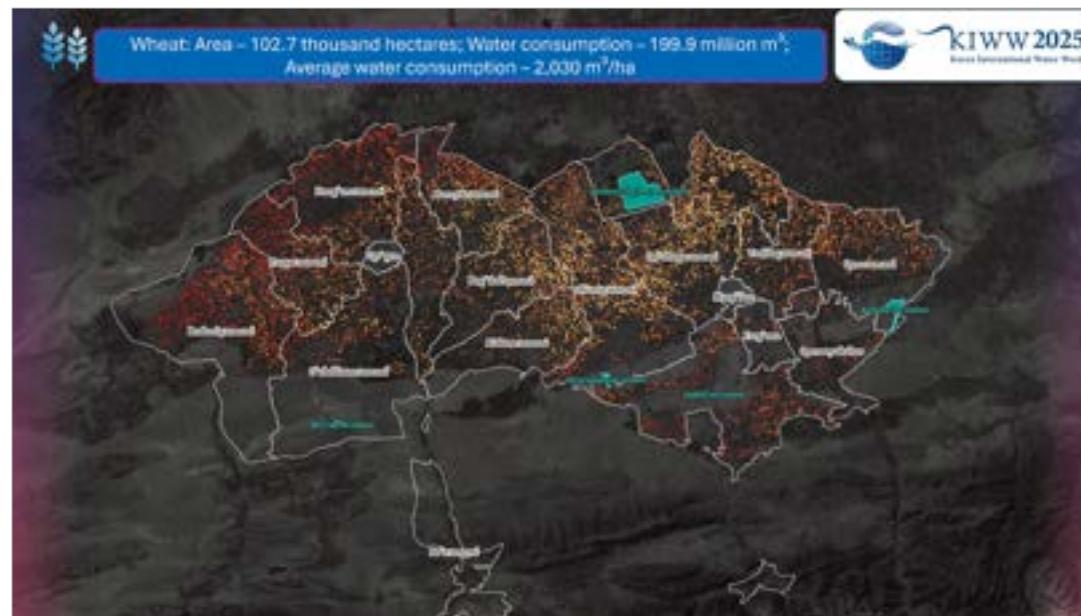
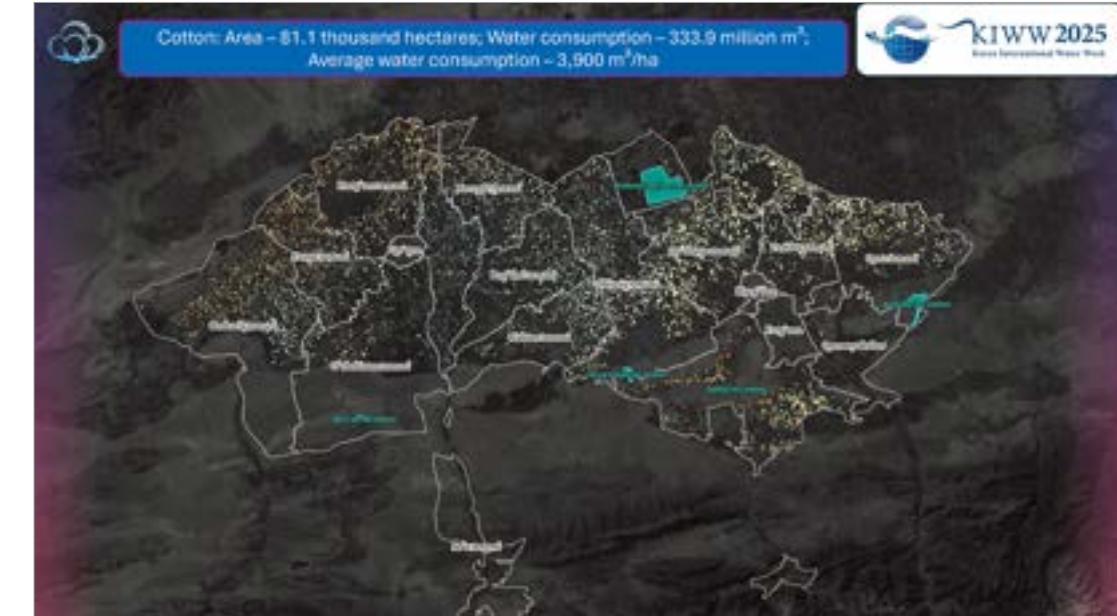
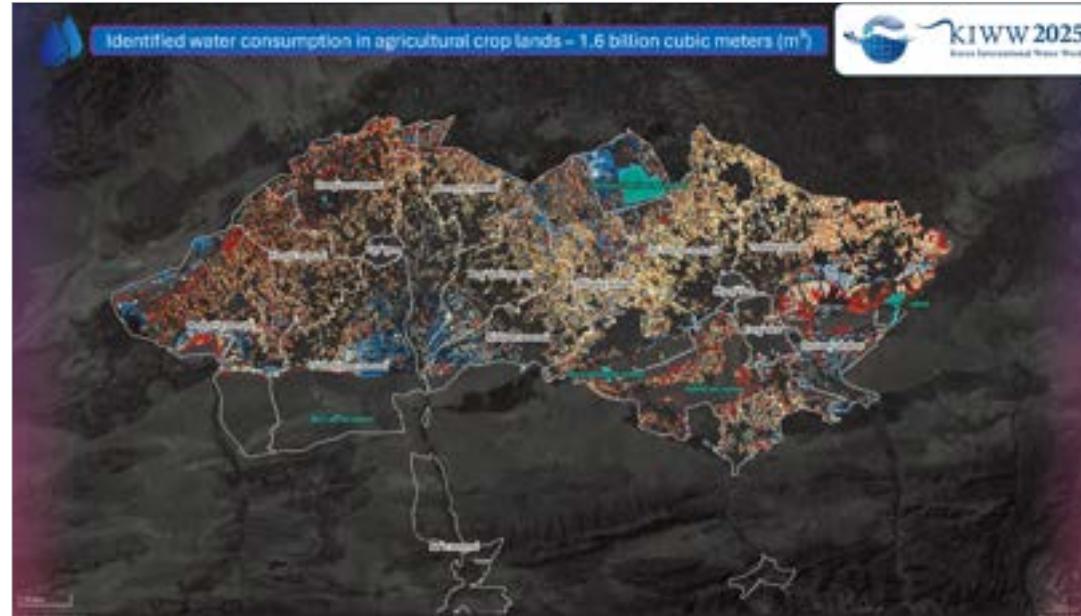


World Water Challenge 2025





World Water Challenge 2025





World Water Challenge 2025



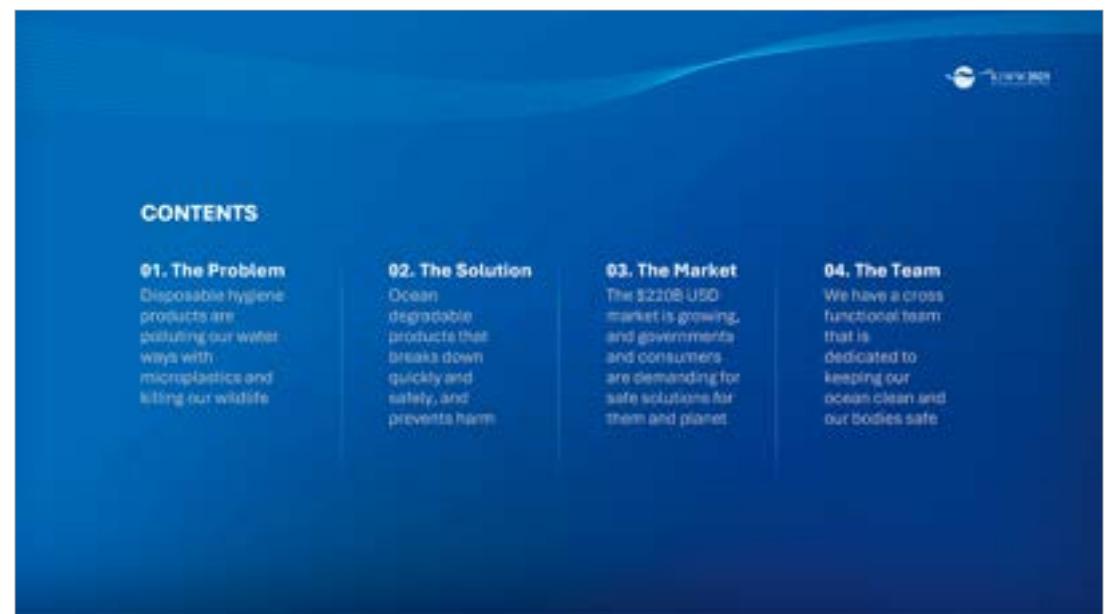
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Aruna Revolution: Circular Fiber Innovation for Aquatic Health and Hygiene Equity

Rashmi Prakash
(Founder)

World Water Challenge 2025





World Water Challenge 2025

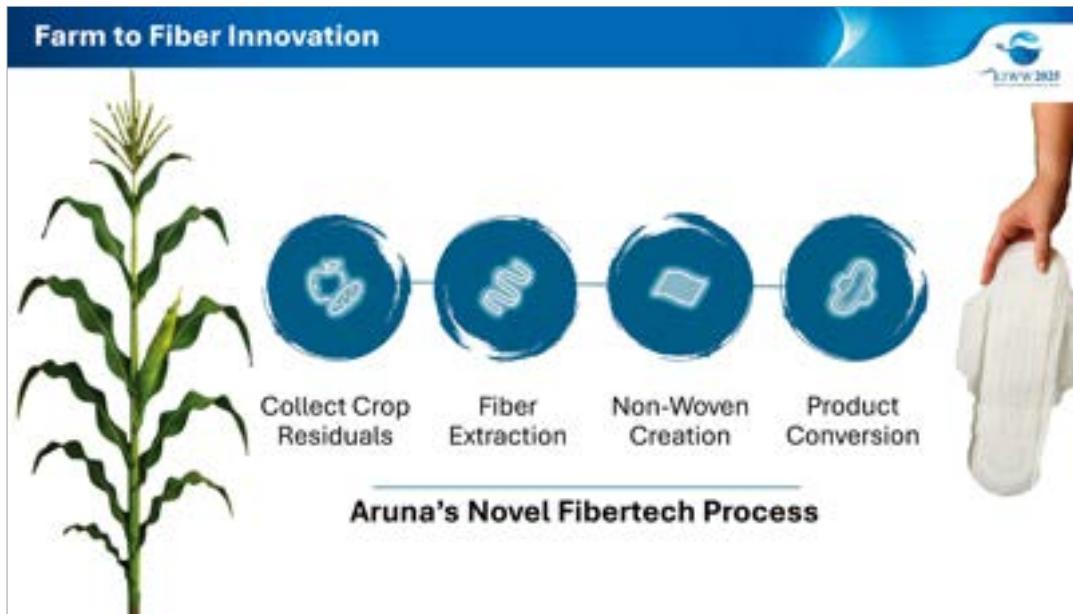


1. The Problem





World Water Challenge 2025





World Water Challenge 2025

3. THE MARKET

Unlocking a \$220 Billion Global Market

Total Addressable Market
Global Disposable Hygiene Product Market

\$220 Billion 2030, 4.6% CAGR

Regulatory Tailwind
Governments globally, including Korea and the EU, are advancing zero-plastic initiatives to protect waterways and oceans.

Major brands (P&G, Unilever, Kimberly-Clark) pledging to eliminate single-use plastics by 2030

Scalable, High Impact Growth

Aligned with Korea's ocean protection and circular economy initiatives



Menstrual Pad Sales
Early revenue + brand & fiber awareness

Fiber Licensing
High Margin, recurring B2B deals

Carbon Credit Monetization
Verified emissions reductions

Why This Works:

- “Powered by Aruna Fibers” creates brand equity for channel partners.
- Licensing enables scale & recurring revenue without heavy CapEx.
- Proven model used by Nvidia, Gorilla & Intel Inside

4. THE TEAM

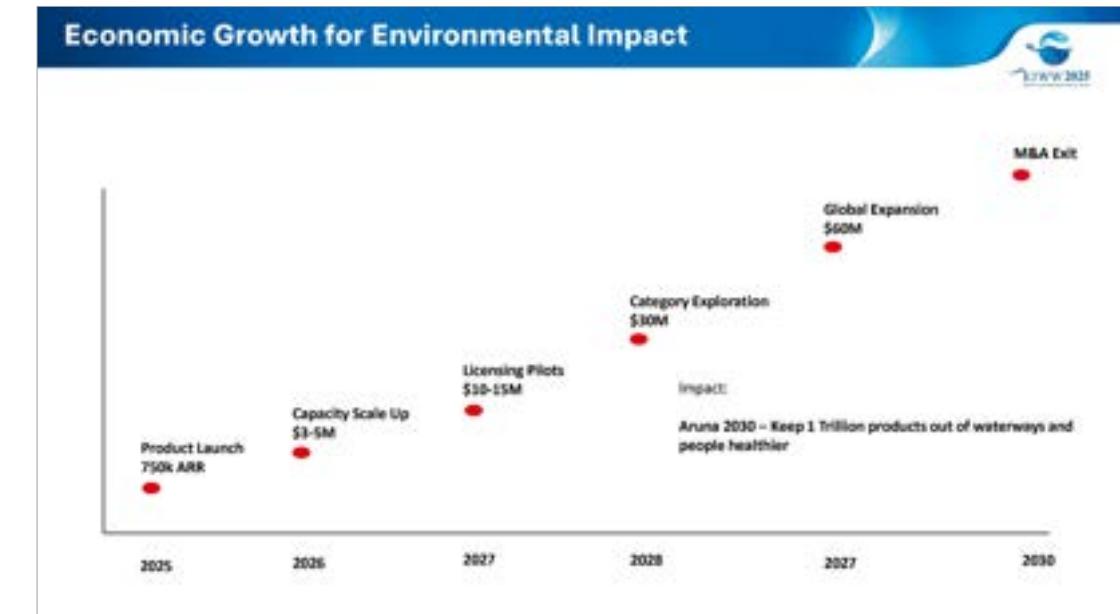


World Water Challenge 2025

Team Aruna – Engineered to Protect the Ocean & Planet

Our Team's Key Milestones

1. Proven Market Demand
 - \$750K ARR in 2025
 - In hospitals, airports, universities
 - Interest from 9+ Verticals
 - In discussion with KC for Huggies
2. Global Footprint & Organic Growth
 - Sold in Canada, Singapore, UK, US, Monaco
 - 100% organic sales & growth
3. Validated & Protected Technology
 - Third Party Verified & Certified
 - IP protected in multiple markets



Team Aruna – Engineered to Protect the Ocean & Planet

John P.
30+ years
Hygiene Product Material Innovation Director
Johnson & Johnson

Vlad N.
30+ years
Hygiene Product Manufacturing Director
P&G

Richard B.
30+ years
Product & Business Development Executive
Nestle

Partners & Affiliations:

- YSpace
- CREATIVE DESTRUCTION
- Emera ideaHUB
- L2M Launch
- MaRS
- III51
- LEAGUE of INNOVATORS





MEMO

A scalable Machine-learned based Framework for cost-effective Sewer Leakage Detection

Muratbekov Erkin
(USTA INTERNATIONAL)

World Water Challenge 2025





World Water Challenge 2025

The Problem: Seasonal Water Imbalance Caused by Glacier Retreats

Seasonal Water Imbalance vs. Peak Meltwater Period

1968 — Glacier coverage area

Current glacier extent

Consequences of water imbalance

Dynamics of natural glaciers

+ 30-40%

USTA 2025

The Product: Glacier.AI — USTA Climate+ Integrated Methodology (Sustainable Engineering, AI Monitoring & Eco-Scientific Tourism)

USTA Climate+
Engineering & Infrastructure
AI & IoT Monitoring
Eco-Scientific Tourism
Community Impact & Replication

AI-USTA
Artificial Glacier
in Akau Valley
Historical Data
1968
Current Area
40

Water Imbalance
Glacier Buffer
15,000 m³
Water Imbalance
Glacier Buffer
15,000 m³

Data source as artificial glacier

AI
IoT
Monitoring
Eco-Scientific Tourism
Community Impact & Replication

USTA 2025

The Solution: Seasonal Smart Water Buffer System

Guaranteed amount of buffer water of over 5,000 m³ per 1 rack of the Artificial Glac.

USTA 2025

Market Opportunity: From Pilot to Regional Scale

6 million \$ (3,000 hectares)
- pilot region of Kyrgyzstan - the Osh Valley

400 million \$ (1 million hectares)
- the entire Kyrgyz Republic

20 billion \$ (10 million hectares)
- Central Asia

100 billion \$ (global market)
- World

6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
13 CLIMATE ACTION

KAZAKHSTAN
TURKMENISTAN
SIBERIA
CHINA
KYRGYZ REPUBLIC
AFGHANISTAN
PAKISTAN
INDIA
SRI LANKA
BANGLADESH
CHINA
INDIA
SRI LANKA
BANGLADESH

USTA 2025



Eco-Scientific Cluster Network

- Eco-Tourism**
 - AI & Data Service Contracts (Glacier.AI SaaS + O&M)
- Research & Education Programs**
 - Local Food & Crafts Sales
- Artificial Glacier Demonstration**
 - Glacier

From Glacier Engineering to Green Investment — the Journey Starts in Mady Kyrgyzstan

CAPEX	Revenue	NET PROFIT	ROI	PB	IRR
500 000\$	210 000\$	140 000\$/y.	28 %	3.5 years	24% (10 years)

Location: Mady Valley, Osh Region, Kyrgyz Republic

Concept: Eco-scientific tourism cluster with artificial glaciers as the central attraction

Components:

- 10 artificial glaciers (Seasonal Smart Water Buffer Systems)
- Glamping park (20 eco-units)
- Science pavilion and climate lab
- Local food market & educational trails

Construction starts in the second quarter of 2026



World Water Challenge 2025



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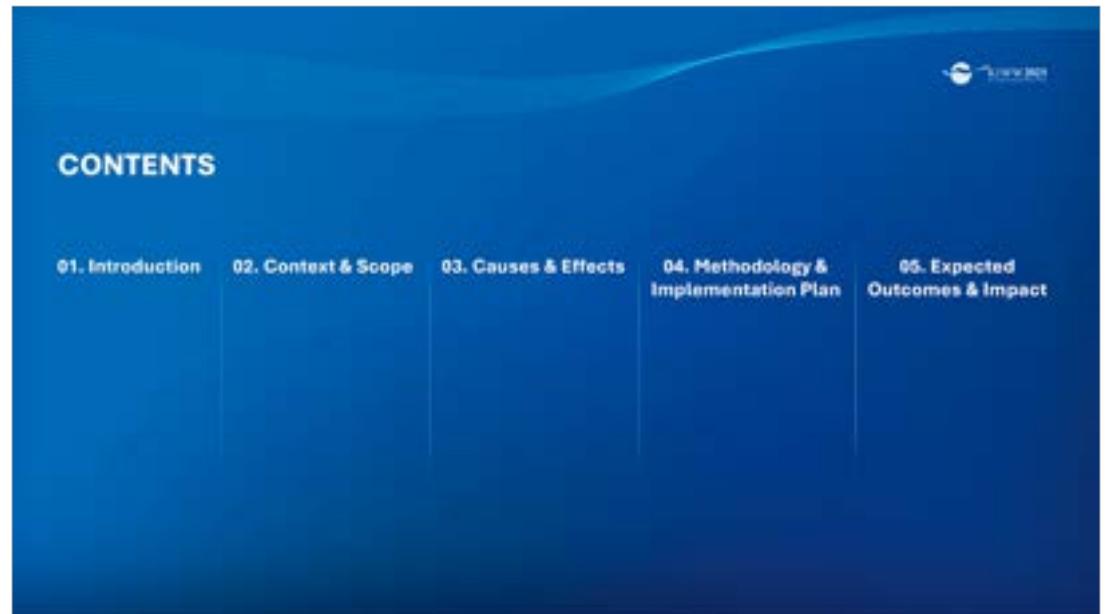


Small Habits, Big Thirst: Smart Behavioral Water Management in Pakistan & South Africa

Hafsa Masood
(FFCG)



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1. Introduction

2. Context & Scope

Introduction:

- Over-watering, open taps, and single-use bottles.
- Waste nearly 1.2 billion liters of drinkable water every year.
- Lahore, Pakistan loses about 20 million liters per day due to pipeline leaks.
- The "Day Zero" crisis reduced water use from 200L + 87L/day which shows the power of behavioral change.

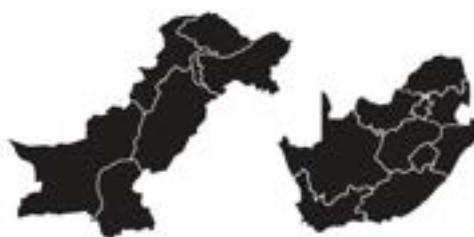


Figure 1. Vector Maps of Pakistan and South Africa

Context & Scope:

- **Geographic focus:**
 - Pakistan: Major urban centers (Lahore, Karachi) and peri-urban agricultural belts.



Figure 2. Vector Maps of Lahore and Karachi



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Context & Scope:

Geographic focus:

- South Africa: Cape Town metro area and adjoining farmlands.

Provinces
Northern Cape
Western Cape
North-West
Free State
Gauteng
Limpopo
Mpumalanga
Eastern Cape
KwaZulu-Natal

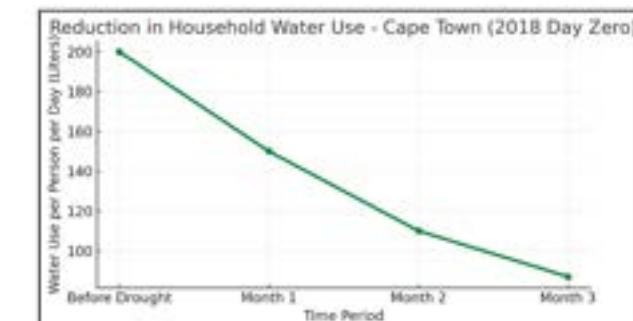


Figure 3. Vector Map of South Africa

Context & Scope:

Local Data & Case Studies

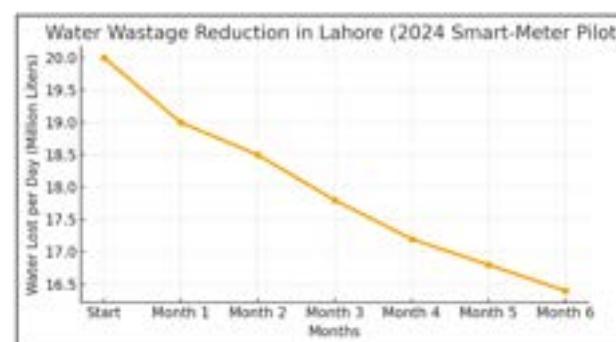
- Cape Town, South Africa: Day Zero drought (2018) reduced average household use from 200 L to 87 L/day; adoption of drip irrigation yielded a 40 % drop in garden water use within three months.



Context & Scope:

Local Data & Case Studies

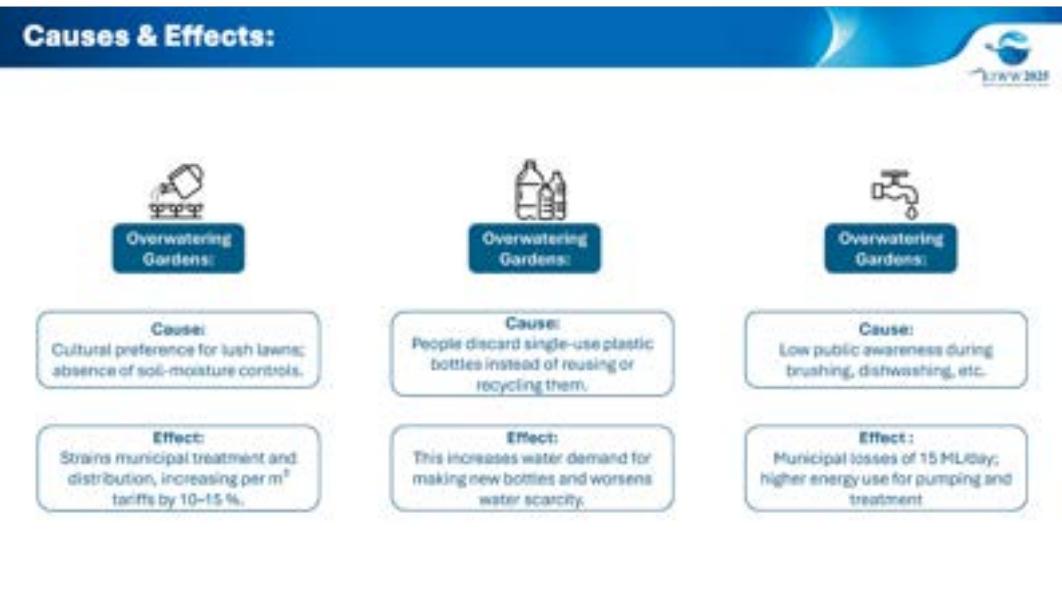
- Lahore, Pakistan: Municipal report (2024) records 20 ML/day lost through undetected household leaks; a pilot smart-meter program cut residential waste by 18 % in six months.



3. Causes & Effects



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Methodology & Implementation Plan:

Phase	Activities	Timeline
1. System Design & Pilot	<ul style="list-style-type: none"> Develop IoT sensor prototypes (leak, flow, soil-moisture) Adapt sensors for the municipal network 	Jul 2025 – Dec 2025
2. Community Engagement & Rollout	<ul style="list-style-type: none"> Pilot in 100 households (Cape Town) Pilot in 100 households (Lahore) Train local water utility staff & farmers (Karachi region) Launch refit station network (10 sites) Workshop with City of Cape Town 	Jan 2026 – Jun 2026
3. Evaluation & Optimization	<ul style="list-style-type: none"> Refine algorithms & hardware Optimize soil-moisture thresholds Collect usage data & user feedback Analyze Cape Town pilot results 	Jul 2026 – Dec 2026
4. Scale-up & Sustainability	<ul style="list-style-type: none"> Hand over to the local water boards Establish maintenance & funding model Expand to 5 additional Pakistani cities Expand to 5 additional South African metros 	Jan 2027 – May 2027

4. Methodology & Implementation Plan

Methodology & Implementation Plan:

Resources Required:

- Hardware:** 2,000 IoT sensors, gateway devices, mobile app maintenance
- Personnel:** 4 engineers, 6 community engagement officers, 2 data analysts
- Budget:** USD 250,000 (development, procurement, training, operations)
- Partners:** Local water utilities, municipal governments, NGOs

Risk	Likelihood	Mitigation
Technical failures	Medium	Redundant sensors; field-service protocol
Low user adoption	Medium	Incentives, user-training workshops, ongoing support
Funding shortfalls	Low	Phased budgeting, co-funding agreements with utilities
Data privacy concerns	Low	GDPR-style data policies, anonymized usage statistics



5. Expected Outcomes & Impact

Expected Outcomes & Impact:

Long Term Vision:

- An open-source platform to help cities manage water more efficiently.
- Local water boards and authorities will lead operations and maintenance.
- Expansion planned for five additional cities in both Pakistan and South Africa.
- Communities stay actively engaged through accessible, real-time water data.



Expected Outcomes & Impact:

Small Habits, Big Thirst: Smart Behavioral Water Management in Pakistan & South Africa

Every Drop Counts Beyond Borders

Together, we can turn small habits into lasting change.

Let's make every drop count — for people, for cities, and for our shared planet.



Figure 4: Smart Behavioral Water Management System

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International Week of Water | Nov 2025



NileSmart: Community-Centered Water Stewardship for a Resilient Egypt

Walid Rezk

(Suez University)



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1. The Challenge

The Challenge: Navigating Egypt's Water Stress

- Nile Dependency**
 - Egypt relies almost entirely on the Nile River for its freshwater needs, making it highly vulnerable to external factors and resource management issues.
- Compounding Stresses**
 - The nation faces severe water stress due to escalating climate change effects, upstream geopolitical challenges, inefficient traditional irrigation methods, and rapid population growth.
- Growing Deficit**
 - Despite resourcefulness, Egypt's annual water deficit currently exceeds 30 billion cubic meters, necessitating urgent, scalable solutions.



NileSmart: A Holistic Approach to Water Resilience

NileSmart is a groundbreaking initiative designed to tackle water scarcity by fusing tradition, culture, and frugal innovation into a community-led model.

Traditional Knowledge
Leveraging centuries of water management experience from Nile cultures to inform modern practices.

Behavioral Change
Using cultural tools like storytelling and arts to instill a sense of water stewardship and sustainable habits.

Low-Tech Innovation
Deploying simple, locally-sourced, and affordable technologies for immediate, impactful results in water conservation.
Our core objective is to reduce waste, improve local water governance, and build climate resilience at the grassroots level.

- Three Pillars of NileSmart Action**
 - 1. Smart Basin Literacy Campaigns**
 - 2. Low-Cost Harvesting & Reuse Units**
 - 3. Women & Youth Water Committees**
 - Establishing local governance groups empowered by mobile technology for real-time reporting of leaks, misuse, and maintenance needs.

Impactful Field Applications

Applications

- Our pilot program demonstrated strong community ownership and sustainable practices in the Menoufia and Suez governorates.
- Community Integration**
- Collaborations established with local schools, mosques, and agricultural unions for maximum reach and participation.
- Resourceful Tools**
- Focus on utilizing local, readily available materials for unit construction, complemented by user-friendly mobile technology.
- Long-Term Ownership**
- The community-led model ensures high local ownership, making the project inherently sustainable and resilient against external funding fluctuations.

Contributing to Global Sustainability

- Environmental**
 - Increases water reuse rates
 - Reduces pressure on Nile ecosystems
 - Promotes climate-smart agriculture
- Social**
 - Empowers marginalized women and youth
 - Fosters social bridges water literacy gaps across generations, cohesion and local governance
- Economic**
 - Creates local jobs in unit construction and maintenance
 - Reduces household expenses on water and energy
 - Prevents significant crop loss due to water stress



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Cost-Effectiveness and Scalability

Frugal Design, Massive Reach

- Unit Cost:** Less than \$50 per household unit.
- Materials:** Simple, locally sourced items like plastic barrels, gravel, sand, and mesh.
- Financing:** Achieved through community co-financing, supported by small microgrants and local government partnerships. The low-cost, decentralized nature allows for rapid adoption across the Nile Basin and similar African regions facing water stress.
- Scalability:** The low-cost, decentralized nature allows for rapid adoption across the Nile Basin and similar African regions facing water stress.

Year	Households Reached (approx.)
Pilot (2015)	1,000
Phase 1 (2020)	10,000
Phase 2 (2025)	20,000
Full Scale (2030)	80,000

Our Vision for the Future

- NileSmart is ready to move beyond the pilot phase and become a foundational element of regional water management.**
- Regional Expansion:** Extend the model to other water-stressed regions across the broader Nile Basin.
- Strategic Partnerships:** Collaborate with international NGOs, local civil society organizations, and universities for technical support and outreach.
- Curriculum Integration:** Work with the Ministry of Education to formally integrate NileSmart's literacy concepts into national water education curricula.
- Global Alignment:** Directly align project outcomes with the United Nations Sustainable Development Goals (SDGs) 6 and 13.
- SDG 6**
- SDG 13**
- Ensure availability and sustainable management of water and sanitation for all.**
- Take urgent action to combat climate change and its impacts.**

Originality and Core Innovation

- NileSmart's uniqueness lies in its cultural deep-dive and commitment to accessible, low-barrier technology.**
- Cultural Fusion:** We blend ancient Egyptian water culture and knowledge systems with modern participatory design principles.
- Behavioral Arts:** The use of poetry, folk theatre, and communal storytelling is a novel, high-engagement method for driving long-term behavioral change in water use.
- Frugal Innovation:** Prioritizing simple, affordable, and durable 'frugal innovation' over complex, capital-intensive technology, making it perfectly suited for rural and underserved communities.
- Future Projection:** With successful scaling, we project the NileSmart model can save 1 billion cubic meters of water per year by 2030.
- Quantifiable Impact from Pilot Projects:**
- Initial results from Menoufia and Suez demonstrate the project's powerful potential for immediate resource conservation.**
- 70% Reduced Water Use:** Percentage of participating households that reduced their water consumption by 20-30%.
- 500+ Children Engaged:** Number of students who actively participated in water literacy and practical application programs.
- 15+ Incidents Prevented:**
- Major leak and misuse incidents identified and resolved early through women's committee mobile reporting.**
- Crucially, women-led maintenance efforts across the pilot sites ensured the longevity and sustained performance of the low-cost water units.**



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Resilient Water Pods: Solar-Powered Water Access and Household Distribution in Rural Karakalpakstan

SHAYXISLAM SEYTIBAEV

(UZB, BETA VERSION SOLUTIONS LLC, ceo)



Resilient Water Pods: Solar-Powered Water Access and Household Distribution in Rural Karakalpakstan

Uzbekistan

Presenter: Shayxislam Seytbaev, CEO of Beta Version Solutions LLC

Problem Statement

The Challenge

- Rural Karakalpakstan faces water scarcity and high contamination from the Aral Sea crisis.
- Over 60,000 people lack stable access to clean water.
- Water transport is costly and relies on diesel-based systems.
- Lack of solar-powered, decentralized water access infrastructure.



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Problem Statement



- The Challenge
 - Rural Karakalpakstan faces **water scarcity** and **high contamination** from the Aral Sea crisis.
 - Over **60,000 people** lack stable access to clean water.
 - Water transport is costly and relies on **diesel-based systems**.
 - Lack of **solar-powered, decentralized water access infrastructure**.

Impact & Achievements



- **15,000 households (60,000 residents)** served in 2025.
- Reduction in **diesel consumption** by 80%.
- Increased access to **affordable clean water** (70% cost per liter).
- **Empowered 25 women** trained as community operators.
- Strong support from **local government** and **community councils**.

Solution



- The Challenge
 - **Modular solar-powered water purification pods** designed for rural areas.
 - Converts **ground or canal water** into **potable water** using solar energy and ceramic filtration.
 - **IoT dashboard** for monitoring usage and maintenance.
 - Already **7 pilot pods installed** in Nukus District.



Scale-up Vision & Funding Need



- Goal: Expand to **100 pods** across 10 rural districts by 2027.
- Seeking **\$150,000 USD** co-financing for phase 2 deployment.
- Partnerships with **UNDP, OPEC Fund, and Korean tech partners**.
- Long-term goal: integrate solar-water pods into **Uzbekistan's rural infrastructure policy**.



Why Solar Water Pods Matter

- Aligned with SDG 6 (Clean Water) and SDG 7 (Clean Energy).
- Community-driven innovation with proof of success.
- Replicable model for Central Asia's water-stressed zones.
- Together, we can ensure every rural family in Kazakhstan drinks clean water.



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