A.W.A.R.E.

Agent for Water Autonomy, Resilience, and Efficiency

CMPE-272: Enterprise Software Platforms — San José State University (Fall 2025)

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GitHub: https://github.com/raymondli01/aware-water-agent

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Abstract

A.W.A.R.E. is a proactive, self-healing AI agent for municipal water utilities that couples a digital twin with a multi-agent decision system. It anticipates failures (e.g., leaks), orchestrates autonomous responses (valve isolation, pump scheduling), and optimizes energy use while preserving safety and compliance. This document applies a Design Thinking approach (*Empathize, Define, Ideate*) to de-risk the product and align it with operator workflows, trust requirements, and measurable outcomes.

Contents

1 Executive Summary

- **Objectives:** Reduce non-revenue water (NRW) and outage minutes via earlier detection and isolation; lower energy cost per million gallons (MGal) through demand/price co-optimization; increase operator trust with explainable recommendations and full auditability.

2 Empathize

2.1 Research Goal

Deeply understand users, their context, and constraints in live water-utility operations.

2.2 User Research Plan

Who. Primary: control room operators, field technicians, asset managers, SCADA engineers. Secondary: sustainability officers, finance/CFO analysts, public works leadership, call center reps. Tertiary: residents in impacted pressure zones; regulatory auditors.

How. Semi-structured interviews (45–60 min); contextual inquiry and shadowing; artifact analysis (incident reports, SCADA alarm logs, energy bills, leak tickets, valve maintenance logs); baseline surveys (alarm fatigue, response times, confidence and tooling satisfaction); de-identified telemetry sampling (pressure, flow, acoustic) with security review.

What we'll study. Leak/contamination decision workflows; pain points including alarm fatigue and GIS/SCADA mismatches; current KPIs (NRW, MTTD/MTTR, energy spend/MGal, outage minutes); expectations for autonomy and auditability; regulatory/reporting constraints.

2.3 Interview Excerpts

- "During storms, the alarms light up like a Christmas tree. We mute half because we know they're noisy." — Control Room Operator
- "If a 6-inch main pops at 2 AM, finding the right valve sequence fast is roulette unless the GIS is perfectly up to date." — Field Tech
- "Our energy spend spikes when we're forced to refill tanks during on-peak. Demand forecasting is guesswork." — Asset Manager
- "Contamination false positives are rare but terrifying—nobody wants to be the one who missed it." — SCADA Engineer

2.4 Interview Transcripts & Observation Notes

Method: semi-structured, 45–60 minutes each; shadowing during two alarm bursts.

Control Room Operator (Night Shift) **Q:** Walk me through a typical alarm burst.
A: "We might see 30–40 alarms in ten minutes. I scan for corroboration—pressure dip plus acoustic hit. Maps aren't perfect; I keep a handwritten list of 'known liars'."
Observation: Used three screens (SCADA, GIS, email). Muted 12 alarms in 5 minutes; annotated two as "likely sensor drift."

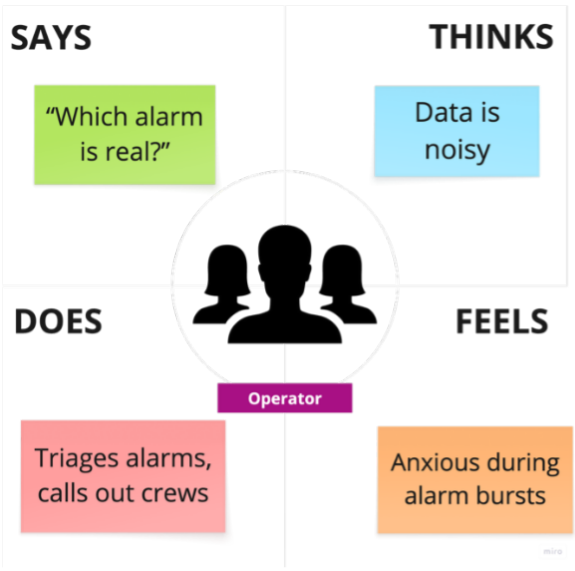
Field Technician **A:** "If I knew the exact valve sequence before I roll, I'd save 20 minutes per job."
Observation: Paper valve atlas in truck; confirmed one valve was paved over (GIS out-of-date).

Asset Manager **A:** "Show me patterns and savings by month. If energy/MGal drops and NRW drops, I'll greenlight scale-up."

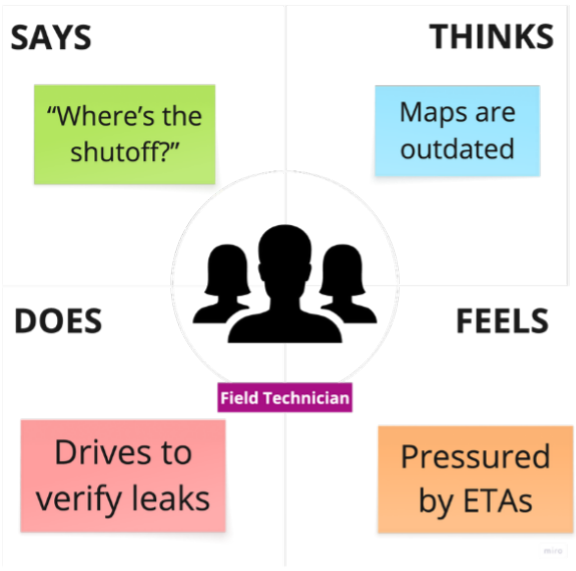
SCADA Engineer **A:** "Any autonomy needs a full audit trail with who/what/when and a dry-run mode."

Artifacts reviewed: 3 incident reports, 2 weeks of alarm logs, 4 energy bills, 6 leak tickets.

2.5 Empathy Maps



(a) Operator



(b) Field Technician

(c) Asset Manager

(d) Resident

Figure 1: Empathy maps distilled from interviews and observations.

2.6 Journey: Leak Event

Stages: (1) Alarm burst, (2) SCADA/GIS visual check, (3) Dispatch crew, (4) On-site verification, (5) Valve isolation, (6) Pressure rebalancing, (7) Customer comms, (8) Postmortem.

Pain points: alarm noise; locating valves; cross-team coordination.

Opportunities: pre-emptive isolation suggestions; auto-updated network state; live playbooks.

2.7 Journey Map (Leak Event)

Table 1: End-to-end journey with pains and opportunities

Stage	Pain Points	Opportunities
Alarm burst	Noisy/duplicate alarms; unclear priority	Fused signal with confidence score; dedupe
Assess	GIS/SCADA drift; valve uncertainty	Auto-isolation options; risk scoring
Dispatch	ETA pressure; incomplete site context	Packet with map, valves, shutoff order
Verify	Access issues; paved-over valves	Live topology corrections; crowd-in photos
Isolate	Risk of over-shutoff	Simulated sequences; customer impact forecast
Rebalance	Tank levels vs on-peak energy	Co-optimized pump/tank schedule
Comms	Manual notices	Auto notifications with affected zones
Postmortem	Sparse logs	Full audit + replay + model rationale

2.8 Key Insights

- Alarm fatigue and noisy sensors delay response ⇒ need confidence-scored, fused detections.
- Valve location and isolation planning are slow ⇒ need auto-generated valve sequences with risk scoring.
- Energy spend is controllable but under-optimized ⇒ need demand/price co-forecasting with automated pump/tank scheduling.
- Trust requires transparency ⇒ need human-in-the-loop controls, explanations, audit trails, and rollbacks.

3 Define

3.1 Point of View

A night-shift operator needs high-confidence, *explainable* leak pre-emption and isolation guidance, because alarm floods and outdated maps delay decisive action, driving excess water loss and service minutes.

3.2 How Might We

1. Fuse acoustic, pressure, and flow into a single confidence-scored actionable signal.
2. Recommend/execute valve isolation sequences that minimize customer impact.
3. Co-optimize pump/tank schedules against day-ahead prices while protecting pressure floors.
4. Surface explanations and *why now* rationales to build trust in autonomy.
5. Auto-update the digital twin topology from field confirmations and GIS/SCADA drift.

3.3 User Personas

Operator (Primary) Goals: restore service quickly; reduce alarm fatigue.
Frustrations: noisy alarms; map drift.
Measures: MTTD/MTTR, false-alarm rate.

Field Technician Goals: safe, fast isolation; fewer truck rolls.
Frustrations: missing valves; unclear sequences.
Measures: time on site; rework rate.

Asset Manager Goals: capex/opex efficiency; plan rehab.
Frustrations: unclear ROI; fragmented data.
Measures: NRW, $/MGal, project payback.

Resident (Stakeholder) Goals: reliable, safe water; timely comms.
Frustrations: sudden shutoffs.
Measures: outage minutes; complaint volume.

3.4 Problem Framing Storyboard

- Sensors detect micro-anomalies; fused models elevate significant patterns.
- Multi-agent fusion proposes a likely fissure (e.g., #P-234, 84% confidence).
- Digital twin simulates isolation options, forecasting pressure redistribution and energy impact.
- UI presents top 3 sequences with predicted service impact and recovery time.
- Operator approves a plan; system actuates smart valves, updates dashboards, and notifies affected zones; complete audit log retained.

4 Ideate

4.1 Brainstorming Outputs

Techniques used: Crazy-8s, SCAMPER, and "worst possible idea" warm-up. 54 raw ideas, clustered into 6 themes.

- **Sensing & Fusion:** acoustic fingerprint library; transfer learning between districts.
- **Isolation UX:** one-click sequence with safety interlocks; AR valve finder.
- **Energy Ops:** tank-as-battery scheduling vs day-ahead LMP.
- **Trust:** Why-panel timeline; policy guardrails; dry-run simulator.
- **Data Quality:** auto GIS–SCADA reconciliation; QR-tagged assets.
- **Civic Signals:** optional citizen audio ingestion for anomaly corroboration.

4.2 Prioritization (Feasibility × Impact)

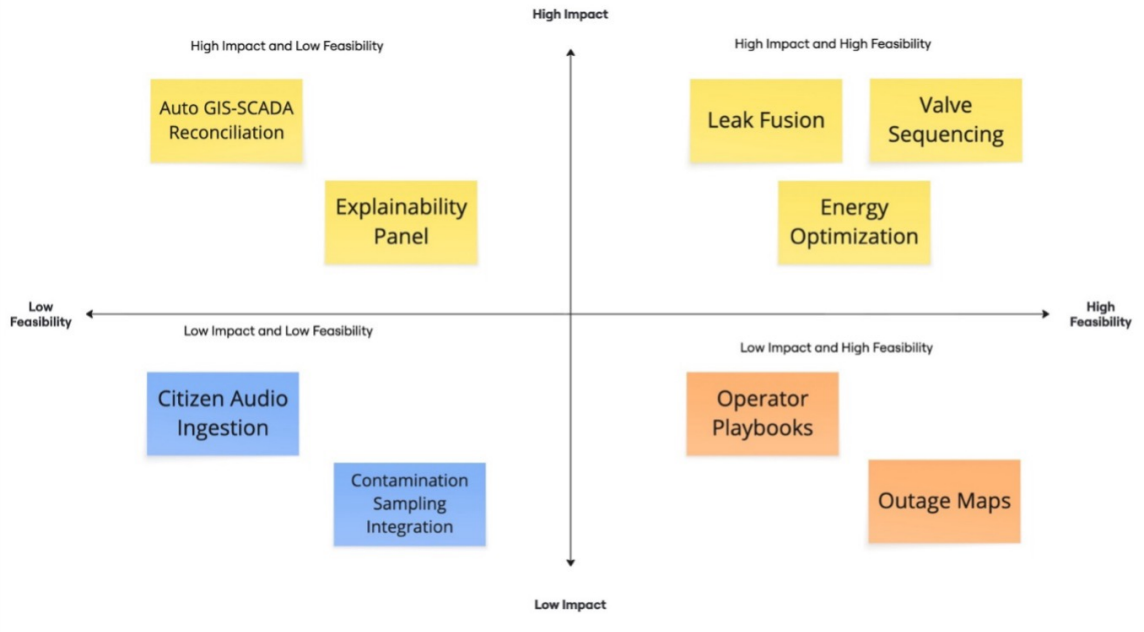


Figure 2: Concept portfolio across feasibility and impact.

4.3 Top Concepts

Proactive Leak Pre-emption: Inputs: acoustic, pressure, flow ⇒ leak-likelihood heatmap; KPI: MTTD↓, NRW↓.
Autonomous Isolation Sequencing: Inputs: confirmed leak, topology ⇒ ordered valve sequence; KPI: outage minutes↓.

Dynamic Energy Optimization: Inputs: demand forecast + day-ahead price ⇒ pump/tank schedule with pressure guardrails; KPI: $/MGal↓.

4.4 Concept Cards

Leak Fusion
Problem: noisy single-sensor alarms.
Solution: multi-sensor likelihood heatmap.
KPI: MTTD↓, false-alarms↓.
Risks: calibration drift.

Valve Sequencing
Problem: slow, risky isolation.
Solution: simulated sequences ranked by impact.
KPI: outage minutes↓.
Risks: GIS inaccuracies.

Energy Optimization
Problem: high $ during on-peak.
Solution: pump/tank schedule vs price with pressure floors.
KPI: $/MGal↓.
Risks: forecast miss.

4.5 System Flow (Conceptual)

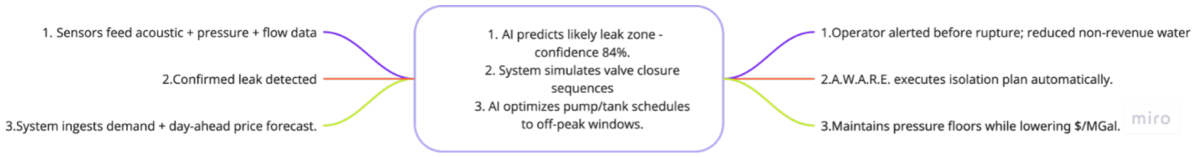


Figure 3: End-to-end loop: sensing, AI inference, simulation, and action.

5 Success Metrics

5.1 Leading Indicators

- False-alarm rate $\leq 5\%$
- Time-to-first-action ≤ 3 minutes
- Confidence calibration error $\leq 10\%$

5.2 Lagging Outcomes

- NRW $\downarrow$ 10–20%
- Outage minutes $\downarrow$ 25–40%
- Energy cost/MGal $\downarrow$ 12–25%

5.3 Trust & Safety

- $\geq 70\%$ operator opt-in to auto-execute by week 8
- Zero safety incidents

6 Scope & MVP (8–10 Weeks)

6.1 MVP Capabilities

Leak fusion (pressure+acoustic demo data), isolation simulation on a simplified digital twin, pump/tank scheduler with synthetic day-ahead prices, explainability panel, and complete audit log.

6.2 Out of Scope (v1)

Contamination lab integrations; citywide GIS reconciliation; citizen-sourced audio ingestion.

6.3 Risks & Mitigations

- **Sensor noise:** smoothing/bandpass + calibration.
- **Topology errors:** operator confirmations before actuation.
- **Trust:** simulation-first execution with one-click rollback.

Appendix

All empathy-map figures (Figure 1), the feasibility matrix (Figure 2), and the mind-map (Figure 3) are included with permission of the authors and used solely for academic documentation of A.W.A.R.E.

Appendix: Interview Transcripts (Selected)

Operator (Night Shift)

Excerpt 1. "Which alarm is real? During storms, I mute repeats and look for pressure corroboration..."
Excerpt 2. "A pre-ranked sequence with predicted impact would let me act faster..."

Field Technician

Excerpt 1. "Maps are outdated—last week a valve was paved over..."
Excerpt 2. "Photos and last-known position in the ticket would help..."

Asset Manager

Excerpt 1. "Prove ROI with NRW and energy/MGal..."

SCADA Engineer

Excerpt 1. “Need auditability and a dry-run for any auto-actuation...”