Master Specification: Pressure & Flow Anchor (PFA) V1.9

Role: Source/Well Monitor & Safety Actuator | **Network Density:** 1 per Well Station (Subdistrict 1 Deployment)

The Pressure & Flow Anchor (PFA) is the "Sentry of the Source," serving as the primary hardware interface for monitoring groundwater extraction and ensuring the mechanical safety of the multi-thousand-dollar pumping infrastructure. Within the FarmSense SFD (Single Field Deployment) architecture, the PFA focuses exclusively on the extraction point—the pump and the aquifer. While the LRZ and VFA nodes monitor the consumption of water at the crop level, the PFA provide the high-fidelity data required to bridge the gap between farm-gate operations and regional aquifer health, serving as the primary gatekeeper for the "Digital Water Ledger."

Subdistrict 1 Economics & Strategic Procurement: This version of the specification reflects the optimized procurement strategy for the **1,280-unit deployment in Subdistrict 1**. At this scale, FarmSense leverages high-volume industrial discounts from established, reliable suppliers (such as Hoffman, Dwyer, and Magnelab) rather than attempting full custom silicon integration. This ensures immediate field reliability, insurance-backed liability protection, and NEC (National Electrical Code) compliance for legal auditing, while maintaining a clear, documented path toward the $300.00 global unit target in future phases of mass-market expansion.

1. Structural Housing & EMI Hardening (The VFD Shield)

Pump houses in the San Luis Valley (SLV) are notoriously hostile environments. They are subject to extreme temperature swings (ranging from $-30^{\circ}F$ in winter to over $90^{\circ}F$ in mid-summer), high humidity from "sweating" pipes, and massive amounts of electromagnetic interference (EMI) generated by high-voltage lines and Variable Frequency Drives (VFDs).

- **The Outer Enclosure (NEMA 4X):** Constructed from a **Hoffman NEMA 4X Ruggedized Polycarbonate Enclosure**. This specific enclosure is utilized for its superior impact resistance and absolute defense against dust, water spray, and aggressive corrosion found in damp, unventilated pump pits. Unlike metal boxes, polycarbonate is RF-transparent, allowing the internal 2.4GHz high-gain antenna to maintain a solid, uninterrupted link to the field's VFA without the need for fragile externalized antenna "pucks."
- **EMI Hardening (The Faraday Effect):** High-voltage VFDs emit severe high-frequency electrical "noise" that can easily corrupt sensitive analog-to-digital (ADC) conversions. The PFA enclosure is internally treated with a specialized conductive coating to create a "Faraday Cage" effect. This protects the NXP processing sled's delicate circuitry, ensuring

that aquifer recovery levels and line pressure data remain pristine and statistically significant for the **Zo math engines**.

- **Environmental Sealing & Longevity:** To guarantee a 20-year operational lifecycle, the internal electronics are available with a fully potted option. This process encapsulates the logic boards in a specialized, moisture-proof resin, isolating every component from the oxidation and condensation common in the unventilated pump houses of the San Luis Valley.

2. Sensing Array & Actuation (The Digital Heartbeat)

The PFA utilizes an industrial-grade sensor suite to simultaneously monitor the mechanical health of the pumping infrastructure and the hydrological state of the underlying water table, all via non-invasive, "cut-less" installation.

- **Energy Monitor (Predictive Analytics):** Three (3) non-invasive **400A Split-Core CT (Current Transformer) Clamps** from Magnelab.
  - *Mechanism:* These clamp directly around the existing 480V motor leads, requiring zero downtime or hazardous wire-cutting. This "cut-less" approach ensures that existing pump warranties remain fully intact.
  - *Predictive Logic:* By analyzing the "Energy Signature" (harmonics, phase balance, and torque ripple), the **Zo Engine** (the Scientist) can detect early-stage cavitation, bearing wear, or impeller inefficiency. This enables "Predictive Maintenance," allowing the farmer to schedule repairs in the off-season rather than facing a catastrophic $20,000 motor burn-out during a 100-degree heatwave.
- **Well Depth Sounder (Legal & Hydrological Defense):** A **Vented 316-Stainless Steel Pressure Transducer (0-100m)** from Dwyer, dropped down the well casing via a 300ft vented PVC tube.
  - *Vented Technology:* The "vented" cable allows the sensor to automatically compensate for changes in barometric pressure, ensuring that the water level reading is purely hydrostatic.
  - *Hydrological Logic:* It captures minute-by-minute static and dynamic water levels. This raw data feeds the "Digital Water Ledger," providing the empirical proof necessary for Water Court testimony and securing the farmer's long-term water rights through documented, sustainable extraction practices.
- **Line Pressure Sensor (Reflex Response):** A **0-200 PSI Industrial SS Transducer** from TE Connectivity.
  - *Cut-Less Integration:* Installs via a simple stainless-steel T-splitter onto the existing analog pressure gauge port. This allows the farmer to maintain their visual gauge while

providing FarmSense with high-fidelity digital data.

- *Safety Logic:* Acts as the heartbeat monitor for the pipe network, instantly detecting sudden pressure drops (indicating a burst mainline) or dangerous spikes (indicating a blocked valve).

- **Control Interface (The Reflex Actuator):** An integrated **30A Industrial Control Relay (Dry Contact)** from Omron, tied directly into the pump's "E-Stop" or "Remote Start" coil.
  - *Reflex Logic:* Receives encrypted "Soft-Stop" commands from the network. For example: "Stop pump if the **PMT** detects a pivot stall" or "Stop pump if the **VFA** detects moisture saturation at deep percolation depths." This prevents "wasteful pumping" where water would otherwise just perk back into the aquifer without hitting the root zone, potentially causing massive soil erosion or nutrient leaching.

3. Edge Computing & The "Blackout Buffer"

The PFA logic is designed for extreme resilience, ensuring that data integrity is maintained even during total grid failures or utility-mandated Public Safety Power Shutoffs (PSPS).

- **Processing Sled:** Features an **NXP i.MX RT (Cortex-M7)** high-speed processing sled. This MCU is chosen for its ability to handle rapid, synchronous sampling of analog inputs, which is critical for capturing the milliseconds of transients that occur during motor start-up or hydraulic water hammer events.
- **Networking & Mesh Protocol:** Utilizes a **2.4GHz High-Gain Link** to communicate directly with the field's VFA anchor. It is programmed with **"Critical Packet Priority"**—if the line pressure drops or a "Soft-Stop" is triggered, the PFA suppresses all non-essential diagnostic pings to ensure the emergency command has a clear, prioritized path to the coordinator.
- **The Blackout Buffer (7-Day Sentry):** Powered primarily via an AC Step-Down transformer, but backed by a massive **40,000mAh Dual-Pack LiFePO4** battery system.
  - *Thermal Defense:* Protected by a 5W Kapton heater and 8mm PE closed-cell foam insulation.
  - *Blackout Resilience:* This massive buffer ensures at least 7 days of continuous logging during a total power failure. This is vital for recording static aquifer recovery levels—data that is only available when the pump is off—which represents the most valuable hydrological data point for regional water management and legal defensibility.

4. Hyper-Granular BOM & Subdistrict 1 Project Costs

This ledger reflects the actual procurement costs for the 1,280-unit Subdistrict 1 rollout, utilizing industrial wholesale pricing and certified professional installation labor.

Category	Component Description	Supplier / Detail	Unit Cost	Ext. Cost
Housing	NEMA 4X EMI-Shielded Enclosure	Hoffman (A080604CHNF)	$55.00	$55.00
Computing	NXP i.MX RT (Cortex-M7) Sled	Digi-Key (RT1020)	$95.00	$95.00
Diagnosis	400A Split-Core CT Clamps (x3)	Magnelab (SCT-1250)	$110.00	$110.00
Hydrology	Submersible Depth Sounder (SS)	Dwyer (PBLTX-Vented)	$185.00	$185.00
Hydrology	Vented Tubing (300ft roll)	Dwyer (Tubing-PVC)	$45.00	$45.00
Pressure	200 PSI SS Line Transducer	TE Conn (1/4" NPT)	$70.00	$70.00
Actuation	30A Industrial Control Relay	Omron (Dry Contact)	$45.00	$45.00
Power	AC Step-Down + 40Ah LiFePO4 Buffer	MeanWell / Custom	$115.00	$115.00
Wiring	12AWG Shielded Control Wire	Belden (Shielded Spool)	$30.00	$30.00
TOTAL	**Per Unit Hardware Cost**			**$750.00**

Subdistrict 1 Total Project Financials (1,280 Units):

- **Hardware Subtotal:** $960,000 *(Includes high-capacity LiFePO4 systems for every well station)*
- **Electrical Conduit & Fittings:** $64,000 *(Covers rigid steel conduit, grounding rods, and weather-proof fittings required to bring every PFA installation up to NEC standards)*
- **Electrician Labor (Install):** $224,000 *(The "Safety First" Protocol: Calculated at 4 hours/unit for Licensed Journeyman Electricians. This ensures the high-voltage tie-ins are legal, insured, and do not create liability for the farmer or the district)*
- **SUBDISTRICT 1 PROJECT TOTAL: $1,248,000**

5. Strategic Value & Credit Generation

By deploying the PFA at this scale, FarmSense establishes the primary interface for **"Credit Generation"** in modern water-saving programs.

- **Conservation Funding:** The PFA's accuracy and tamper-proof mounting are vital for farmers participating in voluntary fallowing or pumping reduction programs. Because it provides verifiable, third-party data, the PFA is 100% eligible for subsidization via State Water Plan (CWCB) and Federal (NRCS) Conservation Innovation grants.
- **Zo-Oracle Coordination:** The **Zo Server** (the Scientist) crunches the PFA's extraction data against the **Oracle** (the Librarian) spatial maps to update the field's irrigation "Worksheet." This allows the system to identify exactly when the pump is operating outside of peak efficiency or when extraction exceeds the crop's calculated Evapotranspiration (ET) rate.
- **Water Court Integrity:** In the event of an water rights dispute, the PFA's unbroken data log