Hydraulic & Water Systems

The **Hydraulics Layer** defines all physical water-handling components governed or monitored by AOFS controllers, including pumps, pipes, tanks, valves, and safety devices.

This layer is **safety-critical**. Hydraulic failures can cause flooding, crop loss, equipment damage, or long-term soil degradation. AOFS therefore treats hydraulics as a **first-class engineering domain**, not an implementation detail.

All AOFS-compliant deployments **must follow the principles and requirements defined here**.

1. Scope & Authority

The Hydraulics Layer covers:

- Water sources and intake systems
- Storage tanks and reservoirs
- Pumps and pumping stations
- Distribution pipes and manifolds
- Valves (automatic and manual)
- Drainage and overflow paths

Authority Rules:

- The **Field Controller** is the only system allowed to make authoritative hydraulic control decisions
- Remote systems may configure schedules or parameters, but **may never bypass local hydraulic safety**
- All hydraulic safety logic must function fully offline

2. Core Design Principles

AOFS hydraulic systems must follow these non-negotiable principles:

- **Fail-safe by default**

Loss of power, controller failure, or sensor failure must result in a safe hydraulic state

- **Local autonomy**

Hydraulic operation must not depend on network connectivity

- **Manual survivability**

The system must remain operable using manual valves and pumps

- **Auditability**

All hydraulic actions must be logged, whether automatic or manual

3. Water Sources

AOFS supports all sorts of water sources:

- Boreholes / wells
- Surface water (rivers, canals, dams)
- Municipal supply
- Rainwater harvesting
- Recycled or treated water

Requirements:

- Each source must be uniquely identified
- Source availability and constraints must be configurable
- Source switching (if supported) must be explicit and logged

Optional source-quality sensors (e.g. turbidity, EC) may be integrated but are not mandatory.

4. Storage Tanks & Reservoirs

Purpose: Buffer water supply and protect pumps.

Mandatory Requirements:

- LOW level sensor to prevent pump dry-run
- FULL level sensor to prevent overflow
- Defined overflow or spillway path

Design Rules:

- Tank geometry and capacity must be documented
- Overflow must never depend on powered components
- Tank isolation valves must be accessible for manual operation

Tank level sensors are **safety-authoritative** and must directly enforce pump shutdown.

5. Pumps

Purpose: Move water from source to storage or distribution.

Pump Types:

- Submersible pumps
- Surface centrifugal pumps
- Booster pumps

- Gravity-fed systems (no pump)

AOFS Requirements:

- Each pump must have a unique identifier
- Pump start/stop actions must be logged
- Pump operation must be interlocked with:
  - Tank LOW level
  - Downstream pressure limits
  - Flow confirmation (if available)

Safety Rules:

- Pumps must never run dry
- Pumps must stop on over-pressure or zero-flow conditions
- Manual pump operation must be explicitly logged when possible

6. Distribution Network

Purpose: Deliver water from pumps or tanks to irrigation zones.

Components:

- Main distribution lines
- Manifolds
- Zone pipelines
- Filters and strainers

Requirements:

- Flow meters on main and/or zoned lines
- Pressure sensors on critical sections
- Filters must be accessible for maintenance

Design Considerations:

- Pipe sizing must match expected flow rates
- Pressure losses must be documented
- Air release and drain points are recommended

7. Valves

AOFS explicitly supports **both automatic and manual valves**.

Automatic Valves

- Electrically actuated (solenoid, motorized)
- Controlled by the Field Controller

- Valve open/close actions must be logged

Safety:

- Default power-loss state must be defined (normally closed or open)
- Valve state feedback is recommended but not mandatory

Manual Valves

Manual valves are **fully AOFS-compliant**.

If automatic valves are not present:

- AOFS must generate clear, step-by-step instructions:
  - Which valve to operate
  - Required action (open/close)
  - Timing and duration
- Operator confirmations must be logged:
  - Operator identity
  - Action taken
  - Timestamp
  - Relevant sensor context

Manual operation is not a degraded mode; it is a supported baseline configuration.

8. Drainage, Overflow & Emergency Paths

Purpose: Prevent uncontrolled flooding and structural damage.

Requirements:

- Defined drainage paths for excess water
- Emergency overflow paths for tanks and basins
- Drainage must function without power

AOFS Safety Rules:

- Drainage paths must never be obstructed by controllable valves
- Emergency water release must not depend on software logic

9. Integration with Sensors

Hydraulic components are tightly coupled with the **Sensors Layer**.

Required integrations include:

- Tank level sensors → pump enable/disable
- Pressure sensors → pump and valve safety cutoffs

- Flow meters → leak detection and flow confirmation
- Rainfall sensors → irrigation lockout

Sensor failure or invalid data must result in a **safe hydraulic state**.

10. Manual Operation & Fallback

AOFS systems **must remain operable without automation**.

Manual fallback includes:

- Manual pump start/stop
- Manual valve operation
- Human confirmation workflows

All manual hydraulic actions should be logged whenever possible to preserve auditability.

11. Documentation & Records

AOFS deployments must document:

- Hydraulic schematics
- Component identifiers
- Pipe diameters and lengths
- Pump specifications
- Tank capacities

Changes to the hydraulic system must be recorded and versioned.

12. Compliance Requirements

An AOFS-compliant hydraulic system must implement at minimum:

- Defined water source(s)
- Storage tank with LOW and FULL protection
- Pump interlocks preventing dry-run and over-pressure
- Flow and pressure monitoring
- Manual operability of critical components

Optional enhancements must never weaken baseline safety guarantees.

13. References

- Field Controller Layer
- Sensors Layer

- Actuation & Control
- Safety & Fail-Safe Design