Smart Water-Saving Irrigation Systems

Technical White Paper

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This editable Word version is developed from the uploaded presentation “Water-Saving Irrigation Solution v2.0”. It is structured as an English technical white paper covering irrigation system structure, engineering water-saving technologies, field irrigation technologies, management water-saving practices, water-use monitoring, and intelligent management concepts.

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Executive Summary

Agricultural water saving is a key direction in modern irrigation development. As irrigated farmland expands, traditional extensive irrigation methods are no longer sufficient to meet the needs of efficient water use, accurate allocation, and scientific management. A modern water-saving irrigation system is not just a single device or irrigation method; it is a system composed of water source facilities, conveyance and distribution networks, field irrigation technologies, measurement and monitoring devices, automated control equipment, and management practices.

Based on the source presentation, this white paper explains the basic structure of agricultural irrigation systems and analyzes the main categories of water-saving technologies: engineering water saving, biological and agronomic water saving, and management water saving. It further discusses canal lining, canal-to-pipe water delivery, automated gates, conveyance pipelines, rainwater harvesting and storage irrigation, sprinkler irrigation, micro-irrigation, drip irrigation, micro-sprinkler irrigation, small-tube outflow, and the monitoring of water level, flow, soil moisture, rainfall, and field conditions.

1. Background and Importance of Agricultural Water Saving

Water saving in agriculture aims to reduce water losses during conveyance, distribution, and field application while still meeting crop production requirements. The source presentation indicates that from 2013 to 2023, irrigated farmland area increased while agricultural water use declined. This demonstrates that improvements in irrigation efficiency can support larger irrigated areas with lower water use.

Key values of water-saving irrigation include:

- Reducing water loss caused by seepage, evaporation, overflow, and deep percolation.
- Improving irrigation accuracy through water level, flow, and soil moisture monitoring.
- Upgrading irrigation management from manual experience-based operation to monitored and controlled operation.
- Supporting sustainable agricultural development and regional water balance.

2. Basic Structure of an Agricultural Irrigation System

According to the source material, an agricultural irrigation system consists of three major parts: the water source system, the conveyance and distribution system, and the field irrigation system.

2.1 Water Source System

The water source system includes rivers, reservoirs, wells, springs, ponds, water storage pools, and tanks, together with gates, valves, and measuring devices. Its role is to secure, store, regulate, and measure the available water supply.

2.2 Conveyance and Distribution System

The conveyance and distribution system includes canals or pipelines, as well as control gates, distribution gates, and valves. This part moves water from the source to the irrigation area. Water losses in this section are commonly caused by seepage, evaporation, and inaccurate control, so it is a major focus of backbone engineering water-saving work.

2.3 Field Irrigation System

The field irrigation system includes field ditches, small channels, or irrigation emitters that deliver water to crops. This is the terminal stage of irrigation, where the final irrigation efficiency is determined.

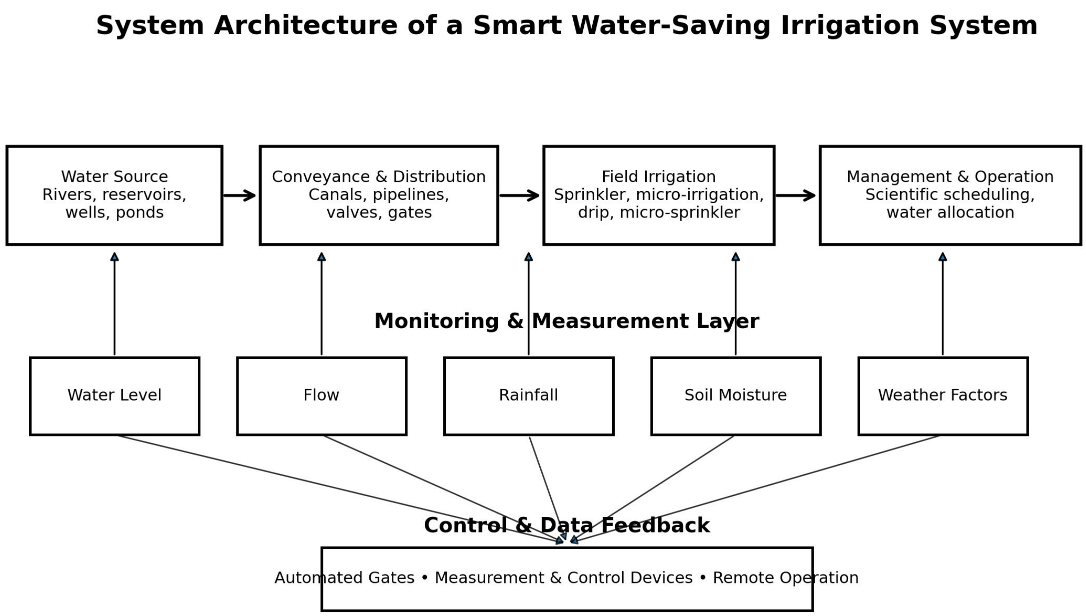

Figure 1. System architecture of a smart water-saving irrigation system.

3. Water-Saving Irrigation Technology Framework

The source material classifies water-saving irrigation technologies into three categories: engineering water-saving technologies, biological and agronomic water-saving technologies, and management water-saving technologies.

3.1 Engineering Water-Saving Technologies

Engineering water-saving technologies improve irrigation efficiency through physical infrastructure and irrigation equipment. Examples include canal lining, low-pressure pipeline water delivery, sprinkler irrigation, micro-irrigation, subsurface irrigation, and surface water-saving irrigation.

3.2 Biological and Agronomic Water-Saving Technologies

These technologies include adjusting cropping structure, strengthening cultivation cover, plastic film mulching, selecting drought-resistant and water-saving crop varieties, and using crop transpiration control methods.

3.3 Management Water-Saving Technologies

Management water-saving includes water pricing, water rights trading, monitoring of irrigation influencing factors, and automatic control. Its goal is to improve irrigation management and support scientific water allocation.

4. Backbone Engineering Water-Saving Technologies

4.1 Canal Lining

Canal lining uses materials such as stone masonry, concrete precast blocks, or cast-in-place concrete to line canal bottoms and side slopes or walls. Its main purpose is to reduce seepage and protect the canal structure.

- Reduce water loss during conveyance.
- Improve structural stability of the canal.
- Reduce slope erosion and maintenance demand.
- Improve hydraulic conditions of the channel.

4.2 Canal-to-Pipe Water Delivery

Canal-to-pipe conversion replaces open-channel conveyance with pipelines, thereby reducing seepage and evaporation losses. Pipeline systems should be equipped with connection valves, maintenance valves, air release valves, drain valves, pressure reduction valves, and flow meters. Common pipe materials include concrete pipe, cast iron pipe, PE pipe, PE belts, and PVC pipe.

4.3 Automated Gate Retrofit

Automated and integrated measurement-control gates can monitor water level and flow and can automatically adjust gate opening according to demand, thereby enabling precise water control. Different gate forms may be used in branch canals, field canals, and farm drainage or irrigation areas.

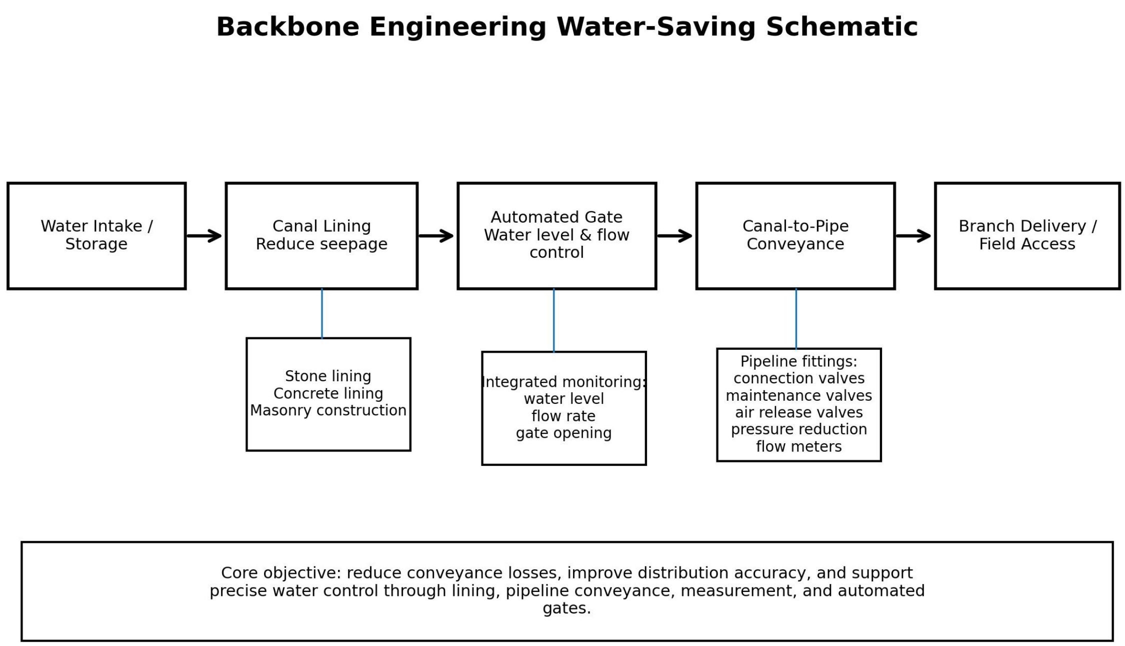

Figure 2. Backbone engineering water-saving schematic.

5. Rainwater Harvesting and Storage Irrigation

In dryland farming areas, rainwater harvesting and storage irrigation is an important supplementary method. The system includes a rain-collection surface, drainage channel, filtration tank, storage cellar, lifting pump, and conveyance pipe. This method improves the use of natural rainfall and supports irrigation in areas where conventional water sources are limited.

6. Field Water-Saving Irrigation Technologies

6.1 Sprinkler Irrigation

Sprinkler irrigation uses power equipment, pumps, pipelines, and sprinklers to deliver water under pressure so that it falls onto the field like rainfall. A sprinkler system generally includes a water source, pump, power unit, pipeline system, and sprinklers. It may be fixed, mobile, semi-fixed, hose-reel, linear-move, or rolling type. It is suitable for field crops except paddy rice, vegetables, fruit trees, and hilly farmland.

6.2 Micro-Irrigation

Micro-irrigation is a local irrigation technology that uses specialized equipment to convey pressurized water to the field and apply it to soil near the crop root zone through emitters. It includes a water source, head unit, distribution pipe network, and emitters.

6.3 Drip Irrigation

Drip irrigation delivers water to crop roots through plastic pipes and drip emitters. It is one of the most effective water-saving irrigation methods in dry and water-scarce areas. Typical emitter flow is 2-12 L/h, and typical operating pressure is 50-150 kPa. Surface drip, shallow-buried drip, and subsurface drip are all mentioned.

6.4 Micro-Sprinkler Irrigation

Micro-sprinklers apply water as fine droplets around the crop canopy or the soil surface near the roots. The source material gives a typical operating pressure of 200-300 kPa and a flow range of 10-200 L/h. Fixed and rotating types are mentioned.

6.5 Small-Tube Outflow

Small-tube outflow connects PE plastic tubes of 3 mm, 4 mm, or 6 mm inner diameter to laterals so that a small stream is delivered to the main root zone. Typical flow is 80-250 L/h.

Field Irrigation Technology Comparison

Technology	Principle	Typical Flow	Typical Pressure	Typical Applications
Sprinkler Irrigation	Pressurized water is sprayed into the air and falls like rainfall.	System-dependent	Pressurized system	Field crops,vegetables,orchards,hilly farmland
Micro-Irrigation	Pressurized local irrigation using a head unit,pipe network and emitters.	Depends on emitter type	Pressurized system	Localized root-zone irrigation
Drip Irrigation	Water is delivered through emitters directly to the crop root zone.	2-12 L/h	50-150 kPa	Dry regions,orchards,greenhouses,vegetables
Micro-Sprinklerr	Water is sprayed as fine droplets around leaves or the root-zone surface.	10-200 L/h	200-300 kPa	Fruit trees,orchards,horticulture
Small-Tube Outflow	Small PE tubes discharge a small stream concentrated near the main root zone.	80-250 L/h	Local pressurized supply	Crops needing concentrated local discharge

Figure 3. Comparison of field irrigation technologies

7. Management Water-Saving Technologies

Management water-saving focuses on improving irrigation management through scientific timing and dosage of irrigation, rational water scheduling, and management reform. The source material highlights irrigation based on crop water demand and soil moisture conditions, rational dispatch of irrigation water, and participation of farmers in water management.

- Scientific irrigation based on crop water requirement.
- Irrigation decisions supported by soil moisture conditions.
- Rational scheduling of irrigation water.
- Improved awareness through water pricing and management reform.

8. Water-Use Monitoring Technologies

Water-use monitoring is the basis of irrigation management. The source presentation includes water level monitoring, flow monitoring, and field environment monitoring.

8.1 Water Level Monitoring

The presentation lists radar water level meters, pressure water level meters, and ultrasonic water level meters. Radar water level measurement is based on radar-wave reflection; ultrasonic water level measurement is based on sound-wave reflection at interfaces; and pressure measurement uses pressure-based principles.

8.2 Flow Monitoring

The listed flow-monitoring equipment includes radar flow meters, box-type ultrasonic open-channel flow meters, and portable ultrasonic open-channel flow meters.

8.3 Field Environment Monitoring

The presentation includes rainfall, flow, water level, soil moisture, field water layer, farmland drought condition, meteorological factors, displacement, leakage, gate opening, and water quality as important observation items.

8.4 Remote Sensing Observation

The source material also refers to satellite and aerial remote sensing information, including multi-source image information, irrigation district water surface area, 3D terrain of ponds during dry periods, water storage in ponds, crop water demand, crop evapotranspiration, crop growth, irrigated area, rice transplanting area, cropping structure, crop water status, and yield.

9. Technical Integration Logic

A water-saving irrigation system should be designed as an integrated system rather than as isolated devices. From the source material, the integration logic can be summarized as follows:

- Source side: secure and regulate water through rivers, reservoirs, wells, ponds, and storage facilities.
- Conveyance side: reduce losses through canal lining, canal-to-pipe conversion, and automated gates.
- Field side: improve application efficiency through sprinkler, micro-irrigation, drip, micro-sprinkler, and small-tube outflow.
- Management side: use crop water demand, soil moisture, rainfall, water level, and flow information for scheduling.
- Monitoring side: support management through field observation and remote sensing.

10. Typical Application Scenarios

10.1 Large and Medium Irrigation District Retrofit

Suitable technologies include canal lining, canal-to-pipe conveyance, automated gates in branch canals, water level monitoring, and flow monitoring.

10.2 Farm Irrigation and Drainage Management

Suitable technologies include field gates, field water level monitoring, soil moisture monitoring, farmland drought monitoring, and irrigation-drainage control.

10.3 Rainwater Harvesting in Dry and Semi-Arid Regions

Suitable technologies include collection surfaces, drainage channels, filtration tanks, storage cellars, pumps, and delivery pipes.

10.4 Orchards and Cash-Crop Irrigation

Suitable technologies include drip irrigation, micro-sprinkler irrigation, small-tube outflow, fertigation, and soil moisture observation.

10.5 Sprinkler Irrigation for Field Crops

Suitable systems include fixed, mobile, semi-fixed, hose-reel, linear-move, and rolling sprinkler systems.

11. Recommendations for System Construction

- Diagnose the site before selecting technologies, considering water source, conveyance conditions, crop type, soil, and management needs.
- Coordinate backbone engineering measures and field irrigation measures to achieve full-system water saving.
- Plan measurement and monitoring points at the design stage, including water level, flow, soil moisture, rainfall, and gate opening.
- Match automated control devices to actual management needs in branch canals, field canals, and farm irrigation areas.
- Promote management reform together with engineering and technical deployment.

12. Conclusion

Water-saving irrigation is a systematic engineering and management process. Canal lining, pipeline conveyance, and automated gates reduce losses in the backbone network. Sprinkler, micro-irrigation, drip, micro-sprinkler, and small-tube outflow improve field application efficiency. Water level, flow, soil moisture, rainfall, weather factors, and remote sensing data provide the basis for scientific irrigation scheduling and water allocation. The future direction of irrigation development is therefore not a single device upgrade, but an integrated system that combines engineering water saving, field irrigation improvement, monitoring and measurement, automated control, and scientific management.

Appendix A. Core Technology Summary

Category	Main Items
Engineering Water Saving	Canal lining; low-pressure pipeline conveyance; sprinkler irrigation; micro-irrigation; subsurface irrigation; surface water-saving irrigation
Backbone Engineering	Canal lining; canal-to-pipe water delivery; automated gates; conveyance pipeline fittings; water level and flow monitoring
Field Irrigation	Sprinkler irrigation; micro-irrigation; drip irrigation; micro-sprinkler irrigation; small-tube outflow
Management Water Saving	Crop water requirement management; soil moisture monitoring; irrigation dispatch; water pricing and water-rights mechanisms; farmer participation
Monitoring	Rainfall; flow; water level; soil moisture; field water layer; drought condition; weather factors; displacement; leakage; gate opening; water quality; remote sensing imagery