Foreword

According to the requirements of Document JIANBIAO [2012] No.5 issued by the Ministry of Housing and Urban-Rural Development (MOHURD) — "Notice on Printing and Distributing 'the Development and Revision Plan of National Engineering Construction Standards in 2012'", the drafting group has conducted extensive investigation and study, summarized the practical experience, made reference to the relevant international standards and other countries' advanced norms and codes, and widely solicited opinions to revise GB/T 50363-2006 *Technical Specification for Water-saving Irrigation Engineering*.

This standard consists of 10 chapters and 2 appendixes, covering: general provisions, terms, planning and design, water source for irrigation, irrigation scheduling and irrigation water use, water use efficiency of irrigation, technical specifications, benefit analysis and evaluation, management and area of water-saving irrigation, etc.

The main contents of this revision are:

1. Adjustment of the original project planning, project planning and measures, benefit, irrigation management to planning and design, technical specifications, benefit analysis and evaluation, management, respectively.

2. Modification and supplement of general provisions, terms, water source for irrigation, irrigation scheduling and irrigation water use, water use efficiency of irrigation and area of water-saving irrigation in the original specification in accordance with relevant standards.

The Ministry of Housing and Urban-Rural Development of the People's Republic of China is in charge of administration of this standard. The Ministry of Water Resources of the People's Republic of China is in charge of its routine management. China Irrigation and Drainage Development Center is in charge of explanation of technical specifications. If you have any comments and recommendations when implementing this standard, please contact China Irrigation and Drainage Development Center (Address: No.60, Guanganmen South Street, Xicheng District, Beijing, Postcode: 100054).

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Contents

1 General provisions

1.0.1 This standard is prepared with a view to ensure the construction, operation and maintenance of water-saving irrigation projects technically feasible and economically viable, to promote sustainable development of water-saving irrigation, and to ensure high-quality development of economy and society.

1.0.2 This standard is applicable to the planning, design, construction, acceptance, management, and evaluation of new construction, extension and renovation of water-saving irrigation projects in agriculture, forestry, and animal husbandry.

1.0.3 The construction of water-saving irrigation project shall give full consideration to local conditions, quality assurance, operation and maintenance, with agronomic, biological, and management measures to achieve rational allocation and efficient utilization of water resources, improve support capabilities of irrigation and protect ecological environment.

1.0.4 Water-saving irrigation projects shall have clear property rights and establish a fully-fledged management organization, perfect rules and regulations for project operation and management, and pay high attention to the long-term and sound operation of projects.

1.0.5 In addition to the requirements stipulated of this standard, construction and management of water-saving irrigation projects shall also comply with requirements stipulated in the relevant current national standards.

2 Terms

2.0.1 Water-saving irrigation

Comprehensive measures to utilize precipitation and irrigation water efficiently based on crop water-demand pattern and local water-supply conditions, in order to optimize economic, social, and environmental benefits of agriculture.

2.0.2 Canal seepage control

Technical measure to reduce water loss due to canal seepage.

2.0.3 Irrigation with pipe conveyance

Surface irrigation method with which pressurized water flow formed by pump pressure or a natural fall, is conveyed through pipes to field water-supply facilities.

2.0.4 Sprinkler irrigation

Irrigation method to use specialized equipment to spray pressurized water streams through a sprinkler head, creating fine droplets falling to the soil surface.

2.0.5 Microirrigation

Irrigation method with which the water and nutrients required for crop growth are delivered with small discharge directly to the soil near the crop roots in a uniform and accurate manner by a pipe network and emitters mounted on the end pipes.

2.0.6 Improved surface irrigation

Irrigation method that uses furrow irrigation, border irrigation or check-basin irrigation to improve distribution uniformity of irrigation water and increase water use efficiency.

2.0.7 Local irrigation with injection

Local irrigation method that uses specialized equipment to inject a certain amount of water into the soil of the root zone of crops (seeds), to improve soil moisture and satisfy water demand of germination and seedling.

3 Planning and design

3.1 Planning

3.1.1 For water-saving irrigation project planning, basic information such as meteorology, water sources, topography, hydrology, geology, soil, crops, water conservancy projects, irrigation experiments, energy, materials and equipment, the economy and society and related planning, shall be collected and rationality and reliability analysis shall be conducted.

3.1.2 Planning of water-saving irrigation project shall be integrated with planning of local water-resource development and utilization, land use, water conservancy development, agricultural development and ecological environmental protection. It shall meet the requirements of modern agriculture, new rural construction, and high-standard farmland construction. Furthermore, it shall make beneficial use of existing water resources facilities, and integrate with the arrangement of farmland drainage, field roads, farmland shelter belt networks, power-supply facilities, etc.

3.1.3 The planning of water-saving irrigation projects shall reasonably select the type and scale of the water-saving irrigation projects according to local conditions such as local natural and socio-economic conditions, water resources carrying capacity, agricultural development requirements and level of water-saving irrigation development. The selection of type of water-saving irrigation project shall be in accordance with the following requirements:

1 Seepage control measures should be adopted for backbone canals with significant water conveyance losses and low water transportation efficiency.

2 Irrigation with pipe conveyance should be adopted in irrigation areas with gravity conditions or lift irrigated area. Irrigation with pipe conveyance shall be adopted in groundwater irrigation areas.

3 Sprinkler irrigation and microirrigation should be adopted in cash crop planting areas, protected agriculture areas, high-efficiency agricultural areas, concentrated and continuous large-scale farming areas, and areas where it is difficult to adopt surface irrigation due to soil texture or terrain restrain. Gravity sprinkler irrigation and microirrigation should be applied in hilly areas by taking the advantage of natural slope of surface.

4 Microirrigation should be adopted in areas with rainwater harvesting as an alternative water source.

3.1.4 Water balance analysis shall comply with the requirements of the most stringent water resources management system. Water-saving irrigation techniques shall be optimized and water demand to meet the probability of irrigation design shall be defined based on water availability, so as to achieve a balance between water supply and demand. In the area where water demand and supply are unbalanced, measures shall be taken to adjust their irrigation methods, irrigation scale, and/or cropping pattern, or reduce irrigation areas. The probability of irrigation design shall meet the requirements of current national standard GB 50288 *Code for Design of Irrigation and Drainage Engineering*. Irrigation project with pipe conveyance shall meet the requirements of current national standard GB/T 20203 *Technical Specification for Irrigation Projects with Pipe Conveyance*.

3.1.5 The layout of water-saving irrigation project shall take existing water projects, roads, forest

belts, power transmission lines, etc into consideration, and shall be determined through social-techno comparison of alternatives. In renovation or extension of canals for seepage control, the original layout shall be reviewed and adjustment shall be made to the deficient canal system. Newly-constructed canal systems shall be proposed after social-techno comparison of alternatives. For canal and drainage (pipe) networks, special soil foundation areas and areas that may experience landslides or be prone to flash floods shall be avoided.

3.1.6 The deliverable of planning shall include the planning report, investment estimation report, and planning layout. The layout of a project with an irrigation area greater than or equal to 333hm^2 should be drawn in topographic maps with a scale of 1:5 000 to 1:10 000, whereas the layout of a project with an irrigation area less than 333 hm^2 should be drawn in topographic maps with a scale of 1:2 000 to 1:5 000.

3.2 Project design

3.2.1 Project design shall be conducted based on the approved plan or feasibility study report, with additional investigations and surveys to obtain reliable basic information. Explanations shall be made to the key technical standards and other relevant documents that are based during the design of water-saving irrigation projects. Class of water-saving irrigation project and grade of each hydraulic structure shall be specified.

3.2.2 During the project design, the results of water-balance analysis in the planning report shall be reviewed, and irrigation design standards and crop irrigation scheduling shall be defined. Irrigation water use under the probability of irrigation design shall be checked so as to specify project construction scope and scale.

3.2.3 During the project design, overall layout and main construction items of projects shall be determined based on comparison of technical alternatives.

3.2.4 The design of water-saving irrigation project shall include those of water-source works, head works, canal or pipe networks for water conveyance and distribution, field works, and various auxiliary works.

3.2.5 The design of water-saving irrigation project shall be in accordance with the following requirements:

1 Comprehensive design shall be carried out for all individual items within the approved scope of project design.

2 The design of water-source works shall include water balance analysis and calculations to determine the water-supply capacity of the designed year. The design shall meet the requirements of current national standard GB 50288 *Code for Design of Irrigation and Drainage Engineering*, GB 50265 *Design Code for Pumping Station* and GB/T 50625 *Technical Code for Water Wells*.

3 During the design of seepage control canal, longitudinal and cross-sectional sections and seepage control lining structures shall be designed based on hydraulic calculations. For large and medium-sized canals, the slope stability shall be calculated and analyzed based on geological conditions along the line and design section situation.

4 For the design of pipe conveyance, sprinkler and microirrigation, the arrangement of control heads and field pipe networks shall be proposed, parameters of emitter or water outlet spigot shall be selected. Irrigation scheduling and arrangement shall be determined, and the results of hydraulic calculations shall be given.

5 For the design of canal seepage control project and irrigation project with pipe conveyance, the size and spacing of field furrow, border irrigation and check-basin shall be proposed to improved surface irrigation.

3.2.6 The deliverable of project design shall include design specifications, illustrations and budget estimation sheets, and provide the following supporting drawings:

1 Layout of water-saving irrigation project.

2 Longitudinal and cross-sectional drawings of canal, pipe or furrow.

3 Layout of headworks.

4 Drawings of water source works.

5 Drawings of main buildings and ancillary structures.

4 Water sources for irrigation

4.0.1 For water-saving irrigation, water shall be allocated in an optimized manner, and rationally utilized and conserved to maximize benefits of the irrigation water. The priority shall be given to surface water for water sources and groundwater shall be used in a rational manner. In irrigation districts with both well and canals, surface water and groundwater should be conjunctive used so as to increase the rate of repetitive use of irrigation water. In surface water irrigation districts, returned water of irrigation shall be used as much as possible properly if conditions allow.

4.0.2 Quality of irrigation water shall meet the requirements of current national standard GB 5084 *Standard for Irrigation Water Quality*.

4.0.3 When the amount of water abstraction of newly constructed or expanded irrigation works are relatively big and prone to the exertion of impacts on the surrounding environment, water resources demonstration system for project shall be strictly implemented construction and water resources evaluation reports prepared.

4.0.4 The amount of water abstraction of irrigation works shall not exceed that of water available for irrigation. For groundwater over-exploited areas or surface water irrigation areas taking up the amount of ecological water, water withdrawal for irrigation shall not be increased, and deep artesian aquifer shall not be exploited for irrigation development.

4.0.5 When rainwater is harvested as an alternative water source for irrigation, the capacity of rainwater collection shall be balanced with storage capacity and shall meet the demand of water use of water-saving irrigation project.

5 Irrigation scheduling and irrigation water use

5.0.1 Irrigation scheduling should be determined based on experiment data of local water-saving irrigation. Irrigation scheduling for areas lacking data may be determined based on experiment data of areas with similar conditions or according to water balance.

5.0.2 Irrigation scheduling shall be determined based on types of various water-saving irrigation technologies, and the probability of corresponding irrigation design.

5.0.3 Irrigation water use shall be determined based on irrigation scheduling for high crop yield or water productivity, with consideration to local water resource conditions.

5.0.4 In the areas of water scarcity, irrigation water use should be determined based on the sensitivity of crops to water shortage at different stages of growth, by means of applying irrigation at critical growth stages, deficit irrigation and other techniques.

6 Water use efficiency of irrigation

6.1 Requirements for water use efficiency of irrigation

6.1.1 Water use efficiency of canal system shall be in accordance with the following requirements:

1 It shall not be lower than 0.55, 0.65 and 0.75 for large, medium-sized and small irrigation districts, respectively. In the irrigation districts where both well and canal irrigation are adopted in the entire area, canal system efficiency may be reduced by 0.10 from the above range for canal irrigation. In irrigation districts where well and canal irrigation are adopted partially, water use efficiency may be reduced in a proportion of the percentage of well and canal irrigation area to the total irrigation area.

2 In groundwater irrigation districts, it shall not be lower than 0.90.

Note: The classification of irrigation districts is based on the scale of designed irrigated area. Large irrigation districts: the irrigated area≥300 000mu; Medium-sized irrigation districts: 100 000mu≤the irrigated area<300 000mu; Small irrigation districts: the irrigated area<100 000mu. (1hm²=15mu)

6.1.2 If pipeline is used for water conveyance, water use efficiency of the pipe system shall not be lower than 0.95.

6.1.3 On-farm water use efficiency should not be lower than 0.95 and 0.90 for paddy and root dry upland crop irrigation districts, respectively.

6.1.4 Water use efficiency of irrigation shall be in accordance with the following requirements:

1 For canal seepage control irrigation project, it shall not be lower than 0.50, 0.60, 0.70, 0.80 for large, medium-sized, small and groundwater irrigation districts, respectively.

2 For pipe irrigation project, it shall not be lower than 0.80.

3 For sprinkler irrigation project, it shall not be lower than 0.80.

4 For microirrigation project, it shall not be lower than 0.85. For drip irrigation project, it shall not be lower than 0.90.

6.2 Determination methods for water use efficiency of irrigation

6.2.1 Water use efficiency of canal system may be calculated by using water use efficiency of canals at all levels. Water use efficiency of canals shall be tested as specified in the standard of Article A.0.1.

6.2.2 For irrigation districts adopting a variety of irrigation methods, efficiency of irrigation water use shall be determined by the ratio of sum of the net irrigation water use of various irrigation methods and the total water withdrawal from the water intake.

6.2.3 Water use efficiency of well-canal combined irrigation districts may be determined by the Formula (A.0.2).

6.2.4 On-farm water use efficiency shall be calculated by Formula (A.0.3-1) or Formula (A.0.3-2).

6.2.5 Water use efficiency of irrigation may be determined by the head-end measurement and calculation method or comprehensive calculation determination method.

7 Technical specifications

7.1 General requirements

7.1.1 The farmland works of irrigation projects of canal seepage control and pipe conveyance shall adopt improved surface irrigation techniques and shall be in accordance with the following requirements:

1 In upland crop irrigation areas, the land shall be leveled and furrow or border irrigation adopted. In gravity-flow irrigation areas, the border length should not exceed 75m, and the furrow length should not exceed 100m for furrow irrigation. In water-lifting irrigation areas, the lengths of the border irrigation and furrow should not exceed 50m. The border width shall be determined by the integer multiple of the operating width of agricultural machinery, and should not exceed 4m.

2 The standard deviation of relative elevation of the horizontal border surface should be less than 2cm. Border length and width should be determined based on available discharge of canal (pipe), layout of field water transmission and distribution system and local conditions.

3 The length and width of the check-basin field in plain paddy areas should be 60m to 120m and 20m to 30m, respectively, which may be adjusted according to terrain conditions of hilly areas. In saline check-basin fields with leaching irrigation, the length and width should be 50m to 100m and 10m to 20m, respectively. Land leveling shall employ check-basin field as the basic unit, and standard deviation of the relative elevation of the field surface within the check-basin field should be less than 3cm.

4 Surface irrigation shall meet the requirements of professional standard SL 558—2011 *Code of Practice for Technical Management of Surface Irrigation Project*.

7.1.2 For irrigation project with pipelines for water conveyance, the selection of pipe materials shall be in accordance with the following requirements:

1 The selection of pipe materials shall meet the requirements of technical and economic. Plastic pipe should be used if the pipe diameter is less than 400mm, whereas polyethylene plastic pipes are advisable in cold areas or areas with complicated terrain. If the pipe diameter is larger than 400mm, fiber-reinforced plastic pipes, reinforced concrete pipes, and concrete cylinder pipes may be used. Metal pipes should be selected in hilly areas without embedment conditions.

2 The allowable working pressure of pipes materials shall not be less than the maximum pressure generated by water hammer.

3 The allowable working pressure of plastic pipes shall not be less than 1.5 times of the designed working pressure.

7.1.3 The layout of pipe network shall be in accordance with the following requirements:

1 The type of pipe network layout shall be determined by comparisons of options alternatives, according to the location of water source, topographic conditions and form of field irrigation.

2 The pipes should be laid out parallel to furrows, canals or roads, and shall avoid filling areas and areas that are prone to landslide or flash flood. The layout of pipelines shall be smooth to reduce turning points and undulation.

3 Pipe network shall be equipped with devices for control, measurement, water discharge, safety protection and monitoring. Freeze-proof measures shall be taken in cold areas.

7.1.4 Measures for pressure regulation shall be taken for pipeline networks with large scale or complex topographic conditions.

7.2 Canal seepage control project

7.2.1 Seepage control or lining shall be performed as a priority for canals or canal segments in areas suffering from severe water shortages, under unfavorable geological conditions, severe seepage in canal, or need to control groundwater depth and in high lift pumping irrigation areas. Necessary of seepage control shall be evaluated in well-canal irrigation areas or areas where seepage control may induce adverse ecological impacts.

7.2.2 The structural type of anti-seepage canal shall be selected based on local natural and socio-economic conditions, technical requirements and conjunctive use of surface water and groundwater, as well as ecological and environmental factors.

7.2.3 For anti-seepage canals with rigid materials and a flow rate of $1m^3/s$ and above, arc slope foot trapezoid or arc bottom trapezoid section should be preferred, whereas a U-shaped cross section should be preferred if the flow rate is less than $1m^3/s$. Expansion joints shall be set for rigid-material anti-seepage canals, whose spacing and type shall be determined based on the size of canal cross section, thickness of seepage control layer, seepage control materials, etc.

7.2.4 For anti-seepage canals with rigid materials and canals with buried membrane for seepage control where the groundwater level is higher than the bottom of the canal, drainage facilities shall be arranged at the base of the canal, and the drainage outlet unblocked.

7.2.5 In the area where the standard frost depth is larger than 10cm, technical measures shall be taken to prevent frost swelling if the frost heave of the base of the lined canal is larger than the allowable displacement.

7.2.6 Warning signs for safety or necessary protection and lifesaving facilities shall be arranged in anti-seepage canals that pass through villages or densely populated areas.

7.2.7 Irrigation project with anti-seepage canals shall be in accordance with not only this standard, but also the requirements of current national standard GB/T 50600 *Technical Code for Seepage Control Engineering on Canal*.

7.3 Irrigation project with pipe conveyance

7.3.1 In upland crop planting areas, one-level fixed pipes may be used if the system flow rate is less than $30m^3/h$. Two-level fixed pipes (main and branch pipes) may be used if the system flow rate is $30m^3/h$ to $60m^3/h$. Two-level or multi-level fixed pipes may be used if the system flow rate is larger than $60m^3/h$. In paddy growing areas, two-level or multi-level fixed pipes may be used.

7.3.2 The length of fixed pipes in the fields shall not be less than 90m per hectare and should not exceed 180m per hectare. That in hilly areas may be increased appropriately, according to local conditions.

7.3.3 The spacing of branch pipes should be 50m to 100m, and a smaller value shall be chosen for unidirectional watering, a larger value shall be chosen for bidirectional watering. The spacing of water outlet spigots should be 40m to 100m, and a smaller value shall be chosen for cash crops, a larger value shall be chosen for food crops.

7.3.4 If mobile ground hose irrigation is adopted, there shall be a reliable water source, and machinery,

pump, and pipe shall be in place. The hose length should not exceed 200m.

7.3.5 Water outlet spigots shall be well-structured, firm and durable, well-sealed, flexible in operation, convenient for operation and maintenance, and sound in hydraulic performance. In severe cold regions, freeze protection measures shall be implemented for water outlet spigots and outlet risers.

7.3.6 In addition to the requirements stipulated in this standard, those stipulated in the current national standard GB/T 20203 *Technical Specification for Irrigation Projects with Pipe Conveyance* shall be complied with in irrigation project with pipe conveyance.

7.4 Sprinkler irrigation project

7.4.1 Sprinkler irrigation units of central pivot, lateral-move or reel-type should be adopted in the contiguous farmlands and the areas with uniform crop planting, no obstacles on the ground, reliable water sources and electrical power facilities and scaled management of land.

7.4.2 Sprinkler irrigation system with small and light units should be selected in hilly areas with sporadic and scattered arable lands, scattered water sources, no power supply, or a low guarantee of power supply. The irrigation area of these small and light mobile sprinkler irrigation units should be designed according to 0.667hm^2 per kilowatt.

7.4.3 Sprinkler systems shall meet the requirements of water use efficiency, intensity, uniformity coefficient, and atomization indicator of sprinkling under the design wind speed. The design intensity of sprinkler irrigation system shall not be larger than the allowable sprinkling intensity of the soil.

7.4.4 The uniformity coefficient of fixed sprinkler irrigation system shall not be less than 0.75, whereas that of self-propelled sprinkler irrigation system shall not be less than 0.85.

7.4.5 The daily running time of sprinkler system should be 12h to 18h, and the maximum duration should not exceed 21h.

7.4.6 Sprinkler irrigation project shall be in accordance with not only this standard, but also the requirements of current national standard GB/T 50085 *Technical Code for Sprinkler Engineering*.

7.5 Microirrigation project

7.5.1 The water for microirrigation shall be purified, and the type and combination of filters shall be selected based on water quality conditions.

7.5.2 The head control unit of microirrigation system shall be equipped with fertilizer and pesticide application devices, which shall be located upstream of the filter.

7.5.3 The emitter shall be selected according to topography, soil, crop and cultivation pattern, and hydraulic characteristics of the emitter. Irrigation system shall meet the requirements of uniformity.

7.5.4 The arrangement of field pipe network and drip line or tape of microirrigation project shall be coordinated with crop planting pattern.

7.5.5 Pipes at the downstream of the filter of the head control in microirrigation project shall be plastic. The pipes laid on the ground surface shall not be transparent.

7.5.6 If drip irrigation is adopted, it shall be comprehensive analyzed whether mulch film has adverse impacts on crop growth and yield, rainfall utilization rate and environment. If mulched drip irrigation is adopted, measures shall be taken to recycle the mulch film.

7.5.7 Microirrigation project shall be in accordance with not only this standard, but also the requirements of current national standard GB/T 50485 *Technical Code for Microirrigation Engineering*.

7.6 Other techniques

7.6.1 Local irrigation with injection shall be in accordance with the following requirements:

1 There shall be reliable water sources, water extraction and transmission equipment. The equipment and amount of water supply shall meet the requirements of crop sowing during optimal period and seedling irrigation, and irrigation shall be uniform.

2 The command area of a water source shall be calculated based on irrigation volume of no less than $75m^3/hm^2$ each time.

7.6.2 Controlled irrigation for paddy field shall be in accordance with the following requirements:

1 During the stages of transplanting and regeneration, a thin layer of water shall be maintained by frequent, shallow irrigation to prevent the field from drying up.

2 In the early tillering stage, shallow-wet-dry irrigation shall be alternately applied to keep the field surface wet.

3 In the late tillering stage, field drying shall be carried out. Under the condition of cloudy and rainy days, fertile lands, vigorous seedlings, clayey soil, and low-lying fields, heavy field drying shall be adopted, whereas light field drying shall be adopted for high-lying and sandy soil fields.

4 In the jointing and booting stages, irrigation shall be conducted timely to maintain a thin water layer on the field surface.

5 In the yellow ripening stage, the field shall be dry, and rainwater in the field shall be drained away promptly on rainy days.

8 Benefit analysis and evaluation

8.0.1 Attention shall be paid to investigation and research, as well as tracking and monitoring of water-saving irrigation benefits. The data used to evaluate the benefits of water-saving irrigation projects upon implementation shall be informative, accurate and reliable.

8.0.2 Planning and design of water-saving irrigation projects shall include national economic evaluations. Economic internal rate of return (EIRR) shall not be less than the social discount rate, the economic net present value (ENPV) and the benefit-cost ratio shall be larger than 0 and 1.0, respectively. Benefit-cost ratio of water-saving irrigation projects shall be calculated by Formula (A.0.4).

8.0.3 Benefits shall comprise of increase of production after the operation of project as well as comprehensive benefits such as saving of water, land, fertilizer and labor. Benefit analysis calculation shall be in accordance with the following requirements:

1 Yield increase benefits shall be calculated according to the actual increase of yield or production value of the year. When nearly same techniques and agricultural measures are adopted, the increased production value of main products and by-products shall be equal to the increase of production value after the implementation of water-saving irrigation project and may be calculated by the Formula (B.0.1). If different technologies and agricultural measures are adopted, the increased production value shall be multiplied by the benefit sharing coefficient of project, as shown in the Formula (B.0.1). The coefficient value may be determined by referring to existing results in similar areas or based on survey data. If no data is available, a value of 0.2–0.6 may be estimated, with a smaller value for wet years and a larger value for dry years.

2 Water-saving benefits shall be calculated and evaluated in line with the differences between the amounts of irrigation water use with and without project implementation. This may be expressed as the amount of water saving or the water-saving rate and calculated by the Formula (B.0.2).

3 Land-saving benefits shall be calculated and evaluated in line with the reduction of area occupied by field canal system with and without the implementation of water-saving irrigation project. This may be expressed as the area of land savings or land-saving rate and calculated by the Formula (B.0.3).

4 Labor-saving benefits shall be calculated and evaluated in line with the differences between labor utilization with and without the implementation of water-saving irrigation project. This may be expressed as the number of labors saving or labor-saving rate and calculated by the Formula (B.0.5).

5 When the economic benefits of water-saving irrigation project are evaluated, the benefits shall not be double counted.

8.0.4 After the implementation of water-saving irrigation project, comprehensive capacity of production of the planting industry in beneficiary area shall be significantly improved, that is, grain crop yield shall increase by over 15% or water productivity increase by over 20%.

8.0.5 After normal operation of one year upon the completion of the water-saving irrigation project, the project shall be evaluated. The evaluation indexes should include production increase, saving effectiveness of water, land, energy, labor, and changes in agricultural production costs. The calculation methods for each index shall meet the requirements of this standard of Appendix B.

9 Management

9.0.1 Project management personnel shall be trained to master the necessary project operation and maintenance skills.

9.0.2 Water measuring equipment of water-saving irrigation project shall be in accordance with the following requirements:

1 A water measurement network that meets the requirements shall be established in surface water irrigation districts. Water billing shall be based on the actual amount of water measured at the inlet of lateral irrigation canals. In the irrigation districts with favorable conditions, metering should be applied down to the field canals.

2 Groundwater irrigation districts shall be equipped with water measuring facility for each well, and should employ measuring control technology of radio frequency card.

3 The allowable error of the measurements is $\pm 5\%$.

9.0.3 In the areas with or prone to secondary salinization, dynamic monitoring systems of water and salt shall be established to control the depth of groundwater. Water-saving irrigation project in ecologically vulnerable areas shall provide water for ecological and environment use within the scope of project area, based on ecological monitoring data.

9.0.4 Large irrigation district shall conduct irrigation experiments according to the current professional standard SL 13 *Specifications for Irrigation Experiment*. Medium and small scale irrigation districts and concentrated continuous groundwater irrigation areas shall carry out field observations of water use at fixed points. Water-scarce areas shall perform deficit irrigation experiments.

9.0.5 If groundwater is used for water-saving irrigation project, monitoring facilities of groundwater table and volume shall be equipped.

10 Area of water-saving irrigation

10.0.1 The area of water-saving irrigation project may be defined if one of the following conditions is met and the indicator of yield-increasing and water-saving complies with the requirements of this standard.

1 Irrigation project with canal seepage control meets the relevant requirements of Chapter 6, Sections 7.1 and Section 7.2 of this standard.

2 Irrigation project with pipe conveyance meets the relevant requirements of Chapter 6, Section 7.1 and Section 7.3 of this standard.

3 Irrigation project with sprinkler meets the relevant requirements of Chapter 6, Section 7.1 and Section 7.4 of this standard.

4 Irrigation project with microirrigation meets the relevant requirements of Chapter 6, Section 7.1 and Section 7.5 of this standard.

10.0.2 The area with the water-saving irrigation measures may be defined if one of the following conditions is met:

1 Irrigation projects with canal seepage-control, pipes for water conveyance, sprinkler or microirrigation meet the requirements of Chapter 7, but does not fully conform to the requirements of Chapter 6, or the dependability of irrigation design does not meet the requirements of the current national standard GB 50288 *Code for Design of Irrigation and Drainage Engineering*.

2 Irrigation project with farmland surface meet the requirements of Article 7.1.1 of this standard.

3 Project of local irrigation with injection meet the requirements of Article 7.6.1 of this standard.

4 Irrigation project with rainwater harvesting meet the requirements of Article 4.0.5 of this standard.

5 Irrigation project with mobile ground hose meet the requirements of Article 7.3.4 of this standard.

10.0.3 The area of water-saving irrigation project and the area of water-saving irrigation measures shall avoid double counting in statistics.

Appendix A Methods of measurement and calculation for the related parameters

A.0.1 The water use efficiency of canal shall be measured by the following methods:

1 Hydrodynamic inflow-outflow measurement method. Based on hydro-geological conditions along the canal route, middle non-branching and typical canal segment shall be selected to observe the amount of water passing through the two cross-sections upstream and downstream at the same period, and the difference between inflow and outflow volume is the amount of water loss. It shall be in accordance with the following requirements:

1) Flow measurement shall be conducted by measuring two selected observation cross-sections (downstream and upstream).

2) Flow shall be stable during observation, with no split flow during that period.

3) Observation conditions and instruments for downstream and upstream cross-sections of the test section shall stay the same.

4) Observation cross-sections shall be selected in a straight section of the canal, and its length shall not be less than 10 times the width of the canal. Water flow shall be uniform, with no vortex or reflux.

2 Hydrostatic measurement method. A typical section of canal shall be selected with a length of 50m to 100m, with both ends blocked. Water level markers shall be set in the middle of the canal, and water shall be filled into the canal to monitor constant and variable water levels, as well as rainfall and evaporation. The loss of water and canal water use efficiency may be calculated according to the change of water level.

A.0.2 The water use efficiency of irrigation for well-canal irrigation districts may be calculated according to the following formula:

$$\eta_c=(\eta_j W_j+\eta_q W_q)/W \tag{A.0.2}$$

Where, η_c—water use efficiency of irrigation for well-canal irrigation districts;

η_j—water use efficiency of irrigation for well-irrigated farmlands;

W_j—groundwater consumption (m^3);

η_q—water use efficiency of irrigation for canal-irrigated farmlands;

W_q—surface water consumption (m^3);

W—total water consumption in well-canal irrigation districts, $W=W_j+W_q$ (m^3).

A.0.3 On-farm water use efficiency shall be measured and calculated according to the following methods:

1 Averaging method.

$$\eta_t=mA/W \tag{A.0.3-1}$$

Where, η_t—on-farm water use efficiency;

m—increase of amount of water in the planned wet layer after a certain irrigation event (m^3/hm^2);

A—actual irrigation area controlled by the end and fixed canal (hm^2);

W—total amount of water released from the end and fixed canal (m^3).

2 Actual measurement method. The plots selected in the irrigation district shall be representative.

Net irrigation quota shall be calculated by measuring the actual change in soil water moisture in the planned wet layer with and without irrigation (1 d to 3 d). On-farm water use efficiency is calculated according to the following formula:

$$\eta_t = 10^2(\beta_2 - \beta_1)\gamma HA / W \tag{A.0.3-2}$$

Where, β_1 and β_2—soil moisture water content in the planned wet layer with and without irrigation (expressed as a percentage of dry soil weight);

γ—dry bulk density of soil (t/m^3);

H—planned wet depth (m).

A.0.4 Benefit-cost ratio of water-saving irrigation project may be analyzed whether there are incremental costs and benefits, and shall be calculated according to the following formula:

$$R = \sum_{t=1}^{n} \frac{B_t}{(1+i_0)^t} / \sum_{t=1}^{n} \frac{C_t}{(1+i_0)^t} \tag{A.0.4}$$

Where, R—benefit-cost ratio;

B_t—increase of production value in nth year of water-saving irrigation project implementation (10 000 yuan);

C_t—operating cost of water-saving irrigation project in nth year (10 000 yuan);

i_0—annual interest rate of capital (%);

n—service life of water-saving irrigation project (years);

t—year of calculation.

Appendix B Calculation methods of the benefit index

B.0.1 Benefits of yield increase shall be the actual increased production value in a given year and should be calculated according to the following formula:

$$B_j=\sum_{i=1}^{n}A_i(Y_i-Y_{i0})P_i+\sum_{i=1}^{n}A_i(Y'_i-Y'_{i0})P'_i \tag{B.0.1}$$

Where, B_j—increased production value within the irrigation district in jth year (yuan);

A_i—planting area of ith crop in the irrigation district without the completion of project (hm^2);

Y_i and Y'_i—yield of main and by-products of ith crop with the completion of project (kg/hm^2);

Y_{i0} and Y'_{i0}—yield of main and by-products of ith crop without the completion of project (kg/hm^2);

P_i and P'_i—unit price of main and by-products of ith crop (yuan/kg);

i—serial number of crop species;

n—number of crop species planted in the district.

B.0.2 Water-saving rate shall be expressed as percentage of water saved after the implementation of project to the original irrigation water, and should be calculated according to the following formula:

$$R_{sh}=\frac{M_0-M_g}{M_0}\times 100\% \tag{B.0.2}$$

Where, R_{sh}—water-saving rate (%);

M_0—annual gross total water use without the completion of project (m^3/year);

M_g—annual gross total water use with the implementation of project (m^3/year).

B.0.3 Land-saving rate shall be expressed as the ratio of difference between the cover area of canal system and the cover area of water-saving irrigation system and the project command area, which should be calculated according to the following formula:

$$R_{sl}=\frac{A_0-A_g}{A}\times 100\% \tag{B.0.3}$$

Where, R_{sl}—land-saving rate (%);

A_0—area occupied by field canal system (hm^2);

A_g—area occupied by water-saving irrigation system (hm^2);

A—total command area by the project (hm^2).

B.0.4 Energy-saving rate shall express as a percentage of amount of power savings from the original amount of irrigation power consumption following the implementation of project, which should be calculated according to the following formula:

$$R_{se}=\frac{E_0-E_g}{E_0}\times 100\% \tag{B.0.4}$$

Where, R_{se}—energy-saving rate (%);

E_0—total annual power consumption without the completion of project construction (kW·h/year);

E_g—total annual power consumption with the completion of project construction (kW·h/year).

B.0.5 Labor-saving rate shall express as the percentage of annual labor saved after the implementation of project to the total number of original annual labor, which should be calculated according to the

following formula:

$$R_{ss}=\frac{G_1-G_2}{G_1}\times 100\% \tag{B.0.5}$$

Where, R_{ss}—labor-saving rate (%);

G_1—total amount of annual labor use without the completion of project construction (man-days/year);

G_2—total amount of annual labor use with the completion of project construction (man-days/year).

B.0.6 Variation value of irrigation cost should be calculated according to the following formula:

$$C_g=A(E_1-E_2)P_E+A(G_1-G_2)P_G \tag{B.0.6}$$

Where, C_g—value of change in irrigation cost (yuan);

P_E—local power tariff for irrigation [yuan/(kW·h)];

P_G—local labor cost for irrigation (yuan/hm^2).

Explanation of wording in this standard

1 Words used for different degrees of strictness are explained as follows in order to mark the differences in executing the requirements in this standard:

1) Words denoting a very strict or mandatory requirement:

"Must" is used for affirmation; "must not" for negation.

2) Words denoting a strict requirement under normal conditions:

"Shall" is used for affirmation; "shall not" for negation.

3) Words denoting a permission of a slight choice or an indication of the most suitable choice when conditions permit:

"Should" is used for affirmation; "should not" for negation.

4) "May" is used to express the option available, sometimes with the conditional permit.

2 "Shall comply with..." or "shall meet the requirements of..." is used in this standard to indicate that it is necessary to comply with the requirements stipulated in other relative standards or codes.

List of quoted standards

GB/T 50085 *Technical Code for Sprinkler Engineering*

GB 50265 *Design Code for Pumping Station*

GB 50288 *Code for Design of Irrigation and Drainage Engineering*

GB/T 50485 *Technical Code for Microirrigation Engineering*

GB/T 50600 *Technical Code for Seepage Control Engineering on Canal*

GB/T 50625 *Technical Code for Water Wells*

GB 5084 *Standard for Irrigation Water Quality*

GB/T 20203 *Technical Specification for Irrigation Projects with Pipe Conveyance*

SL 13 *Specifications for Irrigation Experiment*

SL 558 *Code of Practice for Technical Management of Surface Irrigation Project*