Selecting the Drainage Parameters and Their Correlation with Irrigation Practice

V.A. Dukhovny, H.I. Yakubov, P.D. Umarov

A role of land drainage in arid regions considerably differs from its role in humid regions. If the latter has to control only waterlogging and surface flooding of the farming lands, drainage in arid and semi-arid regions executes two additional important functions. The first function that is well-known and described in western scientific publications [59, 60] is salinity control and creation of conditions for irrigation without leaching fraction. At the same time, the second function is typical only for water-deficit regions and consists in providing the optimal water and salt regime of soils. This function was studied and widely described in the publications of Soviet scientists [62, 63], but, in our view, it was to some extent ignored by foreign scholars. As known, high evaporation and insufficient natural drainage resulting in rising groundwater table under irrigation and accumulation of soluble salts in the aeration zone are typical features for arid regions. The amount of salts being accumulated within the rootzone and a rate of soil salinization depend on a salt content in groundwater and the intensity of capillary upward flux that, in turn, depends on soil properties, depth of watertable, and soil water gradient. A key indicator of drainage efficiency is the ability of drainage systems to keep groundwater table at a design active depth that is specified by such design parameters as a depth of field drain, design of drain pipeline (a pipe diameter, envelop thickness and materials, and drain gradient), and drain spacing. All these parameters should be considered in relation to their areal layout in a field.

Designing the drainage systems for arid conditions taking into consideration the water-saving aspect and controlling removal of soluble salts, preventing salts accumulation with simultaneous keeping of useful nutrients in soils is based on selecting of the optimal land reclamation regime [6, 63]. This problem is considered in many scientific publications. A kernel of this approach can be briefly described as the search of an optimal ratio of average-weighted watertable over area and maximum capillary height under considering different values of groundwater salinity (Table 4.7).

Figure 4.18 shows that minimizing of salts removal and water consumption per unit volume of salts removed [6] corresponds to optimal costs (reduced costs per one hectare). A correlations between the optimal salt and water regime and cotton yields (Fig. 4.19) that are plotted based on data collected at six pilot stations of the SOUZNIKHI[1] and represented in the same publication shows that sustainable and maximum cotton yields are observed under the optimal water and salt regime of soils.

[1] Scientific-Research Institute of Cotton Growing

Table 4.7. Correlation of Groundwater Salinity and a Relative Depth of Groundwater Table under the Optimal Soil Water and Salt Regime

Groundwater salinity	$\frac{H_{mgs}}{h_c}$	Salt removal, t/ha
1 g/l	0.5	1-2
2-3 g/l	0.6	3-7
5-7 g/l	0.9	5-10
>10-15 g/l	1.2	10-15

were: h_c is a maximum capillary height;

H_{mgs} is a mean GWT over a growing season.

1: M = 1 g/l;
2: M = 2 g/l;
3: M = 3 g/l;
4: M = 5 - 7 g/l;
6: M = > 10 - 15 g/l.

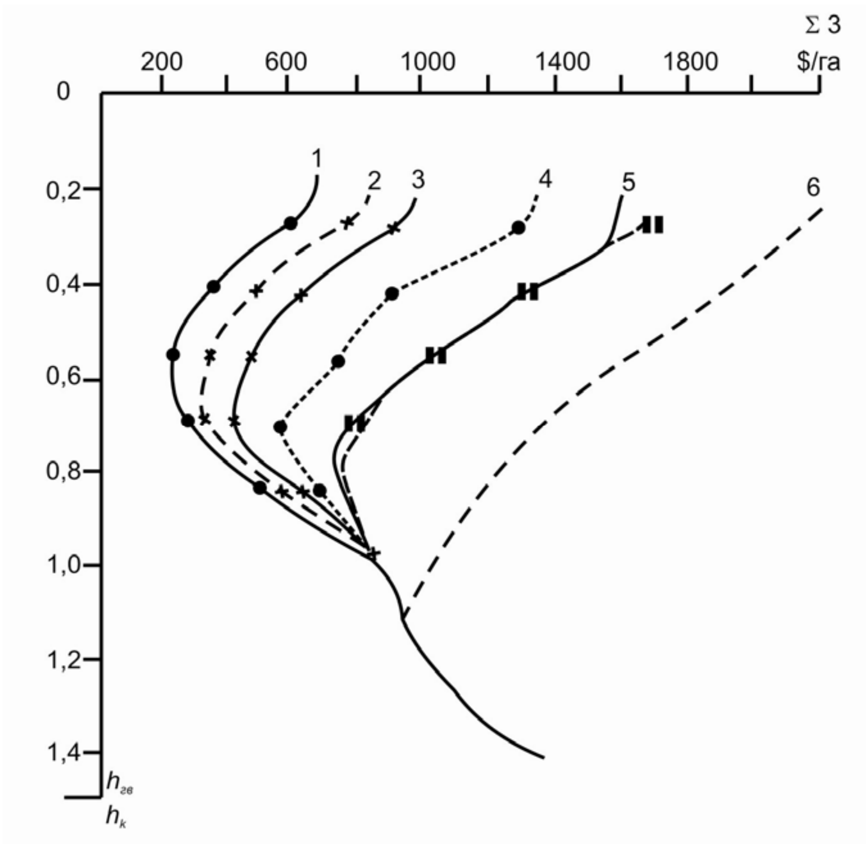


Figure 4.18 Optimizing the GWT regime regarding unit costs taking into account water consumption and crop yield:

Regimes of soil formation:

I – hydromorphic;
II – semi-hydromorphic;
III – semi-automorphic;
IV – automorphic.

Pilot Site of SOUZNIKHI:

1 – Pakhta-Aral;
2 – Bukhara;
3 – Golodnaya Steppe;
4 –Fedchenko;
5 – Akkawak;
6 – Khorezm.

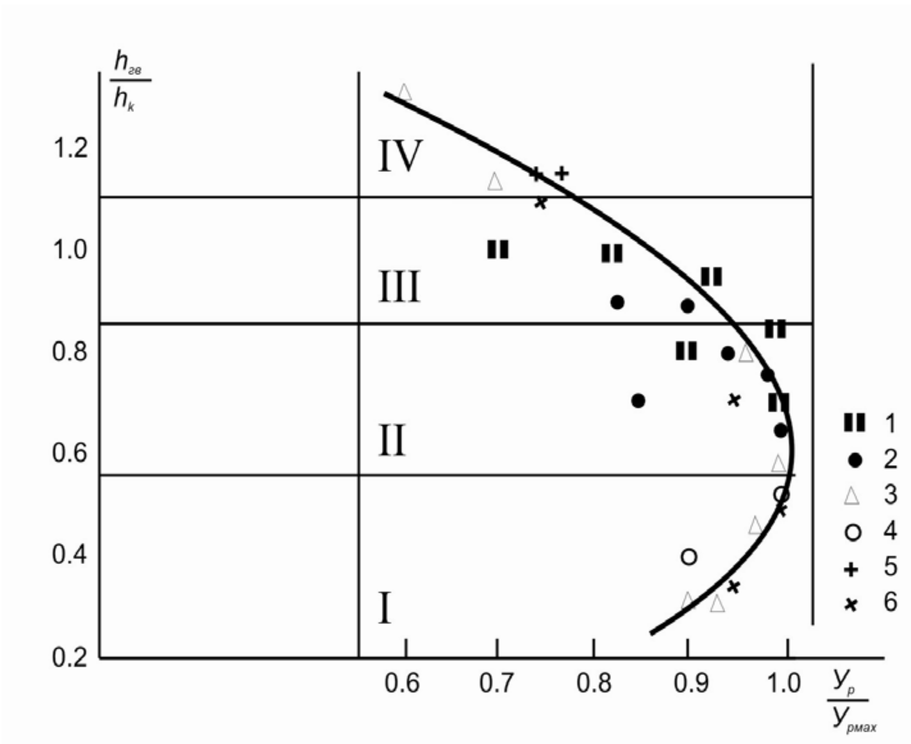


Figure 4.19 Impact of Relative GWT and the Hydro-Ameliorative Regime on Cotton Yield

Without considering other factors, a maximum crop yield corresponds to values of a relative GWT (a ration of an average depth of GWT over the growing season to a capillary height) ranging from 0.5 to 0.75. However, an optimal depth of GWT also depends on groundwater salinity.

A hydraulic head midway between real drains differs from a hydraulic head midway between ideal drains by the entrance head losses that depend on sizes and materials of the envelop, pipe parameters, construction method and by the extra head loss caused by the radial flow when a pipe drains do not reach the impervious layer and the flow lines converge towards drains, as well as an underground water head, if necessary, should be also taken into consideration. Due to the above factors, an actual hydraulic head midway between real drains can be less by 30 to 100 cm. In case of leaching operations or check irrigation, when discharge of drains is abruptly increasing, a so-called “effective drainage depth” can be decreased as well.

It is necessary to keep in mind that the design scheme of subsurface drainage (various design formulas used in our and foreign practice) considers a drain spacing for one specific transverse fragment that is perpendicular to the drain pipeline rather than for an irrigated field as a whole. For assessing the actual situation on the irrigated field some additional transverse fragments have to be considered, and then to evaluate a mean depth of groundwater table over the whole field. However, even under such an approach, it is additionally necessary to take into consideration the influence of deep collector-drain causing the specific drawdown curve in the direction along subsurface drains (Figure 4.20).

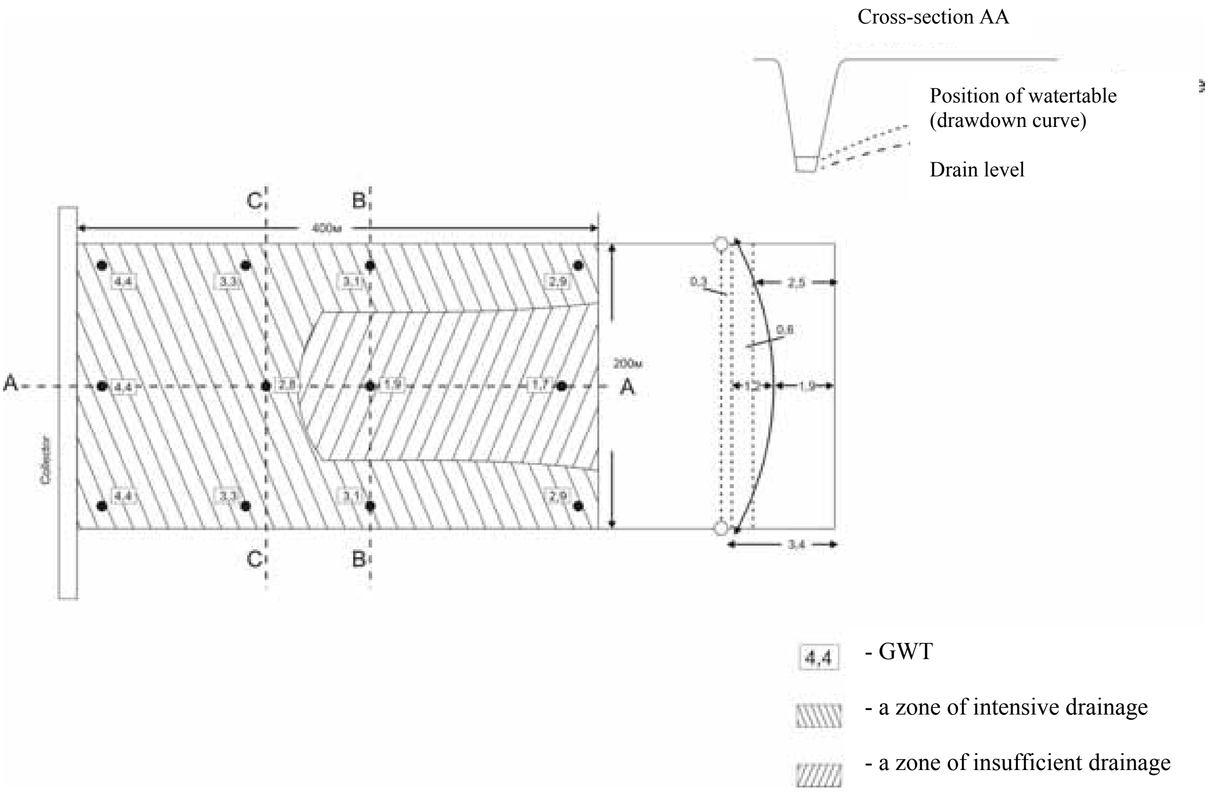


Figure 4.20 Forming GWT on Good-Leveled Fields with Well-Designed Drainage System

Hence, the following interesting facts can be mentioned:

- In the Golodnaya Steppe, where loess soils are characterized by high capillary properties (a capillary rise (h_c) equals 3 m and even more), a depth of GWT averaged over the growing season has to be 2.7 m under groundwater salinity ranging from 5 to 8 g/l; and correspondingly an installation depth of subsurface drains should be 3.0-3.5 m. The correctness of such technical solution was proved by all the practice of land reclamation in the Golodnaya Steppe where land desalinization was provided under gross water consumption of 9,500 to 10,500 m^3/ha;

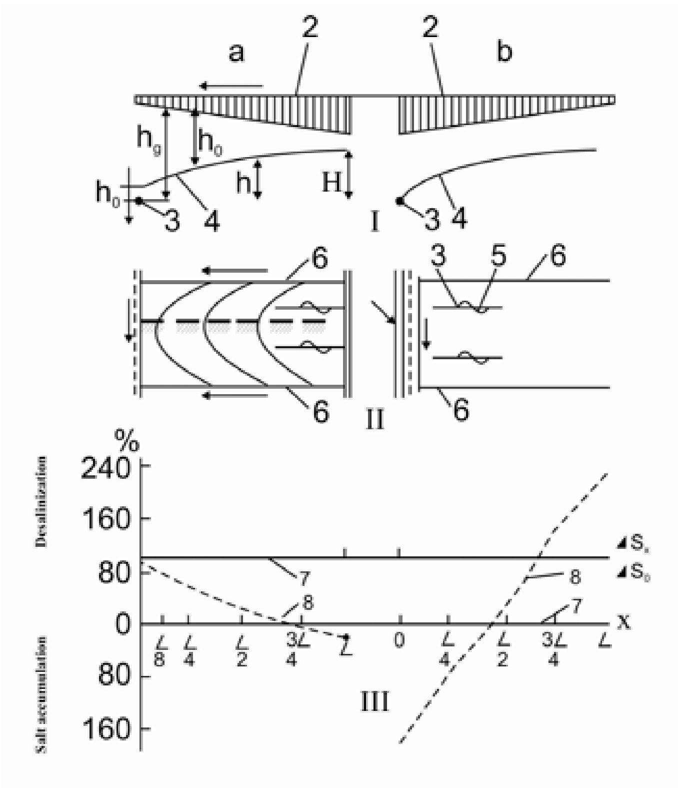
- In lower reaches of Central Asian rivers, in particular in Khorezm Province, stratified soils with thick sand layer (a capillary rise equals 1.6 m), a depth of GWT averaged over the growing season has to be 1.1 m under groundwater salinity ranging from 3 to 5 g/l; and correspondingly a depth of subsurface drains should be 1.5 -2.0 m.

- On irrigated lands with sandy soils (hc = 0.5 m, for example, in the pilot farm of SANIIRI in Khorezm Province), the drainage system with subsurface drains 1.5 m deep has created the automorphic regime causing the need of frequent water applications

Just that very case can explain the success of drainage practice in Egypt on sandy soils of the Nile River delta. There are different soils on drainage sites in India and Pakistan, but it is necessary to keep in mind that the monsoon climate with considerable rainfalls creates the conditions for intense leaching of soils over the vast area of drainage projects in Pakistan and in the state of Haryana in India.

At the same time, we can refer to data collected at their pilot drainage site in Iraq (personal communication of V. Dukhovny with Mr. Hulbols), where in the Dajilakh Irrigation Scheme the leaching regime of soils was provided based on shallow drainage (a drain depth of 1.2 m) only under gross water consumption of 16,000 -17,000 m^3/ha.

Let us consider, for example, a combination of the transverse pattern of furrow irrigation with non-regulated flow in a head of furrows with the transverse network of field subsurface drains. Assuming for estimate the most advanced strip AB (Fig. 21) along the axis of drain spacing, we consider contributors of the salt balance within the aeration zone and their distribution over a length of the strip AB from a collector-drain to an irrigated distribution flume[2].



a – under coincident directions;
b – under opposite directions;
I – cross-section;
II – plan;
III – salt accumulation curve.

1 – an irrigated distribution flume;
2 – an infiltration diagram;
3 – a collector-drain;
4 – a drawdown curve;
5 – a direction of water application;
6 – field drains;
7 – an average design salt accumulation depending on interaction of drainage and percolation flows;
8 – the distribution of salt accumulation areas against interaction of drainage and percolation flows.

Figure 4.21 Desalinization Effect under Different Combinations of Directions of Water Application and Field Drains:

[2] Precast lateral lifted above ground for irrigation water delivery to fields.

Assuming the widespread pattern of field drains lengthwise an irrigated plot 400 m long, a design drain depth of 3.5 m and drain spacing of 200 m, we have assessed the extent of desalinization effect against groundwater salinity up to 8 g/l and irrigation water salinity of 1 g/l. Long furrows, direction of which coincides with field drain gradient, are employed for a water application. As shown in Fig.6a, the decrease in percolation intensity under moving from a drain head is overlapping on the increase in a groundwater depth. Since a minimum groundwater table is observed near an irrigated flume, velocities of convection transport are minimal here, but greater percolation values in accordance with the percolation diagram compensate them. In the direction towards an outlet of field drain, where a maximum groundwater table is observed, water percolation values in accordance with the percolation diagram are tending to zero. As a result, the desalinization is provided over the 90 percentage of field area, having a considerable margin. Under the contrary pattern, where water applications are conducted in the direction from a drain outlet towards its head, percolation intensity over the 50 percentage of field area does not create necessary velocities of convection transfer of salts resulting in the lack of leaching affect over this area that should be delineated (leaching requirements have to be increased 1.8 times here!!!).

As shown in our publication [5], the duration of water applications and the extent of their covering the area that is simultaneously drained and irrigated are also significant for maintaining uniform soil moistening and water percolation downwards. Forming the big local mound in the watertable does not occur if the duration of water application is ranging from 12 to 24 days, but elongating of water application terms and a high percentage of a simultaneously irrigated area within the drainage plot (more than 50%) cause the rise of watertable by 0.5 to 1.0 m and create an additional load on the drainage system (a drainage rate increases two times); in addition, at the same time, useful salts and nutrients are leached and carried away from soils.

From this point of view, introducing the water rotation, control of water application arrangement according to the daily schedule recommended by the SIC ICWC [24] and deconcentration of simultaneously irrigated areas facilitate more uniform soil moistening, desalinization and enhancing soil fertility. More attention should be paid to these matters under introducing the field passports and recommended schemes of water applications.

Organization of Land Reclamation and O&M Works

Problem-free land reclamation activity depends on many factors predetermined by natural conditions within the irrigation scheme and by its irrigation and drainage components as well. Different organizations and even sometimes different departments "have in their hand" the sustainable operation of these territories and simultaneously the irrigation and drainage systems. At the same time, only the coordinated actions of all actors, on which proper irrigation water supply and drainage depend, can provide high crop yields under minimum water consumption based on uniform effects of irrigation and drainage (Fig. 4.22).

Even earlier, under the administrative system of governing irrigation and drainage, it was difficult to provide the coordination and integration of all actors. In the Soviet time, the state water management organizations under supervision of the Provincial Hydro-Ameliorative Expeditions (PHAE) have incurred all costs related to O&M of the drainage systems. Now this task is more complicated due to many causes. However, new forms and methods of the integration have to be searched out under present conditions.

After independence, practically all Central Asian countries considerably abated the activity related to maintaining the drainage systems, especially at the on-farm level. The Republic of Uzbekistan maintains the satisfactory operating conditions of inter-farm and main collector-drains, but has also reduced the scope of O&M works on the on-farm drainage network. As a result, during last 15 years, the operability of drainage systems abrupt dropped. In conjunction with deficit of water resources needed for leaching salt-affected soils, this has resulted in restoration of irrigated land salinization. Up to now, this process is not stopped and continues to strengthen: about 60% of irrigated areas are subjected to salinization in Uzbekistan; 70% in South Kazakhstan and 80% in Turkmenistan.

The problem of organizing O&M of former on-farm drainage systems became more acute after restructuring collective farms and state farms. Without touching the peculiarities of operating the irrigation network that were presented in other sections in detail, we will consider management of drainage systems including drainage infrastructure and issues related to drainage water and salts disposal out of the irrigation schemes.

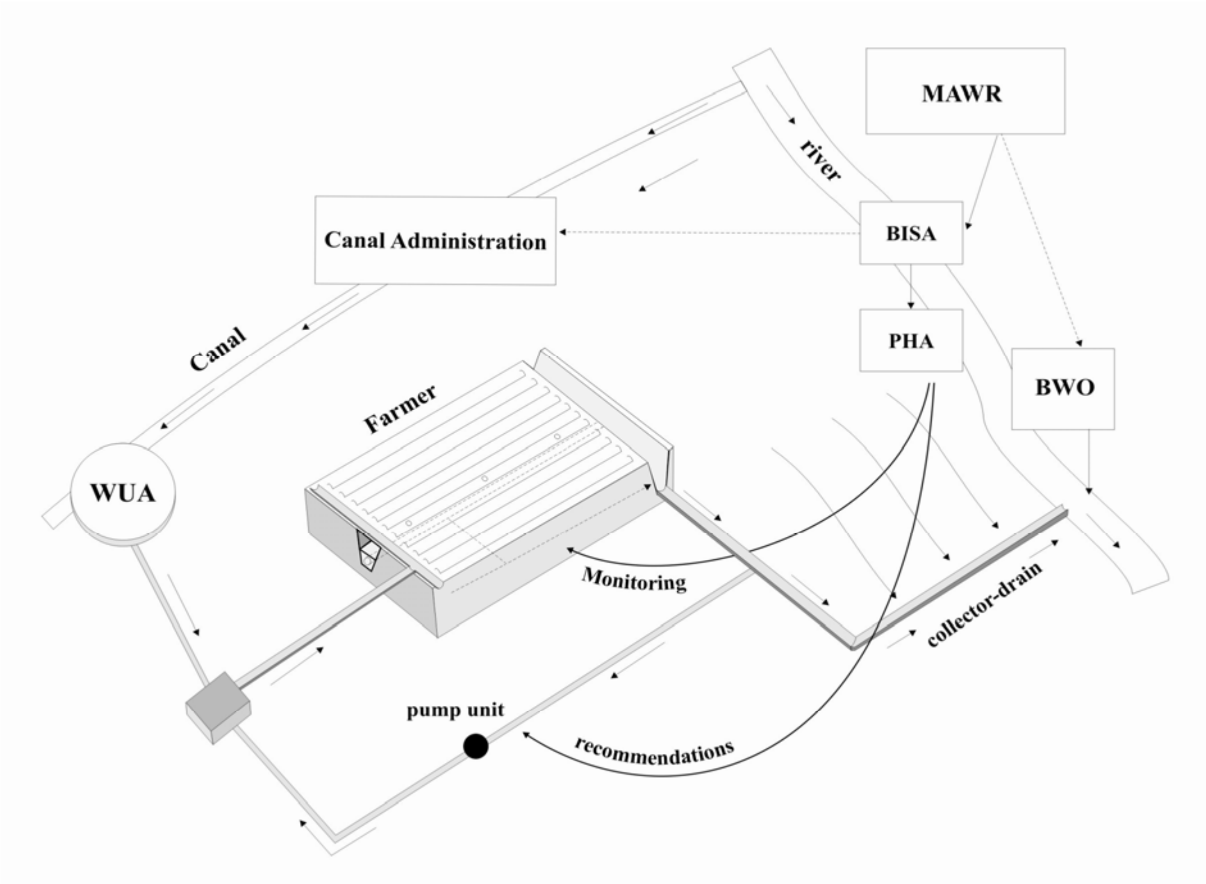


Figure 4.22 The Problem-Free Land Reclamation System

Sustainability of land productivity depends on the following key factors:

- Timely watering of soils and crops depending on their water requirements using the proper method of irrigation and providing uniform water distribution over a field;
- Preventing soil salinization above admissible limits;
- Preventing also waterlogging the rootzone, maintaining soil moisture relevant to specific crops and soil characteristics and properties; and

- Maintaining uniform topsoil quality relevant for supporting the proper crop growth and a field micro-relief to prevent over-application of water and flooding low places and under-application of water on higher places in the process of irrigations.

Keeping in mind numerous technical and agrarian peculiarities of soil salinization processes, a farmer can not in the least know the methods for their specifying, but it is very important in order that partners of farmers such as WUAs and Land Reclamation Bureaus (PHAE) could provide them with required information, on regular basis, and simultaneously execute their commitments regarding land reclamation activity.

On what reasons the implementation of each above requirement depends? And who should provide these ameliorative conditions, without which high crop yields are impossible?

Irrigation water delivery to a field and crops depends on the following aspects:

- Operational condition of the intra-farm irrigation network (the executor: a farmer);
- Submitting the applications covering the current year and season and their adjustment according to the water use plan approved by the WUA based on the existing norms and allocated limits for water use (the executor: a WUA);
- Good preparation of a field; and proper water distribution within the farm (the executor: a farmer);
- Installation of a water meter on the off-take to farmer's field (the executor: a farmer);
- Operational condition of the conveyance canal to a farm (the executor: a WUA with participating a farmer);
- Maintaining sustainable management of irrigation water delivery and distribution within the irrigation network under its responsibility (the executor: a WUA):
- Maintaining uniform, stable and sustainable water delivery to WUAs' irrigation canals according to their water use plans and agreed and adjusted applications (the executor: the WMO);
- Timely payment for WUA's water services (the executor: a farmer);

***Preventing soil salinization above the permissible limits in farms can be provided by*:**

- Field surveying and soil sampling; and then plotting of a soil salinization map of farm fields with the legend containing the advisable norms of leaching operations for a farmer (the executor: the PHAE);
- Studying opportunities for using drainage water for leaching operations (the executor: the PHAE at the expense of the state budget or developing more detailed recommendations according to the decision of WUA and farmers at the expense of farmers);

- Follow-up annual soil sampling and modification of soil salinization maps by the PHAE;
- Construction of necessary additional drainage facilities by the WMO under supervision of the PHAE (at the expense of budgetary funds);
- O&M of field drains and collector-drains within own farm with an annual detailed survey and current inspection every ten days (the executor: a farmer);
- Maintaining the inter-farm drainage network providing its design depth with appropriate preventive and emergency repairing of the collector-drains and field drains (the executor: WUAs);
- Cleaning and repairing the collector-drains and field drains based on the contractual relations with WUAs (the executor: the WMO under supervising by the PHAE);
- Drainage water disposal out of the WUA's area by gravity or using the pumping units for maintaining the design depth of groundwater table over the area of WUA (the executor: the WMO with participation of the PHAE, at the expense of budgetary funds);
- O&M of drainage tubewells are implemented by specialized organizations (PSA) or the PHAE at the expense of budgetary funds in case of the intercepting drainage and with shared financing by farmers in case of regulating the groundwater table over the farm areas; and
- Water delivery for leaching operations in necessary amounts (the executor: the WUA and WMO).

Maintaining a necessary depth of groundwater table can be provided by means of:

- Monitoring and plotting a depth-to-watertable map for farms and developing measures for areas with the inadmissible groundwater table with the purpose of its lowering (the executor: the PHAE);
- Hereinafter, all positions of the previous paragraph is repeated in the same sequence and with the same executors

Creating the uniform background for providing soil fertility over the irrigated area requires the following:

- Assessing the current state of topsoil fertility in farms by means of remote sensing and on-ground surveys implemented by the extension services or specialized organizations based on the contract with farms;
- Implementing the land leveling by employing long-wheelbase scrapers or laser land leveling equipment funded at the expense of farmers, credits or donors' grants;
- Improving the soil texture by means of deep ripping, addition of sand, clay or other amendments (the executor: a farmer);

A field is the area of farm's responsibility. Farmers should monitor the technical state of field drains and collector-drains, and prevent releasing of irrigation water into the drainage network causing its erosion and damage. Farmers also have to clean the collector-drains, to flush pipelines of subsurface drains (by the gravity method) and to mow weeds overgrowing collector-drains within the own plots.

At the same time, farmers must timely prepare their fields for leaching operations and water applications and then implement them according to the established schedule. If possible, farmers should use return water, mixing it with irrigation water based on the permission and recommendations of the PHAE.

The drainage network within the WUA's area is the field of responsibility of a WUA that should maintain collector-drains, sign the agreements on the technical servicing of on-farm drainage systems, monitor and account the drainage discharge, and involve farmers in necessary works on the drainage network using the "khashar"[3] method. In addition, a WUA plans the usage of return water and delivers it for irrigation (sometimes a WUA organizes use of drainage water on the centralized base). However, a WUA itself cannot execute all necessary works within its area; and part of works should be implemented by the specialized organizations.

At that, first of all, funds should be available and, secondly, specialized machinery or the contractors that can execute necessary works based on the agreement are also needed. At the same time, there is no way to turn the works related to cleaning the collector-drains or repairing and flushing subsurface drains into the contractual intervention.

[3] "Khashar" is voluntary participation of the population in socially necessary works profitable for all or as aiding a member of their community.