Executive Summary

1. Introduction

1.1. During the last thirty years over two hundred (200) pilot projects and (field researches) in irrigation and drainage were carried out in Central Asia. The results of these former activities are stored in a widely diverging format at numerous institutions throughout Central Asia and are not readily assessable.

1.2. The previous pilot project started in May 1997 with the objective to make the results of previous pilot projects available for future irrigation and drainage rehabilitation and improvement projects. The two main outputs of the project were defined as follows:

a) Storage of IPTRID[1] style summary forms of some 140 previous pilot projects in the IPTRID Research Data Base and the presentation of this information in report form;

b) A Final Report which presents the results of a re-assessment of the scope and results of selected pilot projects with a view to improve the understanding of the previous design criteria and operating standards of irrigation and drainage schemes in various parts of Central Asia.

1.3. The project was implemented under the Aral Sea Basin Program by five national working groups and one regional working group under leadership of SIC-ICWC, the Scientific Information Center of the Interstate Commission for Water Coordination. The total budget amounted to US$ 100,000 equivalent, funded from the Dutch Trust Fund for the Aral Sea Basin Program.

2. Storage of Information on Previous Pilot Projects in IPTRID Research Data Base

2.1. In total 143 IPTRID style summary forms were prepared of previous pilot projects in irrigation, drainage and salinity control in Central Asia. Each summary gives on two to four three pages information on the following: project title, project location, duration of the project, organization and technical staff involved, costs and funding agencies, objective and technical fields, scientific and technical approaches, physical and environmental characteristics, parameters of pilot projects and technical solutions, methodology, results, key words, most recent publications.

2.2. The summary forms have been completed with sufficient level of detail to assess under which conditions the results are applicable. Several of the reported projects concentrated on similar problems in irrigation, drainage and salinity control. Sufficient repetition appears to be available to draw more general conclusions from the reported pilot projects. Nearly all of the pilot projects closed more than a decade ago. However, the reported results are still valuable because the physical processes in, for example, salinity control and drainage remain unchanged.

[1] International Program for Technology Research in Irrigation and Drainage (IPTRID). The IPTRID Research Data Base is maintained by ILRI, the International Institute for Land Reclamation and Improvement

2.3. All 143 forms were subsequently processed and stored in the IPTRID Research Data Base through IPTRID's network linkage at the irrigation research institute Saniiri in Tashkent. Print-outs of the stored versions were submitted to the national working groups for review and verification. Improvements suggested by the national working groups were used to update the information in the IPTRID research data base. The stored information has been published by ILRI in the DRAIN Journal.

3. Review of Scope and Results Previous Pilot Projects

3.1. Introduction

3.1.1. Five inter-related subjects or themes were defined for a further assessment of the previous pilot projects aimed at extracting valuable results and lessons for upcoming irrigation and drainage rehabilitation and improvement projects. The themes are:

a) Irrigation regime and water consumption norms for major agricultural crops;
b) Management of soil water-salt regime and ecological-meliorative processes on background of drainage, leaching and leaching regime of irrigation;
c) Leaching of saline lands and leaching regime of irrigation;
d) Collector-drainage water re-use for irrigation in place of its origin;
e) Optimal irrigation methods, parameters, technique and technologies.

3.1.2. The various previous pilot projects were grouped under one or more of the above themes. The results of the assessment of valuable information on the above themes are described in this report. A summary of this information is presented below.

3.2. Irrigation regime and water consumption norms for major agricultural crops

3.2.1. 34 pilot projects were selected for this direction from which 7 relate to irrigation regime and water consumption norms for cotton, 10 -for winter wheat, barley and maize for grain and silo, 9 -for rice and 3 -for alfalfa.

3.2.2. Analysis shows that soil water regime is a main factor influencing crops physiological growth, development and yield. Optimum of water factor is established through soil moisture regime created in arid zone by irrigation. Irrigation regime for tilling crops (except rice) was studied under different values of pre-irrigation moisture from maximum water capacity (MWC). In most of tests for cotton soil moisture varied within 55 -80 %, for other crops 60 -90 %. As a result, limits of soil pre-irrigation moisture were established for all crops, under which water consumption norms are optimal and high yield is achieved.

3.2.3. This regime of irrigation with maintaining indicated limits of moisture within rooting zone of cotton according to its development stages is recommended for all regions of Uzbekistan, Tadjikistan and Kyrgyz Republic with soil automorphous regime for semi-automorphous regime with groundwater table depth 2-3 m optimal regime of irrigation is regime with moisture in rooting zone 70x70x60 and for hydromorphous soils (groundwater table depth < 3 m) 70x80x70.

3.2.4. More than 35-40 % of irrigated lands in the region are semi-automorphous and semi-hydromorphous. Automorphous soils are located in AmuDarya and SyrDarya downstream.

3.2.5. For cotton optimal moisture is 70x70x60 and 70x80x60 under automorphous soils and ground water depth 3 -3.5 m. Yield varies within 3.5 -4.7 t/ha and water consumption norms within the limits of 8.5 -10.8 th. m^3/ha for automorphous regime and 5.3 -5.5 th. m^3/ha for hydromorphous soils. Water consumption norms for moisture formation at expense of water supply under automorphous regime reach 88 -90 %, under hydromorphous one -70-75 %. But to prevent soil secondary salinization in hydromorphous soils and soil solution concentration reduction, winter-spring leaching is performed by norm 3.0 -5.5 th.m^3/ha. Under optimal pre-irrigation soil moisture the lowest water expenses for production unit are achieved (930-1200 m^3/t) against 1400-1800 m^3/t in other variants. Water saving under optimal regime of irrigation is 10 -22 % to compare with control fields. Water productivity is 0.4-0.9 kg/m^3 under FAO efficiency criterion 0.4 -0.6 kg/m^3 whereas in control variants it is 0.3 -0.4 kg/m^3.

3.2.6. It is widely known, that under cotton irrigation high pre-irrigation moisture reduces irrigation interval duration, but number of irrigations increases. Under optimal irrigation regime irrigation interval is 14 -18 days while under pre-irrigation moisture 60x60x60 it reaches 25-28 days, that causes water losses increase and plants' stress. Under optimal pre-irrigation regime of soil moisture 8 -10 irrigations are applied during the growing period by norms 700-1100 m^3/ha for automorphous soils and 4 -5 irrigations by norm 770-1230 m^3/ha for hydromorphous ones. Main advantage of frequent irrigations by small norms is, that irrigation water is spent for moisture formation in rooting zone. Soil moisture in rooting zone (0 -1.0 m) after irrigation is 93-97 % whereas on control plots it exceeds MWC on 3 -5 % and specific water expenses increase up to 2-2.5 kg/m^3, i. e. they are higher than FAO upper limit (1.8 kg/m^3).

3.2.7. As to cotton irrigation regime, frequent irrigations by small norms (700-1100 m^3/ha for automorphous soils and 800 -1200 m^3/ha for hydromorphous ones), even under furrow irrigation with optimal elements without discharge regulation, create favorable conditions for water flow management and cause uniformity of mellowing over irrigated plot. In this case furrow irrigation technology approximates to surge and pulse irrigation. Usually irrigation of crops and especially cotton is executed with violation of irrigation regime and furrow irrigation technology. This is one of the main reasons for irrigation water productivity reduction.

3.2.8. Practically irrigation norms reach 1.5-2.5 th. m^3/ha under limited number of irrigations (1.5-3 irrigations) on hydromorphous soils and 4-5 irrigations on automorphous ones instead of 4-5 and 10 irrigations, respectively. This explains low field efficiency that does not exceed 0.2-0.35 against 0.7-0.84 achieved on pilot plots.

3.2.9. In result of tests the following limits of pre-irrigation moisture, under which highest yield is achieved, while minimum water is spent per production unit, are obtained:

- Winter wheat - 70x70x70 and 70x70x80 for automorphous soils: yield 4.5-6.0 t/ha; water consumption 4500-7000 m^3/ha, water supply share p45-66 %; specific water expenses vary within the limits 850-1050 m^3/t; irrigation water productivity 0.9-1.8 kg/m^3 (FAO value is 0.8-1.0 kg/m^3). Specific water expenses and irrigation water productivity in control variants were 1200-3000 m^3/t and 0.3 -0.7 kg/m^3, respectively.

- Winter barley 70x70x70 under automorphous regime: yield 4.45 t/ha, water consumption 3850 m^3/ha, water supply share in water consumption 22 %; specific water expenses per production unit 865 m^3/t and irrigation water productivity 0.6-1.15 kg/m^3 (FAO value is 0.8-1.0 kg/m^3).
- Maize for grain - 80x80x60 and 70x80x70 under automorphous regime: yield 6.8 - 12.0 t/ha, water consumption 4200 -7400 m3/ha; water supply 3500 -06150 m^3/ha, specific water expenses 580-700 m^3/t, irrigation water productivity 0.8-1.8 kg/m^3 (FAO value is 0.8 1.6 kg/m^3).
- Maize for silo - 80x80x80; yield 3.4 -4.6 t/ha, water consumption 7250 -7400 m^3/ha; water supply 6500-3250 m^3/ha. Under semi-automorphous regime optimal pre-irrigation moisture is 70x 70x60, when maize for grain yield is 8.0-9.5 t/ha; water consumption 6400-7400 m^3/ha; water supply share 2540-6000 m ^{3}/ha; water productivity 0.8-1.8 kg/m^3 (FAO value is 0.8-1.6 kg/m^3). In control variants with pre-irrigation moisture 60x70x60 irrigation water productivity does not exceed 0.5-1.0 kg/m^3.
- Alfalfa -on hydromorphous soils optimal MFC for alfalfa of the first year is 90x90x90 and the second and third years 80x80x70. Alfalfa yield is 7.0-10.0 t/ha and 15.0-17.0 t/ha under water consumption 6500-7300 m^3/ha (KzylOrda oblast) and 7000 -8300 m^3/ha (Karakalpakstan). Water supply was 30 -55 % and 45 -70 % were taken from groundwater. Under semi-automorphous regime optimal pre-irrigation moisture for alfalfa is 70x80x70 and 70x70x70 of MFC. Such moisture provides yield 17.6-25.0 t/ha under water consumption 6500-7000 m^3/ha; water productivity varies within 2-2.5 kg/m^3 (FAO value is 1.8 kg/m^3).
- For rice main factor of its growth, development and yield formation is flooding regime and water layer keeping within the checks but not the soil moisture. There are 4 variants of flooding regime: 1- permanent flooding without running flow; 2 - permanent flooding with 50 % flow from water supply; 3 -interrupted flooding (9 days flooding with water layer 10-15 cm and 6 days without water supply); 4 -shortened flooding. Under 4-th option on all pilot plots maximum rice yield (5.0-6.0 t/ha) is achieved under water supply 22-28 th.m^3/ha on saline hydromorphous soils; water consumption share was 9-10 m^3/ha. In control variants yield varied within 2.4-4.0 t/ha under the same irrigation norm. The best results in rice yield increase and irrigation norms reduction were achieved on background of subsurface and vertical drainage under vertical filtration rate 6-10mm/day (6-10 th.m^3/ha for season). Rice yield varied within 5.0-6.6 t/ha. Under those rates the best running flow is provided within the checks for avoiding surface release from the rice field. Under optimal flooding regime the lowest specific water expenses were achieved 3620-4570 m^3/t gross whereas in control variants they were 6000-12200 m^3/t.

3.2.10. Statistical processing of the results shows close links between agricultural crops yield and water consumption. For tilling crops (wheat, maize for grain) and alfalfa relationship between water consumption and yield increase is described by linear equation while for cotton under automorphous and semi-automorphous regime it is described by parabolic equation. Certain dry biomass and crops yield correspond to each level of water consumption and irrigation norm.

3.2.11. Maximum cotton yield on automorphous soils (4.5-5.0 t/ha) is formed under total water expenses 9.5-10.5 th.m^3/ha while on hydromorphous and semi-automorphous soils under the same water consumption cotton yield is 4.0 -4.5 t/ha. Water supply share is 53-55 %

and 70-75 %; rest is covered from ground water and soil moisture accumulation during recharge irrigations and winter-spring leaching. On automorphous soils agricultural crops water consumption is covered mainly by water supply (87-90 %) and precipitation. Increase and decrease of water consumption norm even under intensive technology of crops cultivation leads to cotton yield reduction.

3.2.12. In all pilot plots irrigation water saving and yield increase are achieved. Water saving for cotton, wheat, maize and lucerne was 12-25 %, for rice 15-30 %. Yield increment was for tilling crops 20-40 %, for rice 1.5-2.0 times that saved 250-550 $/ha.

3.2.13. Optimal irrigation regimes application gives possibility to save 20-25 % irrigation water and increase agricultural crops yield. Under irrigation regime calculation and design condition of minimum expenses of irrigation water per unit production and maximum production achieving should be taken into account.

3.3. Management of soil water-salt regime and ecological-meliorative processes on background of drainage, leaching and leaching regime of irrigation

3.3.1. There are 7.95 mln.ha of irrigated lands in Central Asia from which 5 mln. ha are saline or subjected to salinization. Depending on degree and type of salinization damage can be made not only to crop yield, but to express itself through losses of water, inputs, etc. On slightly saline soils cotton yield losses are 15 -20 %, on medium-saline soils 20-50 %, on strongly saline ones 50-80 %. Annual specific water supply to irrigated field with non-saline soils is 20-50 % less to compare with saline ones. Because of that struggle with salinization is the most important issue for irrigated farming. All over the world this problem is solved by irrigated area's drainability improvement through artificial drainage on background of soil leaching and leaching regime of irrigation in combination with different «accelerators» of salt removal.

3.3.2. In all the regions of artificial drainage development certain reclamation effect is achieved when negative water-salt balance is formed with salt removal from 5-10 to 50 t/ha and more. The highest effect is reached in the areas with perfect type of drainage. There are 75 pilot projects dedicated to this field and located in different natural conditions of the Aral sea basin, from those 10 projects belong to large regions with area of 50-15 th.ha and 70 projects are devoted to capital leaching on background of different types of drainage.

3.3.3. Analysis of information submitted shows high reclamation efficiency of perfect types of drainage, which is reflected in the following:
- drainage outflow management;
- soil water-salt regime and water-salt balance management.

3.3.4. Depending on natural conditions horizontal drainage was applied mainly on the low permeable depositions with permeability coefficient 0.03-0.3 m/day. This type of drainage was applied too in case of two- and multi-layer sediments with thickness of top fine-grained depositions ≤ 3-5 m as well as in case of strongly partitioned relief. From 4.7 mln ha irrigated lands requiring artificial drainage, 3.0 mln ha are suitable for horizontal drainage. Vertical drainage was spread over the territories with two- and multi-layer sediments with artesian aquifers with conductivity 200-500 m^2/day. This type of drainage gave maximum effect where top fine-grained depositions' thickness was 10-45 m and sediments' resistance was 25-

700 days. Under top sediments thickness of ≥ 45 m its effect is reduced due to fine-grained deposits resistance.
Irrigated area, suitable for vertical and combined drainage, exceeds 2.0 mln ha from which 1.5 mln ha belong to Uzbekistan and Kazakhstan.

3.3.5. Management efficiency of ecological-meliorative processes on saline lands depends on drainage system parameters (depth of drainage, drains spacing, well discharge and command area), that form head's gradient, drainage modulus (drainage salt outflow) as well as soil water-salt balance and irrigated lands' balance under fresh water inflow.

3.3.6. Drainage system's parameters vary within wide limits. Subsurface drainage parameters change as follow; depth h=1.5-3.5 m; specific length l=20-100 m/ha.. Relatively shallow drains (1.5-2.0 m) are located in the SyrDarya and AmuDarya lower reaches and deep ones - in middle reaches (Karshi and Golodnaya steppe). Drainage modulus varies depending on water supply and underground inflow within wide limits (0.05 -0.3 l/s) and in lower reaches, where rice irrigation systems prevail, it accounts for 0.3-0.8 l/s under head gradient 0.5-2.5 m..

Vertical drainage system (VDS)
3.3.7. VDS parameters vary within the wide limits: depth 35 -80 m; discharge 25 -200 l/s; specific yield - 2-10 l/s.m; command area 80 -300 ha; drainage modulus 0.05 -.0.3 l/s. Main source of water to the field is water supply, which plays important role in water management issues. Annual water supply plus precipitation satisfy requirements of leaching regime of irrigation.

3.3.8. Vertical drainage system gives good effect under conditions of two- and multi-layer sediments with artesian and sub-artesian aquifers overlain by top fine-grained deposits closely hydraulically linked with ground water. Under these conditions VDS operation gave opportunity:

- to create high drainability of the area providing ground water overflow from top sediments into aquifers; overflow varied within broad diapason from 1.5-2.5 (Fergana valley) to 4.5-6.0 th.m^3/ha (Golodnaya steppe, Bukhara oasis, Vakhsh valley);
- to regulate ground water level and artesian water head within the limits from 1.5 -1.8 m (spring) to 3.5 -4.5 m (autumn, winter) before leaching.

3.3.9. Piezometric head was kept 0.4 -1.5 lower than ground water table that created free capacity for acceleration of leaching desalinization effect:

- to manage groundwater overflow rate within the limits of 2-4 cm/day in heavy soils (Golodnaya Steppe) up to 10-15 cm/day in light soils (Bukhara, Fegana oblast, Kyzylkum massif);
- to manage desalinization rate for unsaturated zone through free capacity creation before leaching under irrigation norm from 2 up to 6 -7 th.m^3/ha; average annual water supply varied from 5.6-10 th.m^3/ha, providing leaching regime of irrigation with K = 1.1-1.28;
- to establish negative water-salt balance within unsaturated zone, top fine-grained deposits and the territory as a whole with diapason of salt removal from 7-10 to 25-30 t/ha from saturated zone, 50 -70 t/ha from top fine-grained deposits and 10 -25 t/ha from the territory;
- to level soil spot salinization and create uniform meliorative background;

- almost all lands during 3 -4 years VDS operation were transferred from medium and strongly saline to weakly and non-saline;
- to reach during 3-4 years full desalinization of unsaturated zone and top fine-grained sediments;
- to decrease ground water salinity down to 3-4 g/l under initial salinity 10 g/l and more;
- to reduce and stabilize pumped water salinity;
- to create optimal conditions for soil productivity and agricultural crops yield; cotton yield increment 0.5-1.2 t/ha was reached for 3-4 years; specific water expenses for unit production varied from 2300-3000 to 4300-4500 m^3/t.

3.3.10. Relatively high irrigation water productivity was achieved on all pilot plots: 0.41-0.57 kg/m^3 against 0.2-0.37 kg/m^3 in control and is within the FAO limits (0.4-0.6 kg/m^3).

3.3.11. Results of research on pilot plots with vertical drainage show effectiveness of vertical drainage design and construction on large areas. Water inflow from fine-grained cover sediments exceeds inflow from groundwater to the vertical wells, that allows to sharply decrease of load on drainage and increase well's command area. While on all pilot plots one well's command area was 100-150 ha and share of external inflow in pumped water was 40-50 %, on old irrigated lands of Golodnaya Steppe, Bukhara oblast, Kzylkum and Arys-Turkestan massifs one well's command zone is 200-350 ha and external inflow share is 10-15 %. These results allow to recommend sharp decrease of load on drainage and accept 3.5-5.0 th. m^3/ha against 6-9 th. m^3/ha which were designed in all previous projects. VDS design on large areas and load on drainage reduction down to optimal values will allow to reduce capital investments in construction and operation.

3.3.12. Horizontal drainage [of open and closed type is widely spread on one-layer deposits with ground and sub-artesian waters. Annual water supply to the pilot plots with closed horizontal drainage varied from 6.5-7.0 (Golodnaya Steppe) to 10.2-14.2 th.m^3/ha (Fergana valley). This water supply plus precipitation satisfy requirements of the leaching regime of irrigation under total evaporation 7.5-9.0 th.m^3/ha providing negative water-salt balance on irrigated lands.

3.3.13. Subsurface drainage showed rather high meliorative and technical -economic efficiency and permitted:

- to create high drainability of irrigated lands (0.05-0.34 l/s.ha) and provide optimal semi-automorphous meliorative regime keeping ground water table at the depth of 1.5-2.8 m;
- to provide rather high ground water lowering rate from 2-4 cm/day for heavy soils up to 10-20 cm/day for light ones (Khorezm oblast);
- to perform timely winter-spring leaching with different norms depending on salinity degree (2.5-7.0 th.m^3/ha), achieve accelerated desalinization of unsaturated zone (3-4 years) and stabilize ground water salinity at the level of 3-5 g/l during 4-5 years;
- to establish negative water-salt balance with salt removal 8.3-20 t/ha on heavy soils and 35-50 t/ha on light ones with superficial salinization;
- to establish good hydraulic link over all thickness up to impermeable layer and active zone of water and salt exchange under drainage and canals operation with regard for crops irrigation and leaching. Zone of active water and salt exchange was 18-20 m. Salt removal share from beneath varied within 23-55 %;

- to create favorable meliorative state of land during 4-5 years under actual water supply with the leaching regime coefficient K =1.15-1.3;
- to reach annual irrigation norm reduction along with soil desalinization due to leaching norm reduction;
- to increase gradually soil productivity and agricultural crops output: 3.0-3.5 t/ha for cotton and 5.0-6.0 t/ha for rice and stabilize these achievements;
- to create optimal conditions for irrigated lands and irrigation water productivity improvement.

3.3.14. Under subsurface drainage during 3-4 years yield increment 0.5-1.0 t/ha for cotton and rice was obtained. Specific water expenses for cotton were 2260-2500 m^3/t for river upper reaches, 3000-4500 m^3/t for middle reaches and 4500-6000 m^3/t for lower reaches. Irrigation water productivity under leaching regime of irrigation on background of subsurface drainage varied within 0.35-0.54 kg/m^3 (control plots 0.2-0.35 kg/m^3) (FAO criterion 0.4-0.6 kg/m^3).

3.3.15. Results of research on pilot plots with subsurface drainage show higher effectiveness for bigger depth of drains (2.8-3.5 m) to compare with shallow ones (1.8-2.5 m). On irrigated lands with deep drains (3.0-3.5 m) share of groundwater and salt accumulation intensity by 2-3 times less compared with shallow drains. Deep drains (3.0-3.5 m) allow to manage in optimal manner by soil water-salt regime and water-salt balance of irrigated lands providing minimizing water expenses for soil desalinization. It is evident that more deep horizontal drains are more expedient to be designed and constructed. Shallow drainage (2.0-2.5 m) should be constructed on lands composed by flaky soils, subjected to heaving during construction and operation under groundwater impact (AmuDarya and SyrDarya downstream). These results show as well possibility to reduce load on drainage down to 3.0-3.5 th. m^3/ha against 5.5-8.0 th. m^3/ha foreseen by previous projects. High load on drainage (5.0-5.5 th. m^3/ha) is recommended for areas with artesian recharge.

3.3.16. On all pilot plots of subsurface and vertical drainage due to optimal management of soil water-salt regime certain economic effect was achieved from 250-300 up to 500-600 USD/ha.

3.3.17. Taking into account that more than 50 % of irrigated lands of Central Asia are subjected to secondary salinization due to poor operation of in-farm irrigation network, in perspective fight with soil salinization on base of drainage, leaching and leaching regime of irrigation remains main method of this issue solution. This problem should be solved on base of existing drainage systems workability improvement with set of technical-organizational measures providing sharp decrease of load on drainage and its operation improvement through:

- strict observance of recommended regime of irrigation designed with regard to crops planned capacity;
- sharp reduction of leaching regime share introducing new agrotechnique (organic fertilizers, deep ploughing, etc.);
- implementation of set of measures on inter-farm and in-farm canals efficiency;
- prevention of direct releases to collectors and drains;
- optimizations irrigation plots' size and project leveling providing even moistening and minimum infiltration;
- clearing and maintenance of in-farm and inter-farm collectors. As to perfect types of drainage rehabilitation of subsurface drainage (flushing) providing discharge increase on

60-70 % and cleaning vertical drains by pulse method increasing well discharge on 65-80 %.

3.4. Leaching of saline lands and leaching regime of irrigation

3.4.1. In arid zone soil salinization during irrigated land development is one of the most important factors influencing land productivity. At present time from total irrigated area 7.9 mln. ha 35-40 % is subjected to salinization to different extent. Because of that irrigated farming in Central Asia is closely connected with measures on soil desalinization to threshold of salt toxicity for major agricultural crops.

3.4.2. Results of research on soil and groundwater upper layer desalinization show, that capital leaching is the most effective measure to remove salt from unsaturated zone and desalinize groundwater. Under capital leaching accelerated desalinization of soil and ground water even on hardly reclaimed strongly saline lands is found. But capital leaching is very expensive and requires much water and labor resources.

3.4.3. In current conditions under scarcity of water and technical resources operational leaching in combination with irrigation within the growing season is the most effective. It is dedicated to gradual soil and ground water desalinization and minimization of ecological impact on irrigated land and environment.

3.4.4. Terms and norms of operational leaching are determined by water -physical properties of soil, drainage system workability, year humidity with respect for available water resources allocated to administrative rayons and farms.

3.5. Collector-drainage water re-use for irrigation in place of its origin

3.5.1. In conditions of Central Asia on sandy-desert and loamy soils drainage water re-use with salinity 1.8-4.5 g/l and chloride-sulphate and calcium-magnesium-sodium composition is possible. Drainage water re-use effectiveness has been proved by long-term investigations on areas of 50-12.000 ha.

3.5.2. While irrigating agricultural crops with drainage water during the growing period irrigation regime is supported through frequent irrigations application (10-12 irrigations for sandy-desert soils) by small gifts (800-1600 m^3/ha). On lands, subjected to salinization during fall-winter period, leaching irrigations with norm 3000-3500 m^3/ha or recharge irrigations during the spring season are applied. In order to retain soil salt regime within the permissible limits, annual water supply, to compare with fresh water, was increased on 5-25 %. Total water supply/total evaporation ratio provided leaching regime with coefficient 1.05-1.25. Optimal land drainability was provided under drainage outflow versus water supply ratio 0.25-0.40.

3.5.3. Frequent irrigations allowed to regulate soil moisture within the limits 0.7-0.8 (70-80 % MFC) and retain soil solution concentration within accessible limits permitting to neutralize harmful influence of toxic salts on plants' rooting system under irrigation with drainage water. It is found, that high salinity water use within the phase of ripening is the optimal technology. On the early stage of plant development it is better to use water with low salinity. Such technology provides sustainable crop yield, which does not give in to control one under fresh water irrigation. For instance, cotton yield on sandy-desert soils (Turkmenistan) under drainage water irrigation (water salinity 2.1-2.8 g/l) achieved 3.5-4.4 t/ha. On loamy soils of old irrigated lands yield 2.5-3.6 t/ha was achieved. Irrigation water productivity per unit production varies within 0.21-0.47 kg/m^3 (FAO criterion is almost the same).

3.5.4. While irrigating by drainage water physical-chemical reactions of exchange have place within the soil absorbing complex. In conditions of Central Asia soil and drainage water contain rather high content of gypsum (carbonate and calcium salts). That allows to avoid soil sodification. Concentration of absorbed calcium was 50-90 %., sodium 2-10 % of salts sum and this ratio did not change for many years.

3.5.5. Drainage outflow re-use permitted to reduce pesticides (ammonium, nitrates, phosphorus, potassium) concentration, that plays positive role in ecological restoration of river system. Rather effective system of drainage effluent treatment is developed based on hydro-botanic technology.

3.5.6. Huge volume of return water is formed in Central Asia (30-60 % of water supply). Mainly it is released to the river trunks. This water re-use mitigate water deficit and prevent river water pollution. Under collector-drainage water use it is necessary to take into account water quality and availability of soda, harmful salts, nitrates, chlorides, heavy metals, etc. Very important factor is soil type, convenient for return water re-use; most appropriate are light and sandy loam soils. Total volume of return water is 36-38 km^3/year from which 32-35 km^3 are collector-drainage water and 3.3 km^3 are industrial and municipal wastes. Uzbekistan prevails in return water formation with 25-28 km^3/year. From its volume only 1.4 -2.1 km^3 are used in place of their origin. Water appropriate for irrigation (salinity less than 2 g/l, SAR<10) constitutes about 40% or 15-16 km^3/year.

3.5.7. Assessment of lands appropriate for return water re-use showed that there are 2.5 mln. ha recommended for this purpose.

3.5.8. Rehabilitation of the part of pilot projects and application of Israel and American technologies for salt-resistance trees and plants growing to create «green desert» experimental plots in Kazakhstan, Turkmenistan and Uzbekistan. On these plots efficiency of biological drainage and soil desalinization as well as soil fertility improvement will be demonstrated. Feasibility study of big scale collector-drainage water use for irrigation and «green desert» creation in different natural-economic conditions of the Aral Sea basin.

3.6. Optimal irrigation methods, parameters, technique and technologies

3.6.1. This technical field is represented by 39 pilot projects from which 23 relate to tilling crops' furrow irrigation, 11 -to drip irrigation; 3 -to sprinkler irrigation and 2 -to in-soil irrigation. These pilot projects present all hydrogeological-soil-meliorative conditions of the region with regard for ground water table, soil structure, surface slope gradient, etc.

3.6.2. The major indicators of irrigation technique efficiency were taken as follow: uniformity of discharge in to the furrows; uniformity of root zone mellowing over the area (along the furrow length); irrigation technique efficiency; water expenses (gross) per unit production

(m^3/t) and irrigation water productivity (net) (kg/m^3). Efficiency indicators for pilot plots were compared with the same indicators for control ones. Irrigation technique parameters for pilot plots were selected according to natural conditions.
3.6.3. Review of results obtained showed the following. Different methods of irrigation efficiency, particularly in furrows, depends on degree of land leveling. Highest indicators of water saving were achieved under leveling degree ± 3.0 cm. In this case uniformity of mellowing over the area reaches 0.92-0.96 and irrigation technique efficiency 0.82-0.9 against control 0.8-0.86 and 0.4-0.65, respectively. Yield increment on high permeable soils is 0.5-1.0 t/ha.

3.6.4. All over the pilot plots with tilling crops irrigation on optimally leveled furrows (discharge, depth and length, etc.) with regulation of flows gave better results to compare with the control.

3.6.5. Water saving and water productivity indicators were as follow:

- coefficient of discharges uniformity in to the furrows 0.92-0.96 against 0.85-0.9 on control plots;
- irrigation technique efficiency 0.8-0.9 against 0.25-0.64 on control plots;
- cotton yield increment 0.5-1.25 t/ha (on average 0.83 t/ha);
- irrigation water specific expenses per unit production (gross) 1080 -3040 m^3/t against 3170 -8800 m^3/t on control plots;
- irrigation water productivity 0.4-0.6 against 0.05-0.2 kg/m^3 on control plots;

3.6.6. Highest water saving and irrigation water productivity indicators were obtained on the pilot plots with perfect irrigation technique: drip irrigation, in-soil irrigation and sprinkler irrigation:

- drip irrigation technique efficiency for tilling crops and gardens was 0.92-0.98; for sprinkler and in-soil irrigation it was 0.9-0.94; for control furrow irrigation plots it was 0.47-0.67.
- irrigation water specific expenses per unit production were 710 -1630 m^3/t for drip irrigation and 1860-7060 m^3/t for furrow irrigation; close to drip irrigation results were obtained for in-soil and sprinkler irrigation technique. Cotton yield increment was 0.45-0.99 t/ha for all above mentioned methods;
- irrigation water productivity was 0.43-1.41 kg/m^3 (on average 0.93 kg/m^3) for drip irrigation plots and 0.23-0.54 kg/m^3 (on average 0.36 kg/m^3) for furrow irrigation;
- review shows that perfect irrigation methods introduction will allow to reach water conservation of 1000-1500 m^3/ha in furrow irrigation and 1500 -2500 m^3/ha in drip, in-soil and sprinkler irrigation as well as cotton yield increment 0.45-1.2 t/ha;

3.6.7. Nevertheless, prefect irrigation technique introduction needs high capital investments: 1000-1500 $/ha for furrow irrigation and 4000-7000 $/ha for drip, in-soil and sprinkler irrigation.

3.6.8. Potential yield and irrigation water productivity improvement is determined by certain measures: drip irrigation, sprinkler irrigation, laser leveling, etc. These technologies permit to reduce crop water consumption on 10-40 % to compare with furrow irrigation. But these methods are very expensive and require yield growth on 10-30 %. Limited application of these methods is determined by the following priority:

- irrigation systems with low water availability;

- irrigation schemes with expensive water lift;
- areas with highly permeable soil and high slope gradients, where surface irrigation causes soil erosion.

3.6.9. The first task for most lands is transition from hydromorphous regime to semi-automorphous one. Under the latter irrigation water expenses are reduced, load on drainage is decreased, nutrients washing out of soil is reduced as well. Ground water table regulation should be done due to organizational water losses reduction in irrigation network as well as on the fields.

3.6.10. Real effect on the furrow irrigation schemes can be reached through introduction of optimal irrigation technique elements together with irrigation planning. It will allow to save 1.5-2.0 th.m^3/ha of actual irrigation norm.

4. Common recommendations

4.1. Since 1956 in Central Asia big scale new irrigated lands development and old land reclamation were undertaken on the base of pilot projects.
These projects' results implementation allowed to: reach certain water conservation level; increase irrigation systems efficiency; definite returned water use efficiency; regulate river flow's water-salt regime. This improved as well irrigated land and irrigation water productivity. These results were reached under unlimited water and technical resources. But modern conditions are characterized by:

- water resources deficit and their quality aggravation;
- land salinization and degradation;
- decrease of the technical level of hydro-reclamation systems;
- limited financing for systems operation and maintenance;
- transition to market economy.

4.2. Taking into account above mentioned it is necessary: to rehabilitate certain part of the pilot projects as demonstrative plots for training purposes. Selection of pilot plots should be done according to their representation for certain part of the Aral Sea basin on base of geomorphologic-landscape zoning.

4.3. Meliorative structures should be reconstructed and equipped by means of monitoring. It is necessary to organize:

- integrated monitoring of irrigation and drainage network;
- management of water resources like WUFMAS sub-project and irrigation planning based on FAO CROPWAT methodology;
- workshops for demonstration of irrigation for farmers and leaders of collective farms, rayons and oblasts.

5. Next Steps

5.1. This report is considered a first step to document research results. To broaden audience, publication of (review) papers on the above themes in English journals is recommended. Following the writing and publication of several (review) papers, a book may be prepared with the provisional title "Salinity Control in Central Asia".