### *2.1 Regulation of soil water-salt regimes and management of reclamation processes on irrigated lands on the background of horizontal drainage.*

General provisions

Pilot plots (PP) were widely practiced practically on all new developed lands of the Aral Sea basin within last 30-35 years.

Biggest density of pilot plots has place in the Hungry and Karshi steppes and the low reaches of SyrDarya (Kazakhstan) and AmuDarya (Horezm province and Karakalpak Republic) rivers. All water economy measures such as water sharing, water disposal normalization, irrigation planning and new lands development; water and salt management planning are connected with river sites where study results are used for plan correction and project parameters definition. River sites areas are identical for natural-climatic, geomorphological, hydrogeological-reclamation conditions that the study results could be easily spread over every river site.

Therefore, study results on the pilot projects are presented differentially on large zones of drainage (irrigation massifs) in connection with water related districts. Such river sites and related to their massifs in Syrdarya river basin are :

Upstream - Fergana valley, including Andijan, Namangan and Fergana provinces of Uzbekistan; Osh and Djalalbad provinces of Kyrgyzsatn; Leninabad province of Tajikistan, hereinafter referred to as Fergana zone of drainage.
Middle stream of SyrDarya - Hungry Steppe (new and old zone of irrigaton) of Uzbekistan and Kazakhstan is jointed in the Hungry steppe zone of drainage.
Downstream- Chimkent, Kzylorda provinces of Kazakhstan, drainage zone of the low reaches of Syrdarya - «The low reaches of SyrDarya».

AmuDarya river basin:
Upstream - irrigated zone of the Republic of Tadjikiztan and Surkhandarya province of the Republic of Uzbekistan - drainage zone of AmuDarya upper reaches - «AmuDarya upper reaches».

Middle stream - all pilot projects of Kashkadarya province, Karshi steppe, Bukhara province of Uzbekistan and Chardjou province of Turkmenistan hereinafter referred to as «Bukhara - Karshi drainage zone».

Downstream - objects are located in Republic of Karakalpakstan, Khorezm province and Turkmenistan hereinafter referred to as drainage zone of the AmuDarya low reaches - «The low reaches of AmuDarya».

Connection of pilot projects of close horizontal drainage with adopted zones of drainage is given in table form. Separate objects located out of marked zone are related to one or another group of identical geologic-geomorphological and hydrogeologic-reclamation conditions of district. Those are pilot projects of Chu valley of Kyrgyzstan (Fergana drainage zone), pilot projects of Chardjou province of Turkmenistan related to Bukhara-Karshi drainage zone; pilot projects located in Bugun district of South-Kazakhstan province theoretically related to middle stream of Syrdarya river, the Hungry steppe drainage zone.

### 2.1.1. Hydrogeologic-soil-reclamation characteristics of pilot plots (PP)

Within the SyrDarya river basin 3 large drainage zones are distinguished- Fergana, Hungry steppe and the low reaches of SyrDarya river. Common description of geomorphological-hydrogeological-soil -reclamation conditions of these zones and pilot projects situated in zones (Appendix 2.1) is given below:

**Fergana drainage zone**

Fergana valley is a large intermountain depression boarded from all sites by mountain structures of Tyan-Shan: Turkestan and Alay ranges in the South, Fergana ranges in the East and Chatkal-Kuramin in the Nord. SyrDarya river divides Fergana valley for two asymmetrical parts - Northern (or right-bank) and South (or left-bank). In the West Fergana bowl through a narrow Leninabad throat (8-10 km) gradually mergers with the Hungry steppe plain. Leninabad throat is a single way of natural run-off of ground water from Fergana valley. Specific feature of Fergana is zonal distribution of relief. Zone of high mountains is located within Kyrgyzstan and Tajikistan. To this zone high foothills and adyr belt are bordered. In the South-Western Fergana (Isfara and Soh basins) the adyrs are closed in common massif bordered to the high foothills. In Southern Fergana (Shahkimardan and Isfayram basins) adyrs are divided from the high foothills by out-of-adyr depression plain: Chimion-Auval and Kuvasay; in Eastern Fergana- Osh-Aravan, in Northern Fergana - Iskovat-Pishkaran, Kasansay, and etc. Plain relief of Fergana bowl is created by river sediments of 2 types - alluvial of main rivers (Naryn, KarDarya, SyrDarya) and cones of removal of their lateral inflows: on left-bank of Soh, Isfara and the merged cones of removal of Shakhimardan and Isfayramsay rivers.

On right-bank part of Fergana valley the geological cross-section in all depth is made of coarse-disintegrated rock formations (pebbles, conglomerates) with cover of fine-grained deposits (loess). On left-bank part of Fergana valley (Southern Fergana) the phase-lithological composition of an aquifer varies from the high foothills and adyrs towards SyrDarya. In the belt bordering to foothills and adyrs (head parts of cones of removal) pebbles and conglomerates are developed. Further, pebbles are submerged under loam and sandy loam and are divided by loam layers and clays in vertical section. Thickness of cover is increased up to 40 m to periphery of removal cone and in inter-cones lowering, and pebbles are replaced by sands.

The left-bank of SyrDarya is characterized by availability of ground, sub-artesian and artesian waters. Ground water is devoted to heads of removal cones, in middle parts sub- artesian water is appeared and, accordingly, the periphery parts of removal cones are characterized by full complex of hydrodynamic horizon of closely interconnected ground, sub- artesian and artesian waters. Combination of natural-climatic and agricultural conditions peculiarity defined soil different groups of Fergana depression.

Geographic distribution of soils has altitude-belted character. Upper mountain belt (zone) contents turf- brown soils and their black soils varieties. Within the contour of the main irrigated fund there are automorphic desert zones, automorphic gray soils belt and hydromorphic soils.

Automorphic soils of gray earth belt are presented by desert sandy soils, - semi-fixed and unfixed ridge, hilly and dune sands. Among them there are also spots of desert sandy soils. Degree of sand salinization is 0.05 -0.1 % and spots of sandy soils - 0.1 -1.5 %.

Automorphic soils of gray soil belt are represented by light gristly gray soils and loamy pebbles on proluvial skeleton- fine-grained deposits and skeleton sediments. Salinization degree is 0.3 - 0.6 %. Hydromorphologic soils of desert zone are represented by meadow, meadow-marshy and saline soils. There are clay and loamy soils on proluvial and alluvial stratified fine -grained deposit sediments of saz and gray soil belt. Salinization degree is 1.0 - 3.0 %. In geomorphological direction the pilot projects of close drainage are disposed in inter-cone lowering of Isfayram-Shakhimardan ND Sokh removal cones (02.28 Uz.), I and II over water-meadow terraces of SyrDarya river (02.7 Uz.), on periphery of Isfara removal cone (02.1 Tadj.). Two projects (02.28 Uz., 02.23 Uz.) are located on the territory of one farm with area of 350 ha.

Three projects (02.5 Kyrg.; 02.3 Kyrg.; 02.2 Kyrg.) are disposed on proluvial-alluvial plain of Chu valley, their hydrogeological-reclamation conditions are similar to objects of Fergana valley.

Throughout the Fergana valley the dense collector -drainage network and network of vertical drainage well are developed. Approximate volume of collector-drainage runoff is 7448 mln.$m^3$ per year (on Andijan, Namangan, Fergana provinces) under mineralization of 2.4 -3.7 g/l. Volume and quality of collector-drainage outflow are indissolubly connected as with natural conditions (geological and hydrogeological), so with farm activity and with its time changes. Horizontal drainage is attached to areas with developed fine-grained deposits cover. In Central Fergana horizontal drainage operates under artesian inflow. In connection with it here large number of vertical drainage wells was built - area and linear systems. Linear systems mainly were built on a border ground water seepage zone of removal cone (Bagdad, Altyaryk, Rishtan regions, and etc) for interception of ground water. In spite of significant volume of study, the quantitative characteristics of interconnection of ground and artesian waters are not determined.
In respect to lithology fine-grained deposits with thickness 10 - 20 m contents light, medium and heavy loam with sand and clay inter-layers under permeability of 0.3 -0.6 m/day and clay layer permeability of 0 -0.05 m/day. Horizon with the thickness of 5 -15 m contents, mainly, large-grained sand and rarely pebbles with permeability 3 -5 m/day. Ground water depth is within 1.5 - 3 m. Ground water inflow is 50 -1378 $m^3$/ha per year at expense of overtflow from beneath. Ground-water salinity varies within 5 -38 g/l (02.7 UZ.) to 11.2 -3 g/l (02.1 Tadj.), and aquifer (artesian) salinity is from 1.2 - 3 g/l (02.1 Tadj.) to 3.5 - 4.5 g/l (02.23' Uz). Water type is from sulphate to chloride -sulphate. In separate zones the ground water has insignificant sodification. Soils, mainly, are gray-meadow from light to heavy loam. Salinity is from slight to strong, sometimes salt. Salt content in 1-meter layer is from 0.8 -1.8 (02.7 Uz.) to 0.2 -0.8 % (02.3 Kyrg.) of sulphate and chloride-sulphate type with increased content of gypsum. Content of chlorine is 0.01 -0.23, sulphate is 0.47 -0.95 % of dry soil mass.

**Hungry Steppe drainable zone ( SyrDarya middle stream ).**

On climatic conditions Hungry Steppe relates to semi-desert zone. Climate peculiarities are as follow: cold winter with unstable weather, wet rainy spring with repeated turn of cold; dry and warm autumn; hot summer. Average annual air temperature is +14 ÷ 15 $^0$ C. Vegetation period duration is 200 -230 days with active temperature sum of 4400 -5000 $^0$ C. Rainfall varies from 234.3 to 500 mm per year, from which 70 -85 % are happened in winter -spring period. Evaporability reaches 1420 -1690 mm per year, i.e. much higher than precipitation.

In geomorphological respect the pilot projects are located on proluvial- alluvial plain of the Hungry Steppe plateau - in Djizak removal cone (02.35 Uz.; 02.3 Uz.; 02.27 Uz.), Havast removal cone (02.13 Uz; 02.14 Uz.), dry channel group and other small dry channels of Turkestan ridge (02.12 Uz.).

In lithological structure fine-grained deposits with thickness of 100 -200 m is observed, which is made of (in upper part of section up to 60 m) loam, clay, sandy loam and small layers of sand (1-4 m).

Permeability of top fine-grained deposits (loam) varies from 0.1 to 0.6 m/day; clay - 0.03 - 0.06 m/day. Sometimes gipsum pans on depth of 0.2 -0.6 m with permeability $K_{min}$=0.01-0.06 m/day are occurred.

In hydrogeoilogical respect these lands, mainly, on classification of Dr. D. Kaz are regarded as «very low drained» with difficult engineering-geological and hydrogeological conditions and because of low conductivity of fine-grained deposits for their development the most suitable is horizontal drainage. Ground water depth before development was 3.5 -20 m, and after cultivation - 1.5 -3.0 m. Ground water mineralization varies from 5 -8 (02.13 Uz.) to 40 -60 g/l (02.34 Uz.). Mostly it varies within 10 -25 g/l (02.35 Uz.). Type of salinity is chloride-sulphate and sulphate-chloride.

Irregular ground water level before irrigation is caused by different soil types: automorphic - gray soil; transitional -meadow- gray soil and gray soil- meadow soils; hydromorphic - meadow soils. All soils have deep salinization - upper 1.0 -1.5 m of soil layer is practically non-saline, and in deeper horizons significant supply of salts is contained.

In mechanical composition soils relate to light and middle loam (02.35 Uz.; 02.3 Uz.; 02.12 Uz.; 02.14 Uz.), and soils of separate projects (02.34 Uz.; 02.13 UZ.) - middle and hard loam with gypsum pans. Soil volumetric weight varies from 1.3 to 1.5, rarely up to 1.7 t/m$^3$.

After irrigation secondary salinization is observed everywhere. Salinization degree of 1-meter layer is from spot to strong salt and solonchak. Salt content varies from 0.6 -1. 57 % (02.35 Uz.) to 2.2 - 2.8 % (02.3 Uz.). Type of salinity, is mainly chloride-sulphate, more rarely, sulphate -chloride.

Pilot projects (02.22 Kaz.; 02.4 Kaz.) are located in Bugun district of the South- Kazakhstan province of Kazakhstan.

Climate here is sharply continental with high temperature regime, dry air and insignificant cloudiness. Precipitation is irregular during the year: in spring is about 100 mm that means 35 -50 % of annual norm; in summer- autumn period (May-October) is 135-280 mm, that less than 25 % of annual norm. Under average annual 12 -13.5 $^0$ C the air temperature in July increases up to 27 -29 $^0$ C. Average 10-days air temperature which higher than 14 $^0$ C is constant during 6 months (middle of April -October). Average monthly wind velocity in winter-spring period is 2.5 -5.0 m/sec, and it increases up to 4 -6 m/sec in summer. Evaporability varies within 1200 -1400 mm. Soils of pilot plots are gray, by mechanical content are heavy clay, on depth of 3-5m turned to middle loam then to heavy or light loam, which are lie on gravel-pebbles sediments. Upper layer permeability is 0.35-0.8m/day and for gravel-pebble deposits it is 10 times more.

Plot relief is plain with slope of 0.003 -0.005. Soil volumetric mass of 1-m layer varies from 1.35 to 1.48 g/sm$^3$, and specific mass is within 2.69 - 2.71 g/sm$^3$. Soils and groundwater relate to chloride-sulphate with desalinization to depth of aeration zone (to permissible limits 0.3 %) 0.5, 1.0, 2.5 m and surface horizons of groundwater is correspondingly 13, 15.5, 10.5, 6 g/l. Ground water level in vegetation period does not exceed 2.3 m, and in non-growing period does not lower less than 3,5 m.

**The lower Syrdarya (downstream)**

Only one pilot plot (02.6 Kaz) is referred to drainage zone of the lower Syrdarya. Climate is characterized by low precipitation (average annual norm is 210 mm) and high temperature (total positive air temperature is 4800°C). Average annual air temperature is about 12°C, relative humidity is about 54%, ranging from 31-33% in summer to 77-82% in winter. Soil texture is loam. Thickness of top sediments is 2.1m on average, while permeability is 1.45 m/day. Permeability of underlaying rocks, made mainly of small-grained sands of 60 m thickness, is 12 m/day. Before development groundwater table was 4-5 m, while average salinity was 4.4 g/l. Type of salinity is chloride-sulphate. Within 3 m layer content of salts was 0.313-2.094%, chlorine ions - 0.045-0.182%, sulphates - 0.115-1.195%. 0.032-0.26% of sodium and 0.021-0.346% of calcium were prevalent among cations. Volumetric mass of soil is 1.38-1.51 g/cm$^3$, specific mass is 2.62-2.72 g/cm$^3$. Minimum moisture is 18.5-22.7%. Coefficient of infiltration is 0.37 m/day.

**The Amudarya river basin**

***The upper Amudarya (upstream)***

Four projects, located in Khatlon province of Tadjikistan, are referred to drainage zone of the upper Amudarya. These plots are typical for the whole zone of upper reaches. Climate is semi-desert, continental with very hot dry long summer and rainy winter. Total positive temperature is 5165-6000°C. Average annual air temperature is 15.5-16.8°C. Frost-free period is 220-234 days. Total annual precipitation is 270-670 mm (02.6 Tad). Evaporativity ranges from 1500-1600 mm (02.5Tad) to 1816 mm (02.6Tad) over year.

The plots are located in third terrace of the Vakhsh river (02.5Tad), between Vakhsh and Kafirnigan rivers (02.6Tad), in Yavan valley (02.7Tad) and within plate plane of Tairsu river (02.4Tad). Slope gradient is 0.01-0.07. Lithology: thick, up to 50-60m (02.6Tad), loams with clay, sandy loam and sand interlayers. Permeability is 0.025-1.0 m/day. Beneath are pebbles with permeability of 10-20 m/day. There are artesian waters with head of 0.1-0.6 m. Type of soils is typical gray (02.5Tad) and gray-meadow (02.4Tad) and they are formed under effect of groundwater.

Soil texture: medium and heavy loam. Volumetric and specific mass varies within 1.28-1.72 $g/cm^3$. There are non-saline and alkali soils. Type of salinity is chloride-sulphate and sulphate-chloride. Almost all the plots include gypsum-bearing soils. Groundwater table is 0.5-3.0 m. Salinity is 15-20 g/l. Chemical composition of water is sulphate, sulphate-chloride, while it is calcium-sodium by cations.

**Bukhara-Karshi drainage zone**

This zone includes 5 projects. They are located in Karshi steppe (02.10Uz; 02.28Uz), in Bukhara province of Uzbekistan (02.12Uz) and in Chardjou province (02.1Turk; 02.2Turk). Here, three large areas can be marked out: Karshi steppe, Bukhara and Chardjou oasis. In Karshi steppe (new irrigation zone) climate is sharply continental. Average temperature in July is 30-32°C. Maximum temperature is 47-50°C, while minimum one is -28°C. Average annual temperature is 15.8°C. Total annual precipitation is 180-280 mm. Relative humidity during vegetation is 33-40%, while it is 18-22% in July. Frost-free period is 213-233 days with 4500-4800°C of total temperature.

Annual evaporativity is 1600-1800 mm, including 1200-1300 mm during vegetation. Deficit of evaporativity is 1400-1500 mm.

Area is represented by alluvial and alluvial-proluvial plane of Kashkadarya delta and, partly, by proluvial slope and proluvial differentiated plane.

There are two aquifers with close hydraulic links. Static levels of aquifers are equal or differ by 0.2...0.5 m and more with depth.

Alluvial-proluvial plane is composed by fine-grained soils in top layers, thickness of which ranges from 2.0 to 20 m, and then by sands with sandy loam, loam and, rarely, clay interlayers. Proluvial plane is mostly composed by sandy loam, loam and clays often highly salinized. Prevalent permeability is 10-15 m/day for sands and 0.4 m/day for loam.

Before development groundwaters were saline. Salinity is more than 10-16 g/l. Its type is sulphate-chloride and chloride-sulphate. Groundwater table is more than 5 m.

Non-saline and slightly saline lands covered 70% of Charagyl depression in Karshi steppe, where 02.10Uz pilot plot is located. The plot is a plate area, 3-5 m lower than adjacent plane. The plot is composed by loam with clay and sand interlayers, thickness of which is up to 3 m. Type of soils are meadow-desert, meadow-takyr, etc.

Permeability ranges from 9-14 mm/hour to 20 mm/hour. Full field capacity (of upper 1m) varies within 13.1-16.5% (for light soils) and 25-27.7% (for heavy and medium soils). Bottom and outlying parts are presented by alkali lands (residual and typical), mostly heavy and medium loams with underlaying sandy loam and sands.

Bukhara oasis is represented by 02.25Uz pilot project, located in Alat district of Bukhara province. Climate is formed mainly by Kzyl-Kum desert. This is characterized by very hot summer, cold winter, low precipitation and a lot of sunny days. Annual average temperature is 14.8°C, reaching its absolute maximum of 48°C in summer and absolute minimum of -28°C in winter. Frost-free period lasts 213-214 days. The hottest month is July (28-29°C), while the coldest one is January (-1.5-4°C). Average monthly temperature during vegetation is about 22.8-24.4°C. Total positive temperature during vegetation varies within 4680.7-4794°C. Average annual precipitation in Karakum oasis does not exceed 114-125 mm. Most precipitation (70-75%) occurs during non-vegetation period.

Evaporativity during vegetation period accounts for 1350 mm. Oasis is characterized by heightened wind activity. Only 16-17 days over a year are windless. There are hot dry winds, harmseals, that occur during 3 months. The project is located in second continental delta of Zerafshan river with 0.0002-0.0003 slope gradient.
There are mainly meadow-desert soils. Texture is composed by sandy loam, loam and clay. Permeability is 0-0.1-0.4 m/day. Lands are slightly saline or non-saline. Groundwater salinity is 2-15 g/l (over 80% of area).
Chardjou oasis is represented by two projects (02.1Turk and 02.2Turk) located in Chardjou province of Turkmenistan.
Climate is dry continental. Total effective temperature (above +10°C) is 4900-5000°C. Relative humidity is 70-80% in winter and 30-45% in summer. Wind speed is 2.5-3.5 m/sec. Evaporativity is 1510 mm/year.
Precipitation is no more than 140 mm. Relief is smooth, slope is 0.00023. Top layer is composed by loam and sandy loam. Thickness is 1.5-2.5 m. Permeability is 1.0 m/day. Below are medium- and coarse- grained sands with permeability of 15-20 m/day. Thickness of this layer is 30-50 m. Groundwater level is 1.2-1.5 m in spring and 1.8-2.5 m in spring-winter period.
Groundwater salinity is 5 g/l; salinity of 1 m layer is about 1.0% by solid residue and 0.03% by chlorine-ion. Type of salinity is chloride-sulphate.

**The lower Amudarya (downstream)**

Drainage zone of the lower Amudarya is represented by 7 pilot plots, which are located in Khorezm province (3 plots - 02.1Uz, 02.2Uz, 02.29Uz) and in the Republic of Karakalpakstan (4 plots - 02.2Uz, 02.8Uz, 02.16Uz, 02.26Uz). The plots are typical for irrigated and non-developed lands of the Amudarya river delta and characterize both environmental conditions of the region and irrigation practices. Average annual temperature is 11-13°C, relative humidity varies within 51-81%. In winter minimum temperature is -21-23°C. Frost-free period lasts 200-230 days. High evaporativity of 1200-1300 mm/year under low precipitation of 80-140 mm (precipitation ranges within 95-105mm/year over long-term period) causes large moisture deficit.

The plots are located in alluvial plane of the Amudarya delta. Relief is smooth, slope is 0.0003-0.0004, rarely 0.0005. Lithology: fine-grained soils, loam and clays with limited thickness (2.0-10.0 m). Permeability is 0.05-1.5 m/day. Top fine-grained soils are underlain by fine-grained sands, thickness is 10-15 m, with permeability 10-15 m/day.
Groundwater table is 1.5-2.5 m, that causes salinization due to active participation of groundwater in soil-formation processes.
Groundwater table during vegetation is 1.0-1.5 m, while it is 0.0-1.2 m during leaching. Groundwater salinity varies within 4-25 g/l by solid residue.
Type of salinity is chloride-sulphate. All over the area soils are saline and being desalinized through reclamation measures.

### 2.1.2 General description of irrigation-drainage network and economic conditions

Irrigation-drainage network, economic conditions and design peculiarities of subsurface drainage in the plots are considered in respect to large drainage zones (schemes) in the Syrdarya and Amudarya river basins (Appendix 3.1). Detailed description of subsurface drains and their main parameters are given in tables (Appendix 3.1). Below, there is general description for each zone.

*Fergana zone (the upper Syrdarya)*

Area of the pilot plots (02.23Uz, 02.23'Uz, 02.3Kyrg, 02.1Tad), where experiments on reclamation measures effectiveness under subsurface drainage were conducted, varied within 6-20 ha. These farms cultivate, mainly, cotton and in some plots, as 02.3Kyrg., sugar beet and alfalfa. Area of the plots with subsurface drainage system ranged from 97 ha (02.7Uz) to 1248 ha (02.2Kyrg). Cotton, sugar beet, alfalfa, vegetables and melons were cultivated there.

On-farm irrigation network includes, mainly, concrete flumes. Farm and inter-farm network is laid in open earthen canals. Subsurface drains are asbestos-cement pipes with diameter of 144 mm (02.23'Uz, 02.23Uz) and sometimes two pipes in parallel. There are sections with ceramic and plastic pipes of different diameter. Filters are consisted of sandy-gravel mixture.

*Hungry steppe zone (Syrdarya river middle reaches)*

Specialization of farms, where the plots are located, is cotton growing: share of cotton is 60-70% of total area under crops. Only project 02.6Kaz. deals with rice cultivation. Plots 02.35Uz, 02.12Uz and 02.6Uz have an area of 60-180 ha. Two projects, 02.27Uz and 2.14Uz, have an area of 1192 and 8218 ha, respectively, and study water-salt regime formation in large irrigation schemes.
Irrigation system is typical for new developed virgin lands of Hungry steppe. Canals are coated. Distribution network is consisted of concrete flumes. Efficiency is 0.92-0.96. Capital and inter-farm collectors are open. There are open drains and collectors. Various drain design, pipe and filter materials are used in the plots in order to verify calculated parameters set up in the projects and spread them over large areas during project adjustments. Subsurface drains are made of ceramic pipes (diameter - 100-350 mm, length - 0.33-0.6-1.0 m) laid on gravel-sandy filter, plastic pipes (diameter - 100-150 mm, length - 6-8m), asbestos-cement pipes (diameter - 110-150mm, length - 3-4m) and tile pipes (diameter - 150-250mm, length - 0.33-1.0m) with filter of 10-15 cm from sandy-gravel mixture.

*The upper Amudarya*

Area of the pilot plots ranges from 40 ha (02.5Tad) to 26000 ha (02.7Tad). Specialization of these farms is cotton growing and cattle-breeding. Irrigation network is laid mainly in earthen channels. Efficiency of capital and distribution canals is 0.83 on average. On-farm network is in flumes, efficiency of which is 0.84, while specific length is 76.2 lm/ha. Subsurface drains are made of plastic and ceramic pipes, pipe-filters T-150 and Du-200-300 m with sandy-gravel filters (02.4Tad and 02.6Tad), asbestos-cement pipes with the same filters (02.5Tad). Drain depth varies within 1.6-3.5m, drain spacing is 60-340m, specific length is 37.8-84 m/ha.

*Bukhara-Karshi zone (Amudarya middle reaches)*

Specialization of farms is cotton-growing. Cotton covers up to 80% of irrigated lands (02.25Uz). Area of plots is 50-145 th.ha. On-farm network consists of concrete flumes with efficiency of 0.96-0.98. Inter-farm and capital canals on old irrigated lands (Bukhara and Chardjou provinces) are earthen, while on new developed lands (Karshi steppe) they are coated by monolithic concrete and laid on polyethylene film. Efficiency is 0.96-0.97. Drainage system consists of open capital, inter- and on-farm collectors and drains. Subsurface drains in the plots are mainly made of pottery pipes, diameter of 200-250mm, with gravel-sandy filter (Karshi steppe) and rarely of plastic corrugated pipes with protective-filtering winding (02.25Uz) and with sandy-gravel filter. In this zone there was the first testing of vacuum drainage (plot 02.2Turk), which combines two types of drainage - horizontal, when system operates in natural way, and vertical, when drainage outflow is disposed through pumps. Slopeless drains with flooded mouths were tested in 02.2Turk.

*The lower Amudarya*

Farm specialization is cotton, rice growing and cattle-breeding. Area of pilot plots ranges from 45 ha (02.16Uz) to 26.5 th.ha (02.2Uz). Salinization was reduced with huge depth of irrigation (2000-2500 $m^3$/ha) applied 2-3 times and total gross norm of 11-13 th. $m^3$/ha. At the same time, required norms of spring leaching accounted for 4-7 th.$m^3$/ha applied consequently 2-3 times. Under such conditions raw-cotton and rice yields were 15-22 c/ha and 35-37 c/ha, respectively.

Irrigation system is laid in earthen channels, that causes large water losses. Efficiency of the system is 0.56, while it is 0.65 for on-farm and 0.85-0.92 for inter-farm and capital canals. On-farm network of the projects, located in new developed lands, consists of flumes. Efficiency is 0.86 (02.1Uz; 02.29Uz).
Drainage network consists of various subsurface drains (field ones) and open collectors. Collector system is in bad condition and can not provide required withdrawal of groundwaters, though its specific length is 30-35 m/ha.
Inter-farm collector depth varies within 2.5-3.5 m. Depth of on-farm drains and collectors is 1.8-2.0m, rarely - 2.5m.
In the plots various pipes and filters for subsurface drainage were studied:

- asbestos-cement, sandy-concrete and ceramic pipes having factory standards with filters from sand and road-metal (02.20Uz; 02.8Uz);
- plastic corrugated pipes with gravel-sand mixture (02.8Uz; 02.29Uz; 02.1Uz), with filter from artificial material and with additional sandy pack;
- pottery and ceramic pipes (02.1Uz) with round sandy pack. Pipe diameter is 125-200mm for 02.1Uz and 300mm for 02.8Uz. Primary drain depth is 1.5-3m for 02.20Uz, 1.8m for 02.29Uz, 1.3-1.6m for 02.1Uz and 2.1-2.7m for 02.8Uz. Drain spacing is 400m for 02.8Uz, 150-300m for 02.20Uz, 100m for 02.29Uz and 40-60m for 02.1Uz.

### 2.1.3. Irrigation and water supply regime, drainage outflow formation

Analysis of available data shows that drainage outflow formation in time and its qualitative and quantitative characteristics depend on natural, technical and reclamation conditions of the plot area.
Natural conditions are the following: lithology, thickness and permeability of top fine-grained soils, primary salinization and groundwater salinity, nutrition regime, groundwater head and so on.

Technical conditions include: drainage design, layout, proper operation of all the drainage components, organization of use and timely disposal of collected water.
Reclamation conditions are the following: timely and quality leveling and leaching, irrigation and water supply regime, crop rotation system, fertilization and so on.
Evaluation of these factors relates the plots to one or another drainage zone and allows to determine qualitative and quantitative characteristics of the drainage outflow. Besides, drainage outflow depends on crop irrigation regime and water supply for leachings (Appendix 4.1).
Irrigation and water supply regimes in the pilot plots are the same as those in farms, where the plots are located. Therefore, water supply depends on economic conditions and water availability of the area. Average water supply varied within 6.5-13.6 th. $m^3$/ha for cotton and within 21-33 th. $m^3$/ha for rice (table 2.1).
Depending on water supply drainage outflow was 1.5-7.4 th. $m^3$/ha in cotton field and 2.5-13.5 th. $m^3$/ha in rice field.
Changes in drainage effluent quality (salinity) and quantity and in groundwater salinity under first approximation are defined by drainage outflow ratio to water supply, i.e. D/Ws. The larger the ratio the more intensive groundwater salinity decrease, drainage flow desalinization and salt removal from active layer of water-salt exchange.
Changes in D/Ws and relevant reclamation regime parameters are given in Appendix 3.
Ratio D/Ws ranges from 0.11-0.20 to 0.5-0.6 depending on land development, type of drainage, hydrogeological, reclamation and economic conditions of plots. High ratio of 0.4-0.6 is observed in the plots, where groundwater head exists (Fergana and Chu valley). In these areas drainage outflow is formed by groundwater seepage and groundwater and lower aquifers by inflow from outside.
In the lower Amudarya's drainage zones this value is higher (0.41-0.57) than in other zones, despite absence of groundwater head. This is explained by large water supply due to high salinization and poor irrigation technique (flood irrigation in slightly sloped lands). This value is less in rice fields because of large irrigation norm for rice and continuos release from its fields, which provides running water in checks. Average value of this ratio for drainage zones (table 2.1) is relatively smooth, but tendency of changes over natural-economic zones remains.

### 2.1.4. Changes in drainage effluent salinity

Drainage outflow salinity is a main indicator  for reclamation state assessment. Its changes show intensity of soil desalinization and amount of salt removed. Besides, it determines amount of salts entered to river flow.
Changes in drainage effluent salinity depend on groundwater salinity, salt profile and implemented reclamation measures (crop irrigation regime, leachings, drainage operation and soil-reclamation conditions of irrigated lands).
Groundwater salinity considerably decreased all over the area under used irrigation regime and agrotechnical measures with subsurface drainage. Over 4-10 years of subsurface drainage operation salinity decreased 2-3-fold as compared to its initial level. Intensive desalinization was observed during first 2-5 years. Next years it was slower (table 2.1). Practically, salinity decreased up to admissible level of 4-8 g/l. Analysis of average values by drainage zones shows desalinization of drainage outflow. Drainage outflow salinity reduced 1.5-2.0-fold as compared to its initial value (Fig.2.1). More detailed description for the pilot plots, located in the Amudarya and Syrdarya basins, is given in Appendix 3.

Table 2.1

Average indicators of reclamation regime under subsurface drainage

| Reclamation regime indictors | | Indictors change limits over drainage zones | | | | | |
|---|---|---|---|---|---|---|---|
| | | Amydarya basin | | | Syrdarya basin | | |
| | | Amydarya upper reaches | Bukhara-Karshy | Amydarya lower reaches | Fergana | Golodnaya steppe | Syrdarya lower reaches |
| Water supply, th.m3/year | | 8.8 - 9.4 | 9.1 - 9.9 | 10.4 - 13.6<br>(20.2-33.6) | 6.4 - 9.3 | 6.9 - 9.9<br>(21.0 - 27.5) | -<br>(17.0 - 25.0) |
| Drainage outflow, th.m3/year | | 1.9 - 3.0 | 1.5 - 4.1 | 5.4 - 7.4<br>(6.3 - 13.5 ) | 2.6 - 3.6 | 1.7 - 2.7<br>(2.5 - 8.9) | -<br>(2.1 - 7.3 ) |
| Drainageoutflow to water supply ratio | | 0.29 - 0.32 | 0.19 - 0.23 | 0.37 - 0.48<br>(0.29 - 0.47) | 0.32 - 0.43 | 0.25 - 0.29 | -<br>(0.12 - 0.32) |
| Drainage effluent salinity, g/l | | 4.96-7.77 | 1.9-21.4 | 4.13-13.7<br>(1.4 - 6.9) | 4.5 - 13.6 | 9.6 - 23-4<br>(6.6 - 15.5) | -<br>(2.2 - 3.2) |
| ground water-salinity g/l | Initial | 8.0 - 17.67 | 23.0 - 25.0 | 8.17 - 14.17<br>(8.4 - 27.3) | 5.66-19.0 | 13.25 - 32.5<br>((22.2 - 32.0) | -<br>(4.4 ) |
| | Final | 3.16 - 12.0 | 2.4 - 8.33 | 3.77 - 4.28<br>(6.3 - 9.5) | 4.76 - 8.8 | 7.66 - 11.0<br>(3.5 - 6.5) | -<br>(2.3) |
| Drainage effluent salinity, g/l | Initial | 7.5 | 12.67 | 8.03<br>- | 8.16 | 18.0<br>- | -<br>- |
| | Final | 4.97 | 7.25 | 5.6<br>(5.15) | 3.8 | 9.5<br>- | -<br>- |

<u>Note:</u> Numbers in brackets relate to rice systems.

Over 10 years in Fergana province (plot within Niyazov farm) groundwater was desalinized from 9.03 to 4.85g/l, of which desalinization by chlorine - from 0.245 to 0.075g/l. Drainage waters were desalinizated from 6.11 to 4.017g/l, of which desalinization by chlorine - from 0.167g/l to 0.07g/l.

Over the same period in plot from Buvaidi district (02.7Uz) groundwater was desalinized from 5-38 to 5-10g/l, while drainage outflow was desalinized from 5.5-10g/l to 2-4g/l.
In Khorezm province (02.20Uz) over 3.5 years of drainage operation groundwater salinity decreased from 8.8 to 3.5g/l.

In Hunger steppe in the plots of state farm N6 (02.35Uz) the following results were obtained. Over 9 years in first pilot plot (southern part of the state farm), 60.0ha, groundwater was desalinized from 20-45 to 15-19g/l and drainage outflow was desalinated from 44.8 to 16.1g/l. In second plot (central part), 150ha, groundwater was desalinized from 25-30 to 11-11.2g/l and drainage outflow was desalinated from 26 to 9.1g/l. Over 8 years in third plot (northern part), 200ha, groundwater was desalinized from 25-30 to 12-16g/l and drainage outflow was desalinized from 19.8 to 12.1g/l.

In Bukhara province (02.25Uz) drainage outflow salinity decreased over 4 years from 20.0-52.02 to 9.4-8.5g/l in strongly saline soils and from 9.4-8.5 to 2.5-4.0g/l in medium saline soils. Areas with groundwater salinity of 5g/l increased 3-fold, from 23 to 76 ha. Areas with groundwater salinity of more than 20g/l decreased more 2.7-fold, from 127 to 48 ha.

### 2.1.5. Drainage effect on water-salt regime of aeration and saturation zones

Soil water-salt regime formation depends on natural and economic situation, which differs by regions, and on drainage operation.

**Fergana zone**

In plot 02.7Uz with satisfactory subsurface drainage operation (annual average drainage modulus of 0.16-0.21l/sec/ha) and satisfactory economic regime (irrigation norm of 8480-11500 $m^3$/ha) soils of aeration zone are being desalinized. In 1978 (beginning of the research) almost half of lands (45 ha out of 97ha) were heavy saline, 32.3 ha - medium saline and 10 ha were alkaline soils. In 1986 in the same plot 67.2ha become non-saline, 19.2 ha - slightly saline and 25.4 ha remained medium saline.

In leached soils maintenance of salt regime or further desalinization is carried out by leaching and recharge irrigation. Conducted multivariant experiments (02.23Uz) in Central Fergana with different technological schemes (field and furrow leachings) and with leaching norm of 1500-2500 $m^3$/ha showed salt removal from 1 m layer of 16.4-30% out of initial salt content. In all variants after leachings chlorine-ion percentage in 1 m layer did not exceed 0.004-0.007% (below the maximum permissible concentration), that provided full /young growth of cotton. However, during vegetation period (1986, 1987, 1988) despite irrigation depth of 2870-3865 $m^3$/ha salt restoration was slow.

It was found, that under conditions of Central Fergana with relatively shallow water (1.5-2.2 m) further desalinization of slightly saline soils could be done with recharge irrigation, operational leachings with norm of 1.5-2.5 th. $m^3$/ha and not less than 3-4 vegetation irrigations with depth of 3.5-4 th. $m^3$/ha. The best period for recharge irrigation is March, while for operational leachings it is January and February. Three pilot plots (02.1Tad, 02.2Tad, 02.3Tad) are located in Isfara-Lyakkan valley being a part of Fergana valley.
The main objective of the projects was identification of hydrogeological parameters and causes of reclamation state deterioration, development of reclamation measures and determination of drainage effectiveness (vertical, horizontal and combined). Drainage effectiveness was considered regarding ground flow capture and groundwater level lowering. Salt regime was not studied.

Under identical natural and geo-lithological conditions of Chu valley with sprinkling irrigation (02.3Kyrg) and without (in first two years) or with small leachings (164-585 $m^3$/ha last three years) soil salinization has not considerably changed in 0-100 cm, 100-200 cm and 200-300 cm. Over this period toxic salts content in 0-100 cm layer varied within 0.135-0.228%, i.e. tendency to desalinization or salinization is not observed while keeping soil moisture below the FFC. In fall, fifth studied year, toxic salts content was 0,185% in 100-200 cm layer, 0.212% in 200-300cm layer and 0.204% in 300-350 cm layer. The same situation with salt regime is observed in the plot 02.2Kyrg under sprinkling irrigation. Sufficient leaching seems to be the main condition for desalinization under drainage operation.

**Hunger steppe zone.**

Conducted in 1969-1970 research in new developed lands of state farm N 6 (02.27Uz) identified two periods in salt regime changing. In 1961-1966 there was intensive groundwater salinization of 20...50 g/l (initial levels: 3...5 m on 1540 ha, 5...10 m on 6450 ha and more than 10 m on 3922 ha). To the end of the period the level raised and was as follows: 1...2 m in 2650 ha, 2...3 m in 4804 ha and 5-10 m in 185 ha.

In the result 2650 ha of previously non-saline lands became unusable for crop cultivation due to heavy salinization and 4675 ha of lands transferred to medium saline ones.
In 1967-1972 increase of collector-drainage system capacity from 35.8 m/ha to 73.0 m/ha provided conditions for creating descending desalinating irrigation flow, that along with other measures (leaching irrigation regime, capital and operational leachings, leveling) effected soil salt regime.

Soil salt regime was favorable. In 1966 in southern part of the state farm chlorine-ion content was 0.427% in 0-100 cm layer, 0.273% in 100-200 cm and 0.36% in 200-300 cm. In 1972 it considerably decreased and accounted for 0.032%, 0,033% and 0.034%, respectively. In central and northern parts chlorine-ion content in given 3 m layer ranged from 0.032% to 0.06% in 1966. In 1972 it decreased to 0.028...0.042%. Area of medium- and strongly saline lands (0-100 cm) accounted for 52% in 1966 and decreased to 24.6% in 1972 due to increase of non- and slightly saline lands (75.4%).

Subsurface drainage effect on soil salt regime formation in drain spacing and in different soil depths was studied in 3 representative plots, located in southern, central and northern parts of the state farm (02.35Uz). Clear desalinization between drains is not observed. Salt content changes were 5...7%. Easy mobile chlorine-ion content was maximum in drain zone (6...10 m from drain axis) and accounted for 0.04...0.075%, while it was 0.02...0.04% between drains.

In 1971-1976 in Shardara district (02.6 Kaz) under rice cultivation with subsurface and open drainage annual amount of drainage outflow accounted for 5.3-7.3 th. $m^3$/ha having water supply of 19.7-22.9 th. $m^3$/ha.

After one year of cultivation strongly saline soils were transferred to slightly saline ones. Initial salt storage was 379.2 t/ha in aeration zone and 310.5 t/ha in groundwaters. After one year of rice cultivation salt storage in aeration zone decreased to 231.2 t/ha in area under open horizontal drainage and to 213 t/ha in area under subsurface horizontal drainage. Salt content in groundwaters increased up to 388.6 t/ha under open horizontal drainage and to 374 t/ha under subsurface horizontal drainage. This shows advantages of subsurface horizontal drainage. There is an opinion, that if originally desalinate soils through intensified leachings and leaching irrigation regime then consequently water consumption can be reduced and, thus, irrigation water can be saved. Such experiment was conducted in Bougun district of Southern-Kazakhstan province (02.2Kaz). Leaching and calculated irrigation regime was tested for different initial depths of desalinization (0.5-0.7; 1.0-1.1; 1.5-1.6; 2.5-3.0 m). Analysis of research results shows need in use of leaching irrigation regime for desalinization of saline lands with high groundwater salinity. Without this regime salts are accumulated even under initial depth of desalinization at 2.5-3.0 m (table 2.2).

### AmuDarya upper reaches

Draining zone of AmuDarya upper reaches is represented by the pilot plots (2.04. Tajik; 2.06.Tajik and 2.07.Tajik) where drainage parameters (2.06.Tajik of saline soil leaching with using precipitation on background of horizontal drainage without irrigation (2.04.Tjik) and aeration zone and ground water recharge through infiltration were studied. On the plot 2.04.Tajik salt regime was studied where positive results on lands development without capital leaching were obtained. Main aim of experiment is to create on a base of drainage the free volume in soil. Groundwater table (3,5 m) and significant precipitation (550-650 mm) of winter-spring period providing the ultra-fresh water infiltration to depth of 2,5-3,0m which are able to provide root zone intensive leaching up to slightly and medium saline soil level under initial salt content up to 1,5-2,0% per one mellowing period. During two years of drainage operation without irrigation, area of non-saline and slightly saline lands was 45-47% of total area. Desalinization process is more intensive in layer 0-50 cm; during 3-4 years of drainage operating salt removal from layer 0-50 cm was 70-90%; from gypsum bearing layer 75-100 cm -44-57%; from layer 100-150 cm - 60-70%, and from lower layer 150-200 cm it was 25-30% under the initial salinization 1,0-2,0% of soil weight. Further desalinization was conducted by means of leaching irrigation regime on background of drainage. However, such experiment is limited because relatively high volume of precipitation during autumn-winter period typical for SyrDarya and AmuDarya upper reaches.

### Bukhara-Karshi

Water-salt regime study on a background of horizontal drainage in Bukhara-Karshi drainage zone was conducted on the pilot plots 2.25. Uzb, 2.28. Uzb, 2.10.Uzb. Field investigations of water-salt management on saline desert and meadow-desert soils which are formed in Zerafshan alluvial delta river on background of shallow close drains were carried out on the pilot 2.25.Uzb in Altai rayon, Bukhara oblast (1980-1994). The pilot plots on mechanical soil structure, lithology, groundwater salinization are divided in two sub-sectors:

Table 2.2

Dynamics of desalinization (salinization) under leaching and calculated regime of irrigation and different initial depth of desalinization

| Initial depth of irrigation, m (up to 0.3 % of dry residue) | Leaching regime of irrigation , salt removal | | | | Designed regime of irrigation, salt removal | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-st year, tn/ha | | after 3 years | | 1-st year, tn/ha | | after 3 years | |
| | 0-100 cm | unsaturated zone 0 - 300 cm | 0 - 100 cm | unsaturated zone 0 - 300 cm | 0 - 100 cm | unsaturated zone 0 - 300 cm | 0 - 100 cm | unsaturated zone 0 - 300 cm |
| 0.6 - 0.7 | 9.11 | 12-15 | 20-25 | 30-40 | - | - | - | - |
| 1.0 - 1.1 | 5-7 | 8-12 | 10-13 | 20-25 | +(7..10) | +(10..15) | +(15..12) | +(25..30) |
| 1.5 - 1.6 | 3-5 | 5-8 | 6-9 | 10-15 | +(5...7) | +(7..10) | +(10-15) | +(15..20) |
| 2.5-3.0 | - | - | 6-8 | 10-13 | - | - | +(8..10) | +(10..15) |

Note: Leaching regime -- $\frac{B+O}{\Sigma И} = 1{,}1..1{,}3$

Designed regime of irrigation -- $\frac{B+O}{\Sigma И} = 0{,}9 - 10$

- First sub-sector is presented by heavy and middle loam soils with Кф=0,2-0,3 m/day; lands, in the main, are medium and strongly saline; groundwater salinity from 4 to 60 g/l; drain depth 2,4-2,6 m with drain spacing 80-150 m;
- Second sub-sector, in the main, is presented by slightly sandy loam and loam soils with Кф= 0,5-3,0 m/day; lands are slightly and non-saline with groundwater salinity from 2 to 15 g/l; drain depth 2,2-2,4 m, with drain spacing 300-400 m.

Over the plots irrigation regime was applied under irrigation norm 8,0-10,2 th.$m^3$/ha., drainage outflow was 1,6-2,4 th.$m^3$/ha and leaching irrigation regime was provided. Analysis of four years investigations on water-salt regime regulation showed that established drainage parameters and leaching regime provide stable soil, aeration zone and groundwater upper layer desalinization.

Under ratio Д/В equal 0,19-0,23 areas of medium and strongly saline soil are reduced by 3,5 time; salts disappeared entirely; salt removal from strongly saline lands for 4 years was 274 t/ha, annual average was 27,7 t/ha. In first 3 years of leaching regime creation on background of drainage and leaching the soil desalinization went intensively. During this period strongly saline soils were transformed to slightly and non- saline soils.
Improvement of water-salt regime management over large territories was studied in Karshi steppe (2.28.Uzb). For this purpose on territory of first turn of Karshi steppe development balance contour with area 145000 ha was distinguished; inside of contour in various geofiltration conditions standard farms were distinguished, there were sites were established which detail observation of moisture, salt, irrigation regime were conducted. Due to field investigations results analysis was found that intensive development caused ground water table rapid rise up to 5-7 m/year. Before development groundwater depth more 5m was extended over 85% lands, groundwater depth 1-2m was not available.

In the period of observations areas with groundwater table more than 5m disappeared, and areas with groundwater table 1-2 , 2-3m prevailed. Signs of head recharge and its values did not change practically and were $\pm$ 200-700 $m^3$/ha. Land development for irrigation caused significant saline lands area decrease and non-saline lands increase from 28220 to 58434 ha. Soils desalinization over area is irregular: on alluvial valley with two-layer soil structure and low salt content to depth soil desalinization, in the main, occurred and in zone with huge salts storage to large depth soil salinization increased (collective farms ¹¹ 9,10,11); salt maximum shifted to surface (45-100t/ha), locating in the first meter from land surface (89,6-162,4 t/ha). In spite of that annual average groundwater table 2,83m and salinity more than 20g/l, lands of collective farm ¹ 11 remained medium and strongly saline.

In Karshi steppe (2.10.Uzb.) collective farm ¹ 11 improvements of water soil accessibility criteria assessments which provide reliable management of water-salt regime of saline and subjected to salinity soils were studied. Studies included field investigations of water-salt regime, soil water capillary-sorption potential, soil solution and groundwater salinity. For this purpose two pilot plots with area 25 ha were established on which regular regime observations were conducted.

Actual data on moisture dynamics under irrigations and during irrigation interval as well as capillary-sorption and osmotic pressure of soil solution were obtained. Calculations of soil water total potential show that during the period of investigations the soil water in easily available form is located in root layer only in short time during irrigations. During 3-10 days soil water in medium available form is kept on 25-27cm, and after, along with drying up is transformed to hardly available form and inaccessible for plants. Actually, irrigation intervals from 20 to 30 days are longer than needed. Irrigation intervals under such lands development should be decreased to 10, maximum to 15 days. Depths of irrigation (800-2300 $m^3$/ha) are used under annual irrigation norm during vegetation period 4000-5000 $m^3$/ha are insufficient.

Comparison of capillary-sorption potential values with osmotic one shows that osmotic values prevail.
Along with soil desalinization by means of irrigations the components of total potential become equivalent.

**AmuDarya lower reaches**

AmuDarya lower reaches are distinguished by natural, ecological and water management peculiarities.
On the pilot plot 2.20. Uzb, Yangiarik rayon, Khorezm oblast, the water-salt dynamic on irrigated sites with systematic drainage (closed) of various depth, drain spacing and constructive details was studied.

Lithology of site is represented by multi-layer thickness of quaternary period (1,5-2,5m) of fine-grained deposits: loam clay and clay of soils with Êô=0,14-40 m/day. Water solvable salts content, average over plot, in arable layer are 2,8% of soil mass, and on chlorine-ion - 1,0%. Soils relate to strongly saline and salt types.

On background of close drainage high soil desalinization rate under leaching and leaching irrigation regime was created. According to salt survey data during 4 years of close drainage operation from common salts content near 232 t/ha in 1 meter layer 180 t/ha was removed: with in the first year near 108 t/ha; second -30 t/ha. At the same time, desalinization rate on chlorine-ion was highest and after the first year permissible limit was achieved; active zone of water-salt exchange which value for two and multi-layer deposits with small thickness (1,5-2,5) m varied within the limits of 35-50 m; influence zone of close drainage extends up to 250-300 m and 35-50 m in vertical creating a rising water and salts inflow from beneath without irrigation. From total salt removal, 55-65% correspond to lower horizons, that is significant under drainage parameters selection and reclamation system design. Main result of field investigations over site is water consumption (gross) annual norm reduction down to 17-18 th.$m^3$/ha against 23-25 th.$m^3$/ha under efficiency of 0,56. Annual water consumption norm reduction was achieved due to refuse of heavy operational leaching by norm up to 7,0 th.$m^3$/ha and its replacement by water recharge irrigation.

Water-salt regime formation on background of various drainage types (2.01.Uzb) was studied in “A. Navoi” collective farm, Hiva rayon during 5 years (1986-1990). The pilot plot area is 214 ha which is located in low elevated part of relief (lake-marshy deposits). Soils are salined in various degree from 0,2 to 5,20% ; 0,02-0,78% on chlorine and 0,104-2,47 on sulphate. Salinization type varies from sulphate to chloride- sulphate.
Soil water-physical properties over the pilot plots are changing lamination from quicksand, alluvial sands and light sandy loam to heavy loam and, clay. Cover layer permeability coefficient 0,3-0,6 l/day.

Ground water table was kept within the limits 1,0-2,0 m (spring and vegetation period) due to close drainage operation. From the beginning of September, groundwater table decreased gradually and in November-December achieved 2,5-3,5 m (before leaching). Irrigation norm during vegetation varied from 3800 to 4500 $m^3$/ha and leaching norm varied from 2800 to 4500 $m^3$/ha. During observations time area of medium and strongly saline lands decreased on 17-25%, and area of slightly and non-saline lands was increased on 2,5-3,5 % by means of leaching on a background of drainage operation with desalinization coefficient 1,37-1,88 in 1987; 1,33-1,88 (1988); 1,36-2,58 (1989). Analysis of root zone moisture regime dynamics shows that in 12-15 days moisture decreased down to 0,7 of full field water capacity, in 30 days (without irrigation) up to 0,35-0,4 of full field water capacity; under proved ground water regime by drainage, moisture decrease intensity is lower and does not descend even in 30 days lower than 0,6 of full field water capacity.

Drainability of salinizated lands of the AmuDarya lower reaches increase by means of horizontal drainage construction links with drain depth limitation caused by small gradients of territory, collector slopes weak stability and quicksand-alluvial soils.
Drain depth influence on water-salt regime formation was studied in Hiva rayon, Horezm oblast (2.29.Uzb).

Under irrigation norm 3700-4600 $m^3$/ha (vegetation period) and leaching norm 3600-4470 $m^3$/ha, as well as drainage outflow (average per 3 year) 3700-5000 $m^3$/ha slow soil desalinization occurred.

During observations time area of medium and strongly salinizated lands was decreased on 18%; area of slightly and non-saline lands was increased on 2,5 times. Salt removal rate per year was from 7,8 to 12,9 t/ha under initial salt stock 144,2 t/ha. Annual salt regime analysis shows that maximum of salinization relates to the first ten-days-period of July which causes the damage to agricultural yield. In spite of the high drainage outflow very slow process of soil desalinization occurred because of weak leaching irrigation regime.

Irrigation norm plus precipitation constituted 7300 $m^3$/ha in 1993, total evaporation was 8520 $m^3$/ha. Seasonal non-leaching irrigation regime occurred during vegetation period, and leaching regime was formed during leaching period only. Calculations show that leaching irrigation regime could be created if first irrigation would not be postponed on 2-3 weeks to compare with actual demand, which creates salt accumulation peak by the beginning of cotton bud formation period.

Water-salt regime dynamics under irrigation and development of the largest irrigated massifs under existed water management and hydrogegical-meliorative conditions of AmuDarya lower reaches (the Rep. of Karakalpakstan) during the period of 1970-1996 was represented in project 02.2. Uzb. Considered zone is 500 th.ha. Farms main specialization are cotton, rice and stock-breeding.

Widescale land development for cotton and rice cultivation, was started in 1970 under low technical level of drainage-irrigation systems (efficiency was 0,58) which is typical for canals with earth channels and open horizontal drainage and collectors subjected to sedimentation, overgrowing and slopes heaving under operation process. During the period of 1970-1990, in such conditions, total irrigated area in republic achieved more than 500 th.ha (in 1990) against 160-180 th.ha in initial position under water use coefficient growth from 0,35 to 0,45-0,50. Water diversion, during this period, grew from 4830 mln.$m^3$/year (in 1968) to 11000-12443 mln.$m^3$/year (1980-1984).

According to water diversion water disposal volume changed as well (680 mln.$m^3$/year in 1968 and 2931 mln.$m^3$/year in 1984). The highest specific water supply was in 1970-1980, its value varied within the limits 33-36 th.$m^3$/ha for average irrigated hectare for rice-cotton cultivation. Drainage outflow specific volume was 5,5-8,2 th.m/ha. From the beginning of 1983-1984 after water use limit introduction, the sharp decrease of water diversion as well as water disposal was found. In the period from 1985 to present time specific water supply on average hectare does not exceed 14-16 th.$m^3$/ha . Along with this in 1970-1982, winter-spring leaching share was 8-10 th.$m^3$/ha (5-6 th.$m^3$/ha, gross).

Under such water supply regime, especially in northern zone unstable water-salt regime was formed: in initial period of widescale development till 1975 over irrigated lands under unsatisfactory drainage operation and natural drainability absence, slow groundwater table lift occurred. Lifting rate depending on land use efficiency varied within the limits 0,3-0,5 m/year. Since 1976 groundwater table was stabilized on depth 1,6-2,0m during vegetation and up to 1,0m in winter-spring period. Till 1975-1976 groundwater salinization over irrigated lands increased at expense of salt removal from aeration zone, and then decreased gradually down to 3-5 g/l. Since 1980 groundwater salinization was stabilized within the limits 3-5 g/l, and drainage outflow salinity was some lower then that for groundwater which varied, from 2,5 to 4,2 g/l.

- Soil salt regime formed depending on water regime as unstable by with seasonal salt accumulation in soil layer.

During winter-spring heavy leaching (5-6 th.$m^3$/ha) the salts from soil layer were forced out downward to groundwater and on non irrigated fallow lands, and at the end of vegetation salt restoration occurred.

Coefficient of seasonal accumulation: $\left(\frac{\text{Sum of salts in spring}}{\text{Sum of salts in autumn}}\right)$ varied within the limits of 0,75-0,9; only on individual sites with satisfactory drainability soil desalinization occurred.

Thus, one of the basic conditions for soil desalinization is artificial drainability increase by means of perfect types of drainage and leaching irrigation regime. Close horizontal drainage for AmyDarya lower reaches conditions is more acceptable. Detailed investigations were conducted on area 160 ha. in "Halkabad" collective farm, Kegely rayon (02.8.Uzb). Close drainage of various design construction gave opportunity:

- active soil water regime management;
- creation of necessary (designed) drainability of territory 0,12-0,18 l/sec.ha against 0,17-0,27 over region and groundwater table decrease up to optimal values;
- provision of the high groundwater lowering rate after leaching and vegetation irrigations; groundwater lowering rate in zone of drain influence achieved 20-25 sm/day, on weakly drained territory it was 5-7 sm/day;
- management of soil top layer desalinization rate by means of leaching irrigation regime creation and salinizated lands leaching on the pilot plot, where close horizontal drainage was constructed.

On developed sites under cotton irrigation norm fluctuated from 2500 to 3500 $m^3$/ha. On non developed sites rice irrigation norm fluctuated from 22,0 to 25,0 th.$m^3$/ha. Leaching norm was 3,0-7,0 th.$m^3$/ha. Total water diversion on the pilot plot (without rice) fluctuated from 5,5 to 10,5 th.$m^3$/ha against 14-16 th.$m^3$/ha over region. Such irrigation regime and leaching on background of close drainage created favorable conditions for top layer desalinization.

Since 1985 till 1995 under drainage performance area of strongly saline lands decreased from 81 ha (67,5% of total area) to 18,2ha (14,6%), and area of non- saline lands increased from 0 to 26,3 ha. Slightly saline lands remained without changes, and area of medium saline lands increased by 2,5 times from 24,0 (20%) to 65,6 ha or 52,3% of total area.

AmuDarya lower reaches are the basic zone for rice growing in Central Asia. Soil desalinization under rice cultivation on salinizated lands on background of drainage was studied on the pilot plot which is located in Chimbaisky(02.16.Uzb) and Tahtakupir (02.26. Uzb) districts, the Republic of Karakalpakstan.

During irrigation period, depending on system operation terms, water supply to rice field was from 24,3 to 38,9 th.m$^3$/ha (2.16. Uzb) and 21,3-28,0 th.m$^3$/ha (2.26.Uzb). Maximum water supply hydromodulus in the period of initial checks flooding reached 7-14 l/sec (02.16.Uzb), minimum- 05-1,0 l/sec/ha. By means of drainage within rice vegetation period 9,4- 17,3 th.m$^3$ were disposed. Under irrigation, independently of initial salt content, intensive process of soil desalinization occurred. On the pilot plot (02.16.Uzb) under initial salt content in layer 0-40 cm was 2,66% on dry residue and 0,99% on chlorine-ion; during rice irrigation it decreased up to 0,69 and 0,03%, respectively. After 4 years of rice irrigation salt content in thickness 0-3m was 0,23-0,42% on dry residue and 0,02-0,07% on chlorine-ion, and on the pilot plot (02.26. Uzb) as compared with initial 332,3 th/ha, decreased down to 58,2 th/ha, (almost by 6 times), chlorine content by 8-9 times (under initial up to1%). It shows effectiveness of rice cultivation under strongly saline soils development.

### 2.1.6. Total and partial water-salt balances formation on background of drainage.

One of the basic indicators of drainage performance is soil desalinization intensification by means of influence on water-salt balance of irrigated lands. Depending on quantitative indicators of balance components ratio (structure) intensity of salt removal from soils is determined. At the same time water-balance structure is determined by natural-economic conditions of reclamated objects (table 2.3).

**Fergana zone**

During investigations on the pilot plot 02.7Uzb negative water balance was found. Relation between water supply together with precipitation and total evaporation (B:$\sum$ Tp) was 1,1-1,43. In negative part of balance the total evaporation was 8920 m$^3$/ha/year (892 mm) (average during the period 1978-1986) and prevailed. Drainage outflow was 5690 m$^3$/ha, and salt balance was negative. In aeration zone annual salt removal was 20 th/ha (average for the period 1978-1986). Initial irrigation water descending flow reached 2850 m$^3$/ha on average. Total salt balance shows that under total salt influx about 20-25 th/ha to the plot, annual salt removal was 37-58 th/ha, difference between influx and removal about 17-20 th/ha, it means that leaching irrigation regime is slow desalinizing. Under close drainage operation and optimal meliorative regime maintenance leaching regime share was decreased from 1,43 to 1,05-1,10 that allow to decrease annual water consumption norm on 10-15%.

Table2.3

WATER-SALT BALANCE STRUCTURE ON THE PILOT PLOTS OF SUBSURFACE DRAINAGE (DIRECTION 2)

| Drainage zone | Plot code | Soil-climatic zone | Water allowance | Water balance elements, m³/ha | | | | Salt balance elements | | Salt balance ± tn/ha | Soil desalinization, tn/ha | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Sum of positive compo-nents | including water supply | sum of negative compo-nents | drainage outflow | Salt influx | Salt removal | | 0-1 m layer | unsaturated zone |
| **Syrdarya basin** | | | | | | | | | | | | |
| **Fergana** | 02.7 Uz. | Ц-II-А | V | 16.2-18.6 | 11.5-14.0 | 16.4-18.5 | 5.1-6.1 | 23.0 | 42 | -19.0 | 108 | - |
| | 02.1 Tad. | Ц-II-Б | VIII | - | - | - | - | 39.7 | 19.6 | +16.1 | - | - |
| | 02.2 Tad. | Ц-II-Б | IV,V | 29.8-39.6 | 9.8-14.0 | 29.8-39.6 | 16.7-26.8 | non-saline soil | | | | |
| | 02.5 Kyrg. | Ц-II-Б | IV | 8.12-41.6 | 7.6-40.9 | 8.12-41.6 | 1.84-7.61 | 4.7-24.0 | 20.1-89 | -(15.4-65) | 69-279 | - |
| | 02.2 Kyrg. | Ц-II-Б | IV | 4.11-10.19 | 1.1-3.25 | 4.11-10.19 | 0.09-16.5 | 60.4-75.2 | 54.4-73 | +6..(+2.2) | - | - |
| | 02.3 Kyrg. | Ц-II-Б | IV | 8.59-11.81 | 5.02-7.59 | 8.59-11.81 | 1.41-1.71 | 16.2-20.9 | 16.2-20.9 | 0 | - | 9 |
| **Golodnaya steppe** | 02.35 Uz. | Ц-II-Б | IV,V | 7.8-13.6 | 4.5-10.92 | 7.9-12.8 | 0.12-2.7 | 5.4-22.1 | 4.7-54 | +0.7..(-31.4) | - | до 57 |
| | 02.27 Uz. | Ц-II-Б | VI | 9.07-17.3 | 6.8-9.0 | 2.38-15.31 | 1.3-2.97 | 9.6-27.8 | 15.7-51.6 | -6.1..(-23.8) | 191 | - |
| | 02.12 Uz. | Ц-II-Б | IV,V | - | 4.6 | - | 1.2 | 5.1 | 13.5 | -8.4 | - | - |
| | 02.2 Kaz.. | С-II-$А_1$ | IV | - | 8.4 | - | 4.0 | - | - | -(8..10) | -10 | - |
| | 02.4 Kaz. | С-II-$А_1$ | V | - | 10.2 | - | 2.8 | 4.0 | 18 | -14 | -107 | -110 |
| Syrdarya lower reaches | 02.6 Kaz. | Ц-I-А: | | | | | | | | | | |
| | | ЗГД | VI | 21.3-28.3 | 19.7-22.9 | 21.3-28.4 | 5.3-7.1 | 20.6-27.6 | 30.9-75.3 | -(10.3..47.7) | 97.14 | 124 |
| | | ОГД | Vi | 19.8-28.3 | 17.5-25.2 | 23-28.0 | 2.1-3.0 | 20-24.4 | 27.7-68.0 | -(7.7..43.6) | 88.80 (за 2 года) | 145 (за 5 лет) |
| **Amudarya basin** | | | | | | | | | | | | |
| Amydarya upper reaches | 02.4 Tad. | Ю-I-Г | VI | 11.5 | 7.13 | 11.2 | 1.66 | 5.02 | 5.16 | -0.6 | 14.9 | - |
| | 02.6 Tad. | Ю-I-Г | VII | - | - | - | 15.2 | - | - | - | - | - |
| | 02.5 Tad. | Ю-I-Г | VI | - | 12.5 | - | 4.1-10.7 | non-saline soil | | | | |
| | 02.7 Tad. | Ю-II-Б | V | - | 8.8-25.3 | - | 2.8-7.3 | - | - | - | -(18...34) | 30 |

| Drainage zone | Plot code | Soil-climatic zone | Water allowance | Water balance elements, $m^3$/ha | | | | Salt balance elements | | Salt balance ± tn/ha | Soil desalinization, tn/ha | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Sum of positive compo-nents | including water supply | sum of negative compo-nents | drainage outflow | Salt influx | Salt removal | | 0-1 m layer | unsaturated zone |
| **Bukhara-Karshi** | 02.25 Uz. | Ц-II-A | IV-V | 10.1 | 9.7 | 10.9 | 2.01 | 9.35 | 35.86 | -26.5 | - | 50-270 |
| | 02.05 Uz. | Ю-I-Г | VI | - | 4.5-5.0 | - | - | - | - | - | - | - |
| | 02.28 Uz. | Ю-I-Б | VI | - | 13.4-28.3 | - | 3.7-3.8 | - | - | - | - | - |
| | 02.1 Turk.. | Ю-I-A | IV | 12.7 | 8.0 | 12.5-13.5 | 4.5 | 8.8 | 14.4 | -5.6 | - | 8-10 |
| | 02.2 Turk.. | Ю-I-A | IV | 14.7 | 11.4 | 13.9 | 5.04 | 13.2 | 26.1 | -12.9 | - | 8.0 |
| Syrdarya lower reaches | 02.29 Uz. | Ц-I-A: | VII | 8.85-11.6 | 7.4-8.72 | 12.2-14.1 | 3.7-5.0 | 6.5-8.6 | 12.9-17.5 | -6.4...(-8.9) | - | - |
| | 02.1 Uz. | Ц-I-A: | VII | 10.9 | 8.9 | 10.1 | 2.3 | 86.9 | 71.4 | -15.5 | - | - |
| | 02.20 Uz. | Ц-I-A: | VI | 26.7 | 13.6 | 26.4 | 15.0 | 31.3 | 60.3 | -29.0 | 42.0 | - |
| | 02.8 Uz. | C-II-A | IV-V | - | 3.5-10.5 | - | 2.6-5.6 | - | - | - | - | - |
| | 02.2 Uz. | C-II-A | V | 27.8-38.4 | 21.3-28.0 | 16.6-39.3 | 6.8-26.4 | 19-23 | 29-39 | -(10...16) | 274 | - |
| | 02.26 Uz. | C-II-A | V | - | 14.9-33.8 | - | 2.1-6.7 | 13.2-41.7 | 8.8-25.3 | +(4.4...16.4) | - | - |

**Hungry Steppe zone**

Water-salt balance elements formation and its dynamics under lands development was studied on lands of Hungry Steppe in collective farm ¹ 6 (02.27.Uzb) (1961-1972). Total water-salt balance analysis shows that in 1964-1967 it was positive, ground water table rise on 0,4-1,6 m and salts accumulation 2-6,8 t/ha/year occurred. Since 1968 water-salt balance was negative, annual groundwater table decrease on 0,12-0,18m and salts stock reduction on 18,2-4,2 t/ha. During the period of investigations 101,9 t/ha of water soluble salts were removed.

Over three pilot plots (02.35.Uzb) negative water-salt balance was formed with salt removal 8,3-34,7 t/ha/year.
Analysis of salt content dynamics in 3m thickness shows that within 1965-1968 salt accumulation on the second pilot plot was 32,5 and on the third -43,4 t/ha; in 1969-1972 salt stock decreased on 57,7 and 34,2 t/ha, respectively. The similar is shown by water-salt balance of the second pilot plot, where at the same time, insignificant salt inflow 0,25 and its outflow 44,5 t/ha occurred. Over the third pilot plot in 1964-1966 salt outflow occurred because of deep ground water table lower then drain depth. In 1967 under ground water rise above close drains, which technical conditions was unsatisfactory, salt accumulation of 5,9 t/ha occurred. After close drains repair salt outflow was 89,1 t/ha.

New land development process was studied in farm ¹ 3A Hungry Steppe (02.14.Uzb) in 1976-1983. For leaching and rice irrigation-25-30 th.$m^3$/ha gross were supplied on average, for cotton irrigation- 9-10 th.$m^3$/ha. Leaching on background of rice with water supply 19,7-17,3 th.$m^3$/ha was conducted. Drainage modulus was on average within the limits 0,19-0,20 l/sec. From 12 to 30% of water supply is diverted from hectare. During investigation on background of close drainage operation and leaching irrigation regime and leaching through rice salt balance was negative.
Salt balance for 1976-1981 period was as follow:

- brought with irrigation water - 95,3 t/ha
- stock in 0-1m layer before development - 393,4 t/ha
- stock in 0-1m layer at the end of development - 228,8 t/ha
- removed from layer 0-1m - 259,9 t/ha
- stock in 1-2m layer before development - 247,4 t/ha
- stock in 1-2m layer at the end of investigations - 220,1 t/ha
- removed from layer 1-2m - 287,2 t/ha
- removed with drainage outflow - 274,3 t/ha

Thus, within field investigations process negative salt balance was found which created favorable meliorative regime and ground water table on depth 2-3m during vegetation. Besides, area of strongly saline soils (in top 1m layer) decreased from 72,5% (before development) to 7,3% (1981).

**SyrDarya lower reaches**

Water-salt balance formation on rice fields on background of close drainage was studied in Shardarinsk rayon, South-Kazakhstan oblast (02.06.Kaz) in 1971-1976. Comparative analysis of water balances shows that drainage outflow of open horizontal drains varied from 2960 to 2070 $m^3$/ha (9,1-11,6% of balance negative part), and drainage outflow of close drains fluctuated within the limits 5330-7100 m/ha (25,8-30,5%) (Table 2.8).

Other negative parts are as follow: total evaporation- 12690-13630 m/ha for plot with open horizontal drains and 11750-13880 m/ha for plot with close horizontal drains; groundwater outflow 3520-9800 m/ha and 1340-7300 $m^3$/ha, respectively. Water supply was 89-95% of positive part of balance, under open horizontal drainage varied from 25170 $m^3$/ha to 17710 $m^3$/ha and from 25070 to 19000 $m^3$/ha under close horizontal drainage.

Negative salt balance was created over the plots. Salts influx with irrigation water over the plots with open and close horizontal drains was 20,0-24,6 and 20,6-27,6 t/ha respectively, and salts removal with drainage water was 10,4-18,4 and 24,7-36,1 t/ha; groundwater outflow was 7,3-49,6 and 6,2-39,2 t/ha. Along with this rice yield over pilot plot with close horizontal drainage was 50-60 c/ha, on the site with open horizontal drainage 41-46 c/ha.

**Bukhara-Karshy zone**

Water-salt balance formation on the largest irrigation massifs in Bukhara-Karshy drainage zone was studied in new developed farms of Karshy steppe (02.28' Uzb) in 1975-1979. Positive water balance components are water supply plus precipitation and negative are drainage outflow and total evaporation from irrigated lands (Table 2.3) .
During investigations period water supply fluctuated from 17000 $m^3$/ha to 22700 $m^3$/ha under irregular water supply over farms and its reduction with time. On balance farms water supply decreased from 22500 $m^3$/ha to 17170 $m^3$/ha on collective farm ¹3, collective farm ¹4 - from 28300 to 13400 $m^3$/ha. However, actual water supply exceeds irrigation norms that causes intensive ground water table rise, which exceed forecast calculations.

Water consumption regime does not correspond to actual water supply neither on irrigation norm nor on its annual distribution due to combination of water recharge with leaching irrigation and essential water supply increase at the end of vegetation period; under simultaneous irrigation depth increase, actual leaching norm is not differentiated in dependence on soil texture and degree of salinization. Total evaporation decreased during irrigation period from 10250 to 8070 $m^3$/ha. Drainage outflow, from the territory, where ground water lift occurred, achieved 3700-4800 m/ha under average values 2500-2700 m/ha. Salt removal with drainage outflow could exceed 86-100 t/ha, minimum salt removal 2-12 t/ha is found in farms where groundwater table does not reach drain depth. Investigations show that drainage outflow, accepted by collectors, by 10 times exceeds drainage outflow of the initial drains; it causes, from one hand, in conditions of hilly relief and two-layer deposits collectors capacity exceeds drains capacity; from the other hand, released waters are constituted the significant part up to 50% of water supply (collector Dagut, UÊ, BÊ, etc.).

Water-salt balances of key pilot plots show that on alluvial plain which is represented by two-layer thickness and small salt stock located under groundwater table, satisfactory rate of aeration zone and ground water desalinization occurred under relationship between water supply and drainage outflow 0,34, in spite of uncompleted and partially non operated drainage. For zones with large salt stock under groundwater table causing high ground water salinity stable aeration zone and ground water desalinization even under drainage outflow 4220 $m^3$/ha (collective farm ¹9, 1977) and ground water table average for vegetation 2,4m was not created. Large salt quantity within a year are removed by drainage (collective farms ¹9 - 59,7 t/ha; ¹ 10 -51,46 t/ha and etc. ). Prospective water-salt calculations show that under high salt stock under ground water and water supply volume conservation it is necessary to keep ground water table average for vegetation within 2,6-2,7m.

**AmuDarya lower reaches**

Water-salt balance structure of AmuDarya lower reaches drainage zone has its peculiarities. Desalinization and soil salinity support at acceptable level is obtained at the expense of large water supply volume, because of territory low drainability and technical level of irrigation and drainage systems. Total water supply volume could be decreased at the expense of drainability increase by means of perfect close and open horizontal types of drainage construction. Close horizontal drainage in Yangiarik rayon, Khorezm oblast (02.20. Uzb) is located on area 303,7 ha among irrigated lands and surrounded by operating canal which creates large external inflow and load on drainage. Drain depth is 1,5- 2,0- 3,0m; distance between rows is 150-300m, specific length - 30m/ha. Such drainage operation helped to create high drainability of irrigated lands. Annual drainage outflow varied from 14,4 to 15,6 th.$m^3$/ha under total water supply 22,3 and 26,2 th.$m^3$/ha. From total water supply external inflow was 29,5%. As a result negative water-salt balance was formed. Salt removal was 34 t/ha in the first year, 29,2 t/ha in the second and 12,4 t/ha in the third one. During 4 years of drainage operation on background of leaching irrigation regime salt content in layer 0-100 cm decreased by 4,3 times on salt sum and by 14,8 times on chlorine-ion. Main result of investigations is field water consumption norm (gross) decrease down to 17-18 th.$m^3$/ha against 23-25 under existed system efficiency 0,56.

On other sites (02.1Uzb; 02.29.Uzb) aeration zone water-salt balance was negative. Drainage outflow increased significantly to compare with open drainage; during vegetation it was 1178 $m^3$/ha, in leaching period - 660 $m^3$/ha, consequently, drainage modulus was 0,361 l/sec. However, desalinization rate was significantly lower because of insufficient leaching regime (0,94-1,07). Water-salt balance on large irrigated massifs depend on water-related conditions (irrigation and drainage technical conditions, crop pattern, etc.). Water-salt balance on large irrigated massifs is formed by type of progressive salt stock accumulation. By 1986-1987 salt accumulation rate, fluctuated within the limits 7,3-25,7 t/ha. Intensive salt accumulation occurred on fallow lands. Main salts influx is caused by irrigation water, which value depends on water availability. Maximum value (40-42 t/ha) of salts influx with irrigation water occurred in 1976-1980 under its removal through collector-drainage system in amount of 25-29,6 t/ha. Aeration zone salt balance is formed according to type of seasonal accumulation in soil layer and on fallow lands. At the same time since 1985-1986 water-salt balance of irrigated territory is formed by type of salt removal (2-5 t/ha), through process in aeration zone did not change. Strongly and medium saline lands constitute 55-62%. In conditions of the Republic of Karakalpakstan under poor irrigation and drainage system technical level leaching irrigation regime coefficient, according to balance, fluctuated within the limits 0,44-0,6 against 1,25-1,4 for Khorezm oblast.

Soils and irrigation water productivity are unstable and low, particularly, in northern zone. High cotton (up to 27-31 c/ha) and rice (up to 47 c/ha) yield was obtained within years with high water availability(1978-1981), and low (18-22 c/ha and 32-35 c/ha, respectively) of 1993-1996 with low water availability. Specific water expenses in Karakalpakstan yield unit were 800-900 $m^3$/c against 250-400 m/c in other rayons of Uzbekistan. On the pilot plots where designed values of drainage modulus (02.8.Uzb) and sufficient leaching irrigation regime are provided on background of close horizontal drainage intensive soil desalinization process and salt removal is observed. During 1985-1995 investigation period salt removal increased by 6 times, water supply decreased significantly.

Water-salt balance structure analysis of represented pilot plots (table 2.3) shows that water supply is the main positive part of water balance on which soil desalinization rate depends. Drainage outflow is the main desalinizating element of negative part of the water balance.

The basic conditions of soil desalinization is leaching and leaching irrigation regime on background of drainability sufficient to provide artificial drainage.
Leaching regime is obtained, in the main, by water supply at expense of its increase

$$\left(\frac{В+О}{И+Тр}\right).$$

Leaching regime coefficient over sites fluctuate from 0,9 to 1,5; the higher coefficient more intensive salt removal. In this case, drainage is necessary for ground water and salts withdrawal (figure 2.2). There are no sharp differences in changes of salt removal dependence on leaching regime coefficient over drainage zones. Negative salt balance, starting from coefficient 1,0 is observed over all zones after the first stage of soil desalinization, that is very important for water supply norm establishing for land salinization. Under high coefficients 1,3-1,5 significant salt removal increase occurred only during the first stage of soil desalinization under initial ground water high salinity; higher (more 1,5) characterize the soil desalinization process under leaching or rice irrigations systems.

Analysis shows that after ground water desalinization (up to 5-7 g/l) the leaching regime share could be decreased up to 1,05-1,1, and with fresh ground water (3-5 g/l) up to 1,0-1,05 which provides annual water consumption norm decrease on 10-15%.

One of the generalize indices of salt balance is relation $\frac{Д}{В}$, which defines intensity of salt removal and accumulation.
The attempt was made to establish link between relation $\frac{Д}{В}$ and salt removal under various type of drainage which is constructed in different hydrogeological and meliorative conditions (figure 2.3). Summarized data shows, that zero salt removal is observed under relation 0,10-0,12 under horizontal and 0,22 under vertical drainage; vertical drainage, except infiltration water, pumpes artesian ground water. Intensive salt removal occurred starting from 0,2 and 0,3, respectively, depending on types of drainage, which optimal value for specific conditions is defined by technical-economic calculations.

Value of Ä/Â relation is distinguished, significantly, depending on draining zones and fluctuated from 0,2 to 0,6. Average value for Fergana zone was 0,32-0,43; Golodnostep zone - 0,25-0,29; AmuDarya upper reaches - 0,29-0,32; Bukhara-Karshi - 0,19-0,23; AmuDarya lower reaches - 0,37-0,48 (annex 4).

It should be pointed out, that highest relation values are found on territories where ground waters are artesian (Fergana zone) and large water supply takes place connected with economic activities (AmuDarya lower reaches).

Salt removal depends on distance from close drains distance and depth of drains influence on irrigation water descending flow formation.

Depending on low permeable clay layer depth and drainage depth the distance of active influence is 50-150m under drain depth 2,5-3,5m, although drains influence was fixed on distance 250-300m. Depth of active water and salt exchange was determined. On the pilot plots which are equipped by control measuring equipment (deep piezometer) this depth is 18-20m (02.35 Uzb) under drains depth 2,8-3,5m and working head 0,2-0,8m (Hungry Steppe), 5-10m (02.25 Uzb) under depth 2,4-2,95m and working head 0,3-0,8m (Bukhara oasis), + 20-30m (02.1 Turk; 02.2 Turk) 35-50m (02.20Uzb) under drains depth 2-3m and working head 0,5-1,0m , some times 1,5m (Khorezm oasis), 8-12m (02.7.Uzb) under depth 2,5-3,5 m and working head 0,5-1,0 m (Fergana oblast).

During irrigation and leaching period zone of rising inflow decreased almost twice and water and salt inflow volume from lower horizon decreased as well. Clear water-salt exchange depth dependency on drain depth is not found.
Apparently, it depends on geologic-lithological and hydrogeological conditions and working head on drains. However, processing of investigations results for water-salt exchange depth definition under various working heads was not made; hydrodynamics nets under various working load on drainage were not draw up. Under close drainage operation required territory drainability is created not only under cotton-alfalfa crop rotation but under rice cultivation as well. Drainage outflow, averaged over zones, fluctuated within the limits: AmuDarya upper reaches 0,98-8,77; Bukhara-Karshi 2,4-3,8; AmuDarya lower reaches 4,1-7,6 th.$m^3$/ha (AmuDarya river basin); Fergana zone 2,51-5,05; Hungry Steppe 1,24-5,78 th.$m^3$/ha (SyrDarya river basin).

High rate of ground waters lowering by rate 10 cm/day is provided after operational leaching and vegetation waterings. On rice systems this indicator is 10-20 cm/day. It is important for fields drying up and timely rice yield harvesting. There is opportunity for ground water table regulation from 1,5 to 3,0 which provides soil water-salt regime for normal agricultural crops growth and development.

### 2.2.7. Main conclusions and recommendations

In Central Asia, starting since 1960, intensive new lands development and old lands reclamation were curried out by means of perfect types of drainage (close horizontal and vertical). Many design and construction aspects was not known, first of all, applicability of different types of drainage in various hydrogeological zones, meliorative effectiveness, constructive peculiarities, pipe and filter materials, etc. For different types of drainage and drainage structures tested in various hydrogeological, soil-hydrological-meliorative conditions the pilot sites were established in order to correct the design solutions for large irrigation massifs.

Questions which need to be studied proceed from existing problems of design, construction and operation of specific objects and zones.

Investigations covered the following main questions:
- geologic- lithological, hydrogeological- meliorative and soils parameters definition;
- ground of necessity of soil-hydrogeological detail investigations under perfect systems of drainage design;

- construction technology, different constructive elements workability (pipes, filters, constructions on drains) and main drainage parameters definition (depth, spacing, etc);
- irrigation and leaching regime perfection;
- ground water level and piezometric head regime in natural conditions (before drainage system construction);
- ground water level and piezometric head dynamics within drainage influence zone (establishment of hydrodynamic schemes of drainage operation);
- soil moisture dynamics within aeration zone under leaching and vegetation irrigations;
- drainage discharge, flows and drainage modulus dynamics;
- collector-drainage net work technical conditions;
- irrigation, drainage and ground water salinity and chemical composition;
- water balance and salt soil regime structure;
- horizontal drainage desalinizing effect under influence of vegetation irrigations and leaching;
- close drainage technical-economic indicators;
- possibility of experimental data spreading over large territory, etc.

However, investigations were limited depending on equipment, data and financial sources availability, that makes difficult to come to general conclusions and proposals.
Large investigations data were collected only from the pilot plots in "Niyazov" farm, Akaltin rayon, Fergana oblast (1960-1973), "Pravda" farm, Yangi-Arik rayon, Khorezm oblast (1966-1973), "F. Khodjaev" farm , Altai rayon, Bukhara oblast (1989-1994) and farm ¹ 6 in new irrigated zone of Hungry Steppe (1967-1972) consisting of three sites. Above sites are representative for corresponding regions. Results of sites investigations are basic for recommendations development on soil water salt regime regulation and close drainage and its parameters effectiveness establishment for large irrigation massifs (annex 5).

Main conclusions and recommendations on the pilot sites investigations are as following:
- close horizontal drainage, under suitable, geologic-lithological, hydrogeological-meliorative and soils conditions, gives higher meliorative effect as compared with other types of drainage (vertical and combined). Area of such drainage application is, in first turn, territory where fine-grained deposits have largest thickness with low permeable layers and low permeability; ground waters have no recharge from outside and from lower layers; salt distribution is regular along profile of fine-grained deposits or increases with depth of profile;
- close horizontal drainage construction significantly influenced on water use- irrigation water release from irrigated lands is absent. Water supply significantly decreased for field irrigation at expense of operational leaching replacement by water recharge irrigation (or reduced norm) and leaching share of irrigation norm decrease at expense of drainability increase.

Comparison of actual water supply, observed on the pilot sites and averaged over oblasts of Central-Asian republics shows that perfect types of drainage, introduction including close horizontal drainage, gives significant irrigation water saving (annex 6). Specific water supply on the field border decreased from 1,0 to 6,0 th.m$^3$/ha under existing water management conditions. However, in other oblasts (SyrDarya, Djizak, South-Kazakhstan) water saving is absent. It is explained by the fact that because of water resources shortage water supply is less then needed for soil water-salt regime maintenance.

- favorable meliorative conditions are created. Negative water-salt balance was formed on background of close horizontal drainage which provides intensive salt removal (table 2.3). Soil desalinization occurred. For 3-4 years of drainage operation on background of leaching and irrigation leaching regime strongly salinizated soils and salt disappeared everywhere. Lands transferred in to slightly saline and non- saline category.
- in dependence on initial soil salinity, water supply and disposal salt removal fluctuated in large limits. On the first stage of soil desalinization under high initial salinity, especially during 2-3 years, salt removal intensity is highest, and then it significantly decreases. Salt removal from aeration zone during1 year fluctuated from 10,0 to 110 t/ha, and specific water expenses for 1 t salt removal were from 90 to 1080 t/$m^3$ (table 2.4). Average water expenses for 1 t salt removal over drainage zones are:

for Fergana zone 531-688 $m^3$
for Hungry Stppe zone 243-286 $m^3$
for AmuDarya upper reaches 487-900 $m^3$
for Bukhara-Karshi 172-328 $m^3$
for AmuDarya lower reaches 478-659 $m^3$

- ground and drainage waters desalinization occurred on background of close horizontal drainage. Desalination intensity in the first 3-4 years was high, ground water salinity was decreased by 2 times from its initial value. In the following years desalination intensity decreased (figure 2.2). It is worth to note, that on new saline lands ground water salinity increase was observed at expense of salt leaching from aeration zone. Duration of meliorative period was from 3-4 (Khorezm oblast) to 6-8 years (Hungry Steppe).
- close drainage construction is provided as worth while as under old irrigated drainage systems rehabilitation, so under new saline lands development. Annual economic effect was from 400 to 670 ruble/ha. Limited cost were established for 1 km drain length under various natural- economic conditions and construction technology.
- the base of economic effect is agricultural crops yield increase. Yield increase occurred at expense of soil desalinization. Stable cotton yield (25-30 c/ha under initial 10-15 c/ha) was obtained on background of close drainage. There is a possibility to obtain additional production at expense of stripes along drains development within 2-4 years after drains construction. Irrigated lands increase due to stripes along drains development is 3-5%. Thus, term of capital investments return under close drainage is from 3-4 (Khorezm oblast) to 6-8 years (Hungry Steppe).
- distance of active close drains influence on irrigation water infiltration flows formation has very significant meaning for drainage parameters establishing. Recommended depth of active water-salt exchange is as follow:

  for Fegana zone 15-20 m
  for Hungry Steppe zone 25-30 m
  for Bukhara-Karshi 20-25 m
  for AmuDarya lower reaches 30-40 m

  However, this value should be corrected depending on drain working head which in turn depends on ground water designed depth.

  Recommended ground water depth is as follow:
  for Fergana zone 1,5-2 m against critical depth 2,0-2,2 m;
  on Hungry Steppe zone 2,4-2,8 against 2,4-2,5m;
  for Bukhara-Karshi 1,6-1,75 against 2,0-2,2 m (Bukshara part) and 2,0-2,5m (Karshy Steppe);
  for AmuDarya lower reaches 1,8-2,0 against 2,0-2,8

Table 2.4

Specific water expenses for 1 ton salt removal on background of subsurface drainage

| Drainage zone | Project code | Project duration, years | Water supply (annual), th. $m^3$/ha | Drainage outflow, th. $m^3$/ha | Salt removal from unsaturated zone, t/ha | Specific water expenses for 1 ton salt removal from unsaturated zone | Source of information |
|---|---|---|---|---|---|---|---|
| Syrdarya basin | | | | | | | |
| Fergana | 02.7’ Uz | | | | | | |
| | 02.7 Uz | 9 | 11.18-14.2 | 5.1-6.1 | 20.0 | 559-710 | salt balance |
| | 02.3 Kyr | 5 | 5.02-7.59 | 1.41-1.71 | 7.5-10.04 | 670-750 | -”- |
| | 02.9 Kyr. | 7 | 3.29-5.45 | 1.7 | 9.2 | 365-605 | -”- |
| Average for zone | | | | | | 531-688 | |
| Golodnaya steppe | 02.35 Uz | 7 | 4.5-10.92 | 0.12-2.68 | | | salt survey (author calculations) |
| | South part | -”- | -”- | -”- | | 105-140 | |
| | Center part | -”- | -”- | -”- | | 122-144 | |
| | North part | -”- | -”- | -”- | | 135-160 | |
| | 02.27 Uz | 4 | 6.8-9.0 | 1.3-2.97 | 21.65 | 314-415 | salt balance |
| | 02.2 Kaz | 3 | 8.1-8.6 | 4.0 | 15.0 | 560 | salt survey |
| | 02.4 Kaz | 3 | 10.2 | 2.8 | 110 | 92 | salt survey |
| | 02.6 Kaz | 3 | 19-25 | 5.8 | 50.8 | 374-492 | salt survey (rice system) |
| Average for zone | | | | | | 243-286 | |
| Amudarya basin | | | | | | | |
| Amudarya upper reaches | 02.7 Tad. | 5 | 8.8-25.3 | 2.8-7.3 | 30-40 | 251-722 | removed by drainage |
| | 02.6 Tad | 4 | 10.2-15.0 | 13.8-15.2 | 14.1 | 723-1078 | salt survey |
| Average for zone | | | | | | 487-900 | |
| Bukhara-Karshi | 02-25 Uz | 4 | 9.7 | 2.01 | 27.7-68.5 | 141-350 | salt survey |
| | 02.2 Турк | 10 | 1.14 | 5.04 | | 230-330 | author calculations |
| | 02.28’ Uz | 4 | 13.4-28.3 | 3.7-3.8 | 86-100 | 144-304 | salt balance |
| Average for zone | | | | | | 172-328 | |
| Amudarya lower reaches | 02.29 Uz | 4 | 7.4-8.72 | 3.7-5.0 | 15.0 | 493-581 | salt balance |
| | 02.1 Uz | 5 | 8.9 | 2.3 | 11.05 | 809 | salt balance |

| Drainage zone | Project code | Project duration, years | Water supply (annual), th. $m^3$/ha | Drainage outflow, th. $m^3$/ha | Salt removal from unsaturated zone, t/ha | Specific water expenses for 1 ton salt removal from unsaturated zone | Source of information |
|---|---|---|---|---|---|---|---|
| | 02.20 Uz | 4 | 22.3-26-2 | 14.4-15.6 | 25.1 | 495-582 | salt survey |
| | 02.8 Uz | 10 | 5.5-10.5 | 0.075-2.66 | 13.4 | 410-783 | drainage outflow |
| | 02.26 Uz | 4 | 14.9-33.8 | 2.1-6.7 | 68.5 | 217.5-493 | salt survey (rice) |
| | 02.16 Uz | 2 | 24.3-38.9 | 9.4-17.3 | 54.7 | 444-711 | salt balance (rice) |
| Average for zone | | | | | | 478-659 | |

However, final ground water table and corresponding drainage depth are established in accordance with natural-economic and technical-economic conditions.

- the main condition for soil desalinization is leaching and leaching irrigation regime on background of sufficient drainability.

Recommended drainage outflow/ water supply ratio under which desalinization process over draining zones is effective is as follow:

| | |
|---|---|
| for Fergana drainage zone | 0,3-0,4 |
| for Hungry Steppe zone | 0,25-0,3 |
| for AmuDarya upper reaches | 0,3-0,35 |
| for Bukhara-Karshi | 0,20-0,25 |
| for AmuDarya lower reaches | 0,3-0,4 |

Leaching regime coefficient predetermines water supply volume for water-salt regime of saline soils maintenance. Its value established before 1963, was 1,25-1,3. Multi-year investigations on the pilot plots gave possibility to determine this value and recommend, it depending on ground watersalinity. For all drainage zones after ground water desalinization up to 5,0-7,0 g/l leaching regime share could be decreased to 1,05-1,1; and on desalinized ground water with salinity 3-5 g/l up to 1,0-1,05 that provides annual water consumption decrease on 10-15%.

In dry years, temporary for 1-2 years, water consumption could be decreased to 0,9-0,95, but with following compensation in humid years.