2.2. Regulation of water-salt regimes and management of meliorative processes on vertical drainage systems background (in artesian, sub-artesian and non-artesian hydrogeological conditions)

General

In Central Asian republics (in particular, in Uzbekistan) vast work was being carried out on water-related construction: perfect irrigation system in Hungry steppe is created; development of lands in Karshi, Djizak, Surkhan-Sherabad steppes and Central Fergana, in Karakalpakstan and Khorezm oblasts and others. Large irrigation systems were constructed in Chu valley of Kyrgyzstan, Vakhsh valley of Tadjikistan, in Karakum canal zone of Turkmenistan, Arys-Turkestan and Kyzylkum massifs of Kazakhstan and others.

Big water-management works are conducted on increase of irrigated massifs water supply and irrigation network reconstruction, as well as saline lands reclamation on base of drainage and land leaching. Of total area, provided with drainage systems (2.8 mln ha), about 400 th ha were drained by vertical drainage, where more than 3.5 th of high capacity wells are operated.

Vertical drainage is spread much in USA, India, Pakistan, Mexico, Arabian and other countries. In these countries total area of vertical drainage development exceeds 10 mln ha and just in India more 12 mln of pumping wells is used.

However, vertical drainage is applied abroad, mainly, as technical tool for water obtaining for irrigation, there is no experience of direct application of vertical drainage in order to desalinize irrigated lands. Such use of drainage requires another approach to design, construction and, mainly, perfection of systems exploitation regime.

In conditions of arid regions secondary lands salinization brings big damage to agriculture. Scientific researches determined, that secondary salinization is closely connected with groundwater table rise, proceeding under lands development and irrigation of large regions, where soils are initially saline in process of quaternary deposits formation because of insufficient natural drainability or area, where outflow is not available.

In these conditions the main method of soils salinity control is intensification of area drainability by means of artificial drainage construction and conduction of leaching and irrigation leaching regime on its background.

Last 20-30 years, during introduction of vertical drainage scientific-research institutes and design organizations perfected methods of calculation of well and system parameters, construction of pumping wells and their filters, systems operation regime and other issues. Simultaneously wide researches of meliorative effectiveness of vertical drainage wells were organized in different natural-economic conditions by means of observations of soil water-salt regimes formation, water-salt balances of areas, aeration zone soils, groundwater and top fine-grained deposit.

Generalization of experimental-production researches is given below on revelation of effectiveness of water-salt regimes and meliorative-ecological processes regulation on background of drainage, irrigation and leaching. In this case - on background of vertical drainage.

2.2.1. Hydrogeological-soil-meliorative conditions of experimental-production plots

2.2.1.1. Climatic conditions of vertical drainage pilot plots

Geography of extension of field researches on revelation of meliorative effectiveness of vertical drainage wells scopes almost all large geomorphological-hydrogeological-soil-meliorative conditions of the Aral Sea basin, including areas from semi-arid to insufficiently humid. Appropriately, according to climatic conditions considered area belongs to semi-desert and desert zone.

Precipitation here varies within 97-124 mm per year in Fergana valley, up to 350-383 mm per year in Chu valley of Kyrgyzstan. In winter-spring period maximum rainfalls are noted, in summer and autumn in the most part of area they are almost absent at all.

Sum of effective temperatures fluctuates from 3 600 ^{0}C in Chu valley of Kyrgyzstan to 5500-6000 ^{0}C in Vakhsh valley of Tadjikistan.

In Fergana valley, Hungry steppe and South Kazakhstan it is 4000-4800 ^{0}C.

Relative air humidity over zones significantly differs and is within 44-75 %.

In the conditions of area with insufficient irrigation under high air dryness and strong winds in summer period, which cause high evaporation of water from soil surface, evaporation reaches 1100-1700 mm per year in Fergana valley and Hungry steppe and 2075 mm in Bukhara oblast that by 4-17 times exceeds total rainfalls.

Moisturing coefficient (relation between total precipitation and total evaporation) in the Aral Sea basin is 0.06-0.33, that characterizes this area as arid and very dry.

Climatic characteristics of represented pilot experimental-production plots are shown in Appendix 2.2.

2.2.1.2. Geomorphological-hydrogeological conditions

Geomorphological peculiarities of area define degree of relief partition, its gradients, lithological structure of active water exchange thickness and, as a result of this, conditions of ground water formation, degree of their natural drainability, salinity and chemical structure.

Geomorphological-hydrogeological characteristics of vertical drainage objects are represented in Appendix 2.3.

In conditions of Chu valley of Kyrgyzstan geomorphology is represented by low gradient proluvial plain, which is broken by broad gullies, which continue river plains of pre-mountain zone, and gradients of this place are 0.004-0.04. According to hydrogeological conditions ground water is placed not deeply - from 0 to 5 m. Groundwater salinity varies within 3-5 g/l, and artesian ground water ($\Delta h = +1$ m) 0.5 - 1.0 g/l.

In Fergana valley the following geomorphological regions may be distinguished:

a) peripheral parts of removal cones, composed of clay and loam sediments with inter-layers of sandy loam and sands;

b) sinks between cones;

c) alluvial valley of SyrDarya river.

Here gradients are within 0.0015 to 0.04 and relief – slightly corrugated, sloping or hilly plain.

Lithology is represented by two- and multi-layer rocks with top fine-grained deposits thickness from 6 to 18 m in West Fergana and from 20 to 50 m in Kuva rayon. Groundwater salinity fluctuates within wide range from 3-5 to 10 g/l; artesian groundwater usually exceeds groundwater table (Δh = +0.5-1.0 m) and has low salinity from 0.5 to 1.0 g/l, seldom 2.0 g/l.

Hungry steppe area concerning geomorphology is represented: in Southern part by pre-mountain zones of Turkestan ridge, ancient sub-aerial deltas of removal cones of rivers and streams, lake-proluvial plain of massif central part and in north-eastern and north-western parts - by alluvial deposits of SyrDarya river modern valley. Gradients here fluctuate within 0.0001 to 0.006.

Hungry steppe area is distinguished by big thickness of top fine-grained deposits – from 15 to 40 m, in north-east and north-west parts, beneath which is inter-laying thickness of sandy-gravel deposits. In SyrDarya river flooded plain. Top fine-grained deposits thickness changes within 3-10 m. Fine-grained deposits consist of two- and multi-layer rocks, represented by loam and clay soils with inter-layers of sand, sandy-loam and clay. South and south-west parts of Hungry steppe are mainly represented by one-layer deposits which thickness reaches 150-400 m.

Groundwater table on certain massifs before development were deep - from 10 to 15 m and deeper; in process of irrigation development groundwater table started to rise and on undrained lands were on the depth only 0.5-1.5 m from land surface. Groundwater salinity fluctuates within 1.5-3.0 g/l in dependence of soil salinity of top fine-grained deposits.

Kyzylkum massif of vertical drainage development, which is placed in the beginning of SyrDarya river lower reaches, is represented by flat alluvial plain with gradients of 0.0002-0.0005. Lithology is characterized by two-layer thickness of quartenary age with top fine-grained deposits thickness from 0.1 to 11 m, consisting of sand, sandy loam and loam soils, beneath which inter-laying aquifer is composed of fine-grained and small-grained sands. Groundwater table before development was deep (> 10 m) and along with irrigation development and, especially, under rice crop, started to rise. In present conditions groundwater table changes within 1.5-3.0 m from land surface. Groundwater salinity is not high - from 1.2 to 3.8 g/l.

In AmuDarya river basin experimental-production plot of vertical drainage is placed in Vakhsh valley. Concerning geomorphology it represents the third alluvial terrace of Vakhsh river. Relief is kind of bowl with gradients from 0.0017 to 0.01. Lithology is represented by two-layer complex with fine-grained thickness 6-7 m, underlain by gravel-pebbles deposits. Prevailing initial groundwater table was 0.5-3.0 m. Groundwater salinity in south-west part is very high - up to 50 g/l and near canals - 3-5 g/l. Salinity of artesian (Δh=+0.2-0.6 m), ground (and pumped) water is - 8-10 g/l.

Vertical drainage objects in AmuDarya river middle reaches - Bukhara oblast are placed on the second and third alluvial terraces of Zarafshan river; relief - plain with gradients of 0.0005-0.0006.

Lithology is represented by two-layer rocks, fine-grained thickness 4-15 m consists of high-permeable soils - K_f=0.5-4.0 m/day.

Groundwater table is 2-3 m, in fine-grained deposits they have salinity 2-5, 5-10, seldom 20-40 g/l. Groundwater in pebbles has low salinity 0.8-2.0 g/l and in sands - saline (9-15 g/l and more).

Therefore, geomorphological, hydrogeological, lithological conditions of areas considered were favorable for vertical drainage application.

2.2.1.3. Soil-meliorative characteristics

Soil-meliorative conditions of vertical drainage objects in SyrDarya river upper reaches - Chu valley of Kyrgyzstan are characterized by meadow and gray-meadow soils. On salinity degree soils vary from slightly to strongly saline in complex with spots of salts; salinity type is sulfate-sodium-calcium. Sometimes sodium tracks are met. Salinity is mainly superficial, with content of easily-soluble salt 0.5-1.5 %. Soil volumetric weight fluctuates within 1.2-1.58 g/cu cm (appendix 2.4).

In Fergana valley top fine-grained deposit consist of loam - light, middle and heavy, filled with sand and sandy loam inter-layers. Soils have good water-physical properties: water availability coefficient changes within 0.11-0.19. Volumetric weight is within 1.4-1.56 g/cu cm, specific weight 2.60-2.72 g/cu cm. Salt availability coefficient is 0.72-1.12.

Easily-soluble salts in soils mainly prevail in aeration zone, that is usually typical feature of zones with artesian groundwater. Dry residue fluctuates from 0.3-0.5 to 1.5-2.0 %, chlorine-ion - from 0.01 to 0.05 %. Soil salinity type is sulfate and sulfate-chloride.

Concerning desalinization complexity of top fine-grained soil pilot plots area belongs to simple category.

In conditions of Syr Darya river middle reaches - Hungry steppe soils are represented by sandy loam, light, middle and heavy loam. Field researches of salt stock distribution within 20-30 meters soil thickness determined that in natural conditions in irrigated zones depending on their geomorphological-hydrogeological peculiarities several types of salt profiles are formed:

1. Non-saline from land surface to all zone of quaternary deposits. It is typical for well drained areas (upper part of removal cone, pre-mountain, upper terrace of rivers, etc.);
2. Non-saline in upper soil horizons up to depth of 1-1.5 m (salts) with increase of salt content downward profile. Such salt profile is formed on plain slightly drained areas under deep saline groundwater table.
3. Strongly saline from land surface onto depth up to 3-4 m with sharp lowering of easily soluble salt content downward this layer. It is formed in rayons, where area is slightly drained under relatively shallow groundwater table (3-3.5 m) with their artesian water recharge (500-1000 m^3/ha per year);
4. Regularly medium- and strongly saline in upper 30 m thickness of quaternary deposits. It is formed in zones of groundwater seepage and rayons without outflow, represented by low permeable small-grained deposits with shallow ground water-table (3-3.5 m);
5. Strongly saline in upper horizons (up to 1.5-2 m) with higher content of salt stocks in lower layers. It is characteristic for drained plain areas under shallow ground water-table (2-3 m) with heavy soils downward the profile;
6. Slightly and in some places strongly saline in upper horizons of the profile (0.5-1.0 m) with sudden reduction of salt stock in lower horizons. It is formed in conditions of weak ground water outflow with shallow ground water-table under absence of ground water inflow;
7. Alternation of strongly and medium saline salt profiles with non-saline and slightly saline. Such type of salt profiles is formed in slightly drained rayons, represented by flaky deposits (majority of stocks corresponds to soils with heavy soil structure and the least stocks with light one).

On the base of field researches of salt stock distribution, qualitative and quantitative analysis of natural conditions within plain part of Hungry steppe 10 regions are distinguished (5 in zone of proluvial-alluvial deposits and 5 in zone of alluvial-proluvial deposits), which differ from each other with salt profiles for 20-30 m thickness and salt structure.

The first region with area 58200 ha, is placed within the second terrace of SyrDarya river, represented by light and middle loam with thickness of 10-15 m. Rayon is represented by 6 types of salt profile. Soil profile salinity is from slightly to medium, and lower - salt content on all depths of small-grained deposit is negligible.

Total salt stocks are not large and they are only 890 t/ha for 20 m thickness, of them chlorine - 45, sulfate - 408 t/ha. Salinity type is chloride-sulfate to sulfate.

Groundwater has low salinity from 1.2 to 5 g/l. Under development of irrigation and drainage significant growth of drainage outflow salinity is absent.

The second region with area of 74800 ha is represented by the I type of salt profile and takes in the south watershed part of Djizak removal cone, in the west merges with pre-Kyzylkum plain, and the north and the north-east periphery represents proluvial-alluvial plain of Sanzar and Zaaminsu rivers.

Soils consist of sandy loam or light loam with thickness of 2-3 m. Before irrigation groundwater table was on the depth of 10-20 m and did not participate in soil formation (zone of deep submergence). Soils on all depth are slightly saline. Top 1-2 m (sometimes 4-5 m) thickness is desalinized up to 0.1-0.2 %, deeper salt content reaches up to 0.5-0.7 %. Salinity type is sulfate, sometimes - chloride-sulfate.

Groundwater salinity, on depth of 10-20 m from 6-8 g/l (chloride-sulfate) to 14.7 g/l closer to Arnasay sink (sulfate-chloride type). Under irrigation development unfavorable salt regime is observed locally and special complicated measures and drainage are not required.

The third region with an area of 160800 ha is represented by 4 types of salt profile, scopes broad watershed part of the third terrace of SyrDarya river is represented by two- and multi-layer deposits with thickness 10-30 m. Basic salt mass is distributed up to depth 12-14 m more or less regularly and fluctuates from 0.5-0.6 % to 0.8-1.0 % on dry residue. According to depth their content sharply lowers. Total salt stocks in 20 m thickness are 1436-1498 t/ha on dry residue, 80-102 t/ha on chlorine-ion and 700-780 t/ha on sulfate. Salinity type is chloride-sulfate, sometimes - sulfate.

Groundwater salinity in elevated parts of relief is 2.5-7.0 g/l, in sinks 9.5-14 g/l. Under irrigation development in soil salt regime formation and drainage outflow salinity salt stocks participate within 20-30 m thickness.

The forth region with an area of 34400 ha is represented by 3 types of salt profile, being placed within Shuruzyak sink, consists of two-layer deposits from surface up to 20-30 m: by top small-grained deposits (K_f=0.07-0.1 m/day), underlain by sandy-gravel-pebble thickness.

Shallow water salinity is 4-8 g/l on irrigated and 20-40 g/l on non-irrigated lands; groundwater salinity is 1.3-1.9 g/l. Salt stocks in top 5 m layer are 700-750 t/ha (55 %), while all over the thickness only 1300 t/ha is found. Salinity type is chloride-sulfate, in sinking parts of relief sulfate-chloride. During irrigation in formation of water-salt regime and drainage outflow top fine-grained deposit salt stocks participate.

The fifth region with area of 55280 ha is represented by narrow stripe along South-Golodnostepsky Canal within Zaamin removal cone. Concerning lithology it consists of proluvial-alluvial deposits with light and middle loam with thickness from 10-25 m to 45 m.

Characteristic peculiarity of massif salinity is availability of salt maximum on depth of 4-5 m in aeration zone with dry residue 1.5-2.0 % and on chlorine-ion 0.06-0.12 %. Downward profile is slightly desalinized up to 0.2-0.3 %, that is explained by rising groundwater flow washing out effect. Salinity type is sulfate, to the north changes to chloride-sulfate. Salt stocks in top 0-5 m layer is 1025 t/ha and in all thickness of 0-20 m is 1820 t/ha,

i. e. large stocks correspond to upper horizons.

Groundwater salinity is within 5-15 g/l. During irrigation development in soils water-salt regime and drainage outflow formation all thickness of quaternary deposits participates.

The sixth region with area of 31000 ha is placed in transition zone from ephemeric steppes to Kyzylkum sandy desert. It consists of sandy loam with thickness of 3-15 m, downward by inter-laying of loam, sand and clay. It is represented by 6 types of salt profile. Salt maximum corresponds to zone of capillary fringe of groundwater on depth from 0.5-1.0 to 4-5 m, where sum of salts changes from 0.8-1.2 to 2.5 % on dry residue, 0.05-0.12 % on chlorine and 0.6-1.4 % on sulfate.

Total salt stocks in 20 m thickness are 1755 t/ha, of them in top layer (to 5 m) 816 t/ha is located. Salinity type is sulfate in upper and chloride-sulfate in lower horizons.

Groundwater salinity is within 5-30 g/l. Salinity type is chloride-sulfate.

The seventh region with area of 135800 ha, which is represented by 2 types of salt profile, occupies broad central part of Hungry steppe, adjacent to central Golodnaya-Steppe-Collector, and consists of proluvial-alluvial deposits (with inter-layers of loam). Top 0.8-2 m soil layer is desalinized to 0.15-0.3 % on dry residue, the deeper salinity sharply increases and in all 20 m thickness is 0.8-1.8 %. Salinity type of top desalinized layer is sulfate, lower – chloride-sulfate.

Groundwater salinity is high – within 18-36 g/l and more, type is chloride-sulfate and under irrigation creates unfavorable meliorative regime of soils.

The eighth region with area of 24320 ha, consisted of 4 types of salt profile, occupies peripheral part of sink between Djizak and Zaamin removal cones. Soil strong salinity over all 20 m thickness is observed. Value of dry residue 2-3 %, chlorine 0.2-0.8 %. With depth salt content reduced and is on dry residue 1.5-1.8 % and on chlorine 0.2-0.4 %. Total salt stocks over all thickness (0-20 m) are 3705 t/ha. Groundwater salinity is from 10-20 to 50 g/l, salinity type is from sulfate-chloride in the south to chloride-sulfate in the north and under irrigation very unfavorable meliorative regime is formed.

The ninth region with area of 88.2 ha with salt profile of 4 types is placed within Djetysay-Sardoba and Kara-Karay depression. It is represented by proluvial-alluvial deposits. Soils are salts. Salinity is very high: on dry residue 2-4 %, chlorine – 0.4-0.6 %, sulfate – 0.8-1.0 %.

Easily-soluble salt stocks reach 4800 t/ha in the central and south-east part and in the north-west direction reduce to 2300-2500 t/ha. Salinity type is chloride-sulfate. Here in formation of water-salt regime and drainage outflow all mass of salt participates, which is contained in top fine-grained deposits.

The tenth region with area of 55080 ha, represented by 2 types of salt profile is placed within SyrDarya river flooded plain and consists from surface of top fine-grained deposits with thickness from 1 to 4-5 m, composed of heterogeneous soils. Salinity type is from chloride-sulfate to sulfate. Value of dry residue is 0.8-1.7 %. In top 2 m layer up to 63.8 % (307 t/ha) is contained, in lower horizons - 30-35 %. During irrigation in water-salt regime and drainage outflow salinity whole mass of salt participates from top fine-grained deposits. However, solution of the problem of meliorative processes management is relatively easy.

In Arys-Turkestan massif of Chymkent oblast top fine-grained deposits soils on complexity of desalinization belong to simple category. Top fine-grained deposits, comprised sandy loam-loam deposits, has high conductivity and K_f is 0.2-0.8 m/day. Soils are mostly non-saline or slightly saline. Easily-soluble salt on dry residue has value 0.2-0.3 %, seldom 0.5 %. Salinity type is mainly chloride-sulfate and sulfate.

In AmuDarya river basin – Vakhsh valley on area on experimental-production plot soils are represented by irrigation gray soils and their meadow sub-types. Before development 72 % of area was occupied by salts. According to complexity of desalinization they belong to complex category – volumetric weight increases downward up to 1.28-1.72, and specific weight – up to 2.48-2.81 g/cu cm, i. e. structure becomes heavier. Soils on 40 % of area are gypsum-bearing. Easily-soluble salts content on dry residue reaches 3.5 % and on chlorine-ion - 1.0 %. Salinity type is chloride-sulfate and sulfate-chloride.

Area of experimental-production plot of vertical drainage system in Bukhara oblast (AmuDarya river middle reaches) is represented by top fine-grained deposits, composed by flaky soils, light and middle loam and sandy loam. According to complexity of desalinization they belong to comparatively simple category - top fine-grained deposits thickness is 8-15 m and K_f=0.5-1.0 m/day; water availability value M=0.1-0.12 is high and salt availability coefficient L=0.75-1.5.

Soils salinization is superficial: easily soluble salts are placed in active zone of 0.5-1.0 m. Salinity type is sulfate, sulfate-chloride. Value of dry residue is 1.2-2.2 %, chlorine-ion 0.1-0.12 %.

Given data show that soil-meliorative conditions of vertical drainage system objects significantly differ on soil desalinization complexity of top fine-grained deposits. All categories have place - from simple to complex and very complex.

2.2.2. Irrigation-economic characteristics of experimental-production plots

Characteristics of irrigation network and existing collector-drainage system on all pilot plots and large systems are shown in appendix 3.2.

These tables show that areas of researches significantly differ from each other: concerning experimental-production researches areas changed within 12-157 th ha and under regional researches of vertical drainage system effectiveness they changed within 660-937.0 th ha.

Irrigation network within considered objects is mainly fulfilled in earthen channel. Specific length of canals and on-farm irrigation network is within 16-30 m/ha. The higher efficiency correspond to on-farm ditches - within 0.75-0.98 and system efficiency is 0.6-0.75.

Collector-drainage network, represented by open and close horizontal drainage, on experimental-production plot had specific length 8-10 (Hungry steppe and Kyzylkum objects of vertical drainage system and Chu valley objects) to 25-45 m/ha (objects of vertical drainage system in Fergana and Vakhsh valleys). Drain depth is within 1.5-3.0 m, collectors to 4.0 m. drains spacing is within 200-600 m.

In the majority of experimental-production plot horizontal drainage modulus fluctuated within 0.012-0.05 l/s/ha and drainage outflow 390-1500 cu. m/ha per year, which did not provide necessary rate of groundwater table regulation and salt removal from area. Water-salt balances on these experimental-production plots before vertical drainage system construction, as usual, were composed on salt accumulation type.

On certain experimental-production plots as, for example, plot in Besharyk rayon of Fergana valley of Uzbekistan (02.24 Uz), in Vakhsh valley of Tadjikistan (02.1 Tad) specific length of horizontal collector-drainage system was extended to 40-45 m/ha. But in connection with high groundwater inflow available from outside (3-12 th cu. m/ha) it did not provide timely their depletion and, appropriately, groundwater table regulation and water-aerial, water recharge regime of aeration zone. And though on some of these plots negative water-salt balance was provided, salt removal rate was very low - 3-4 t/ha per year, that did not meet requirement of meliorative well-being of lands as well.

2.2.3. Design parameters and technical charcteristics of vertical drainage wells operated in pilot plots

Every vertical drainage well needs to be considered as central element of hydro-meliorative system, representing complex hydrostructure. It consists of submerged part of intake and surface structure, providing system normal operation and water diversion on purpose. Underground diversion structure has the following constructive elements:

- inlet; usually gravel-sandy envelop is used, which operates in contact with aquifer;
- casing tube with screen, through which water is transported;
- pumping-power equipment;
- water level sensor.

Screen and its selection is a very important element of well design.. Filter design choice depends on lithology (fractional composition and aquifer thickness), economic significance of wells, abstraction volume, etc.

In coarse disintegrated rock formations as well as in sandy-gravel the most simple screen is used, i.e. perforated tube with slots or round orifices. Under these conditions in the process of construction a natural gravel filter is formed around the well. Therefore, for head losses reduction is necessary to found an openness, sizes and form of filter frame orifices depending on the fractional composition of aquifer.

To prevent small particles removal from fine-grained aquifer more complex screen design is used beside perforated tube - gravel envelop, porous block filters, etc. More fine-grained fractions within an aquifer more complex is well design. In all pilot plots the wells were constructed with sandy -gravel filters around metallic tubes 326 -429 mm in diameter.

Vertical drainage is widely used in zones of intensive inflow or ground water seepage, where horizontal drainage had not provided previously ground water drawdown.

Design parameters and technical characteristics of vertical drainage wells, constructed and operated in different zones of the Central Asia, are given in Appendix 3.3.

Data of Appendix 3.3 show that in SyrDarya river upstream vertical drainage systems (VDS) are operated in Chu valley of Kyrgyzstan (index PP 02.1 Kyrg.), and on territory of Uzbekistan - within Fergana valley. In these districts VDS were built in zones of intensive ground inflow with shallow saline ground water. Piezometric levels, as a rule, are higher than ground water level, sometimes higher than the land surface (for example, pilot plots in the Panfilov district of the Chu province of the Kyrgyzstan and pilot plots in the Kuva district of the Fergana province of the Uzbekistan). But in Besharyk district of Fergana province (pilot plots 02.24 Uz. and 02.33. Uz.)VDS was constructed in the zone of intensive seepage of ground water with high underground inflow.Depth of wells varies from 20 to 70 m in the Fergana valley up to 100 -110m in the Chu province (App. 3.3).

Captured aquifer thickness is 15 -40 m and more, and the aquifer of this zone is presented, as a rule, by gravel-pebble. They have high conductivity > 500 m^2/day and permeability coefficient

K_f =25 - 40 m/day.

One well command area in this zone varies from 30 to 115 ha, and the number of wells on these pilot plots (PP) is from 2 to 7 and in large systems as Kuva district of Fergana province -230. Well discharge is from 10 to 70 l/s under workability coefficient (WC) from 0.5 to 0.7. Volume of ground water abstraction on these PP is from 210 -420 m^3/ha in Chu valley to 4100 -7880 m^3/ha in Kuva and Besharyk districts of the Uzbekistan (02.17 and 02.24 UZ.).

Pumped water salinity in the upper reaches of SyrDarya river, as a rule, does not exceed 0.3 - 1.6 g/l and rarely reaches 2.5 g/l(App. 3.3).

In SyrDarya river midstream VDS are presented on an example of PP constructed within the Hungry Steppe - SyrDarya province of the Uzbekistan, in Kirov, Djetyusay, Pakhtaaral as well as Arys-Turkestan and Bugun districts of Chimkent province of the Kazakhstan(App. 33). Areas of VDS efficiency study are from 8 to 13000 ha and well number varies from 5 to 1794. Well depth is from 25 to 100 m, well screen length is from 10 to 40 m. Screens are perforated or slotted tubes with gravel or sandy-gravel envelop.

Distinguishing feature of VDS constructed in the Hungry Steppe is great thickness of fine-grained deposits (15 -40 m), which have low water permeability (K_f = 0.03 -0.05 m/day), because of it the hydraulic relation between captured aquifer and top fine-grained deposit is slowed down: W = 0.002 -0.0625 m/day. Aquifer is presented by two- and multi-layer deposits, thickness of which reaches15-100m and which are made of sand and gravel.

Depending on aquifer lithology, its conductivity and screen design the various well discharges are obtained. The highest discharge (150 -200 l/day and more) was reached on PP «50 years of the Uzbekistan» state farm (02.19 Uz.) of SyrDarya province, where aquifer conductivity exceeds 1500 -2000 m^2/day, well diameter is from 700 to 900 mm, and screen length is 25 -40 m.

Drainage modules of VDS vary within 0.04 -0.28 l/day/ha. Pumped water salinity changes from 0.3 to 18 g/l and, in overwhelming majority of cases, from 1.0 to 6.0 g/l.

In Arys-Turkestan massif of Chimkent province (Arys, Bugun and Turkestan districts) of the South Kazakhstan the common number of wells is 504, and in this massif the number of wells is from 5 to 60. Area commanded by one well varies from 100 to 200 ha. Well depth here is 25 -45 m, and screen length is 15 -18 m with sandy-gravel envelop.

Thickness of fine-grained deposit is 10 -30 m, of aquifer - 10 -50 m, which is made of gravel-pebbles deposits with permeability 20 -400 m/day.`

Well discharge on the Arys -Turkestan massif changes from 20 to 59 l/day, and specific discharges are from 2 to 4 l/day/m. Volumes of ground water abstraction vary within 1300 - 4000 m^3/ha per year, and average annual drainage modules are 0.04 -0.13 l/day/ha. Salinity of captured ground water changes from 0.5 -1.5 and rarely up to 2.0 g/l. VDS help to solve water availability problem of the territory at expense of pumped water.

<u>In the low reaches of SyrDarya</u> - in Kzylkum massif - quaternary deposits are presented by low thickness top deposits with K_f =0.3 - 0.4 m/day.

Aquifers are presented by small-grained to medium-grained sand. Thickness of water bearing formation from 21 -36 m near river to 117 -176 m towards the western part of massif.

Totally in Kzylkum massif 275 vertical drainage wells were built with depth of 37 -59 m with gravel-sandy filters. Drilling diameter is 1016 mm, filter length is 10 -27 m. Well discharge is 35 -60 l/sec and specific discharges are 1.8 -5.6 l/sec/m. In PP considered the number of wells varies from 6 to 8, and on massif as a whole 208; command area for one well is 80 -370 ha.

Drainage modules of VDS changed within 0.06 -0.20 in cotton growing state farm and 0.24 - 0.29 l/s/ha depending on crop cultivated, and system workability 0.19 -0.48 (average annual) under maximum of 0.52 - 0.9 in June -August. Such regime was accepted by farms using pumped water for irrigation. Pumped ground water salinity in massif is low and varies from 0.8 to 1.5 g/l, seldom up to 3 g/l. Work regime peculiarity under conditions of two-layer low thickness top fine -grained deposits is necessity to support ground water level on depth, which excludes desiccation of soil upper layer.

VDS in the AmuDarya river basin

Study results was presented by three PP of VDS. One from them in upper reaches of AmuDarya - Vakhsh valley and 2 - in midstream - Bukhara province of Uzbekistan. In valley of Vakhsh river the territory of VDS is presented by two -layer complex: top fine-grained deposits with thickness of 6 -7 m and K_f = 0.025 -1.0 m./day, underlain by pebbles with thickness of 100 m with sandy filling and K_f = 10 -20 m/day. Ground water head is 0.2 -0.6 m. Well number in Tadjikistan PP is 3, depth-up to 51 m. Command area of one well is 130 ha. Well discharge is 36 -68 l/s. Drainage modules of VDS vary from 0.28 to 0.52 l/s/ha and average annual volume of abstracted ground water is 8890 -16400 m^3/ha under well work duration from 68 to 205 days. Artesian inflow from pebbles horizon is from 8460 to 12 560 m^3/ha. Pumped water salinity is from 4 to 10.4 g/l.

In middle stream of Bukhara province the area of VDS introduction in Zeravshan delta is 52 th. ha and number of wells is 232, from them in Kagan district 127 wells were built on area of 21500 ha. Given zone of VDS introduction is presented by two-layer thickness: from the top by low fine-grained deposits from 4 to 15 m, underlain by gravel-pebbles with K_f = 40-45 m/day. Aquifers are artesian or non-artesian. Depth of well is from 20 to 45 m; thickness of captured layer strongly varies from 1.8 to 45 m. Length of perforated and slotted filters is 8 - 10 m, with gravel filling. Well discharge changes within 5 -120 l/s, and specific values are 3.0 -13 l/s/m.

Total volumes of ground water pumped within annual cycle vary from 2000 to 4800 m^3/ha. In last years the volume of pumping reduced down to 1000 -1200 m^3/ha.

Generalized technical characteristics of VDS in typical PP over different waterrelated zones of SyrDarya and Amudarya rivers basins are given in table 2.5.

Table 2.5

Technical parameters of vertical drainage systems in different water-related districts of Syrdarya and Amudarya basin

Indicators	Experimental plots and farms							
	Chaldovar Chu valley, Kyrgyzstan	Besharyk Fergana province, Uzbekistan	Pakhtaaral Golodnaya steppe	50 years of Uzbekistan, Syrdarya province	Arys-Turkestan massif, Chymkent province Kazakhstan	Dostyk Kyzylkum massif Kazakhstan	Safarov Vakhsh valley, Tadjikistan	Bukhara Uzbekistan
Area, ha	60	1243	11500	3000	52400	1724	400	2700
Top soil thickness, m	14-16	8-16	15-28	18-25	0.2-20	0.2-6.0	6-7	3-11
Aquifer thickness, m	16-55	13-33	15-50	50-100	54	29-72	> 100	6-25
Permeability, m^2/day, top soil aquifer	-	4.3-5.0 200-550	3-3.8 äî 1500	1.5-1.8 2000	-	3-4 äî 1000	-	5-5.5 240-1080
Number of wells	2	12	74	28	504	8	3	27
Depth, m	105	28-50	60-75	67	30-45	40-59	-	18-45
Diameter, mm	500	500-1000	1000	äî 1000	-	1016	400	500
Screen lenght, m	-	15-25	17-35	20-35	-	15-20	-	7-13.5
Screen diameter, mm	-	429	429	429	-	426	-	429

Indicators	Experimental plots and farms							
	Chaldovar Chu valley, Kyrgyzstan	Besharyk Fergana province, Uzbekistan	Pakhtaaral Golodnaya steppe	50 years of Uzbekistan, Syrdarya province	Arys-Turkestan massif, Chymkent province Kazakhstan	Dostyk Kyzylkum massif Kazakhstan	Safarov Vakhsh valley, Tadjikistan	Bukhara Uzbekistan
Well discharge, l/sec	30	25-45	55-80	100-150	35-40	25-60	36-68	25-45
Specific yield, l/sec/m	-	3-5	4-8	8-15	-	1.8-5.6	-	3-8
Well workability coefficient	-	0.3-0.64	0.45-0.67	0.65-0.7	0.6-0.72	0.19-0.48	-	0.28-0.75
Drainage modulus, l/sec/ha	0.007-0.013	0.09-0.16	0.19-0.36	0.20-0.3	0.04-0.13	0.04-0.21	0.28-0.52	0.13-0.28
Diapason of groundwater table regulation, m	2-3	1.8-3.5	1.5-2.5	1.5-3.9	2-3	2-3	2.5-4.0	1.6-3.5

2.2.4. Formation of common and partial water -salt balances of irrigated lands on the background of vertical drainage on pilot plots and large irrigated massifs.

Analysis of water-salt balances allows to show the direction of reclamation processes (desalinization and salinization), to define common quantitative changes of indicators for certain periods as well as main factors impacting them.
Main equations of common and partial water -salt balances are well -known from literature sources (S. Averyianov et al). Generally for irrigated zones equipped by horizontal and vertical drainage these equations are as follow:

a) <u>general water -salt balance:</u>

$$\Delta W = W_k - W_n = O_c + B + F_{mc} + B_{cdf} + B_{vd} + \underline{P} - \underline{O} - Et_v - C_p - C_e - D_g - D_v \pm R,\ m^3/ha$$

$$\Delta C = C_v + C_{f.mk} + C_{v\ cdf} + C_{\underline{p}} - C_{\underline{o}} - C_{sp} - C_{ea} - C_{Dg} - C_{Dv} - C_r,\ t/ha$$

b) <u>water -salt balance of aeration zone</u>

$$\Delta W_a = W^a{}_k - W^a{}_n = O_c + O_r + B_{cdf} + B_{vd} + (1 - L)F_{vh} - C_p - E_{tp} \pm D,\ m^3/ha$$

$$\Delta C_a = C^a{}_k - C^a{}_n = C_{or} + C_{v\ cdf} + B_{vd} + C\ (1 - L)\ F_{vx} - C_{sp} \pm C_D,\ t/ha$$

c) <u>ground water balance</u>

$$\Delta W^r = \Delta h.\ M = L_1 + F_k + D - \underline{P} - \underline{O} - D_g - D_v \pm P,\ m^3/ha$$

$$\Delta C_r = C_1F_k + C_{d1} - C_{\underline{p}} - C_{\underline{o}} - C_{dg} - C_{Dv} \pm C_r,\ t/ha$$

where, **Δ W, Δ C -** general change of moisture and salt supply within balance contour; $\mathbf{W_n}$ and $\mathbf{W_k}$ - initial and final moisture supply; **B** - water diversion; $\mathbf{F_{mc}}$ **-** filtration losses from magistral canal; $\mathbf{B_{vd}}$ - pumped water volume from VDS used for irrigation (if it takes place); $\mathbf{B_{cdf}}$ - collector-drainage water volume used for irrigation (if it takes place); **<u>P</u>**, **<u>O</u>** - inflow and outflow of ground water to balance territory from outside; $\mathbf{E_{tv}}$, $\mathbf{E_{Tp}}$ **-** evapotranspiration from territory (gross or irrigated); $\mathbf{C_p}$ - unproductive releases from the field surface; $\mathbf{C_e}$ - organizational losses; $\mathbf{D_g}$ - water diversion by horizontal drainage; $\mathbf{D_{vd}}$ - ground water pumped by vertical drainage; **± P** - vertical water exchange between balance layer and underlaying one; $\mathbf{C_v}$, $\mathbf{C_{f\ mc}}$, $\mathbf{C_{v\ cdf}}$, $\mathbf{C_p}$, $\mathbf{C_o}$, $\mathbf{C_{sp}}$, $\mathbf{C_{se}}$, $\mathbf{C_{dg}}$, $\mathbf{C_{dv}}$ **-** salt content in corresponding water balance elements; **L** - filtration from canals share overflowing to ground water; **± d** , $\mathbf{C_d}$ - water -salt exchange between aeration zone and ground water; $\mathbf{W^a{}_k}$, $\mathbf{W^a{}_n}$, $\mathbf{C^a{}_k}$, $\mathbf{C^a{}_k}$, $\mathbf{W^r}$, $\mathbf{C_r}$ - initial and final moisture and salt supplies in the aeration zone and ground water, correspondingly.

Methods of water -salt balance calculation are well -known.
Before consideration of actual water -salt balance results for different pilot plots it is necessary to
analyze conditions of tests implementation in the vertical drainage plots as far as initial hydrogeological-soil-reclamation conditions of objects and cropping patterns differ greately.

Conditions of test implementation on the vertical drainage plots and large systems are given in App. 4.2.

Table shows that areas of PP, where vertical drainage is used, are from 60 ha (Kyrgyzstan) to 450.0 th. ha (whole territory of Hungry Steppe (Uzbekistan). Well number in these plots and large systems varies from 2 to 1800.

Main agricultural crop cultivated in these plots is cotton (up to 60 -80 %), in PP of Chu valley - lucerne and maize; in Kzylkum massif, beside cotton, it is rice.

Actual irrigation regime study on plots with VDS shows the following:

On cotton fields of the upper reaches of SyrDarya river (mainly Fergana valley) during vegetation period from 4 to 7 irrigations with duty of 700 -2500 m^3/ha are conducted; irrigation norms for vegetation period vary from 6500 to 9600 m^3/ha. On saline lands, as a rule, annual autumn-winter leaching is used or spring recharge irrigations with duty of 900 - 3000 m^3/ha. Annual norms of water supply to irrigated field are 7800 -11100 m^3/ha.

In PP of Kyrgyzstan (Chu valley), where lucerne and maize are grown, irrigations number is 4 -13, and irrigation duties vary in wide diapason from 130 to 2320 m^3/ha. During season here 4900 -7600 m^3/ha of water are supplied. Average annual water supply (taking into account recharge irrigations) is 6300 -9200 m^3/ha.

Limits of soil moistening regulation vary usually from 60 to 90 % from full field water capacity (FFWC).

In middle stream of SyrDarya river (Hungry steppe) the irrigation regime differs by smaller number of irrigations (2 -4) and irrigations duties are 910 -3500 m^3/ha. Norms of autumn-winter leaching irrigations here depending on soils salinization degree change from 1200 to 7800 m^3/ha. Average annual norm of water supply varies within 4400 -13900 m^3/ha.

Rice fields, where water in checks is continuously, irrigation norms are 20.000 -29.000 m^3/ha, (App. 4.2). Similar irrigation regime is used also in pilot plots which are typical for the AmuDarya river basin.

<u>Analysis of actual water-salt balances of PP with vertical drainage</u>

Results of available actual water -salt balances formed in different PP and large systems of VDS shows the following:

Under fixed irrigation regimes, land leaching and water disposal the water -salt balances of PP in most cases have the desalinizing direction (app.7).

In positive part of water -salt balance the water supply for irrigation field plays main role constituting up to 90 % from total inflow. Share of rainfall is no more than 10 -20 %.Typical feature for the upstream of SyrDarya river is that in PP located in Fergana valley (index PP 02.17, 02.24, 02.33 Uz.) the ground inflow of artesian and underground waters occurs in amount from 3.5 to 4.72 th. m^3/ha per year. High inflow of ground water is observed also in PP disposed in Vachsh valley - up to 10.4 th. m^3/ha.

In negative part of balance usually total evapotranspiration share is the biggest, value of which in conditions of arid zone varies depending on ground water depth from 5780 to 9100 m^3/ha for cotton fields and up to 13780 m^3/ha per year for rice systems, disposed at the Kzylkum massif (Kazakhstan, PP - 02.3 Kaz.).Second place in negative part of balance usually belongs to drainage outflow. Value of drainage outflow varies from 1400 to 8470 m^3/ha, and for rice systems up to 11600 m^3/ha. In conditions of Vachsh valley (Tadjikistan - PP 02.1 Tadj.) the drainage outflow reaches 15290 m^3/ha per year as a result of ground water inflow.

The analysis of positive and negative water balance elements ratio throughout all PP shows that in all PP the leaching regime of irrigation is supported. Water supply ratio plus rainfall ($B + O_c$) versus total evapotranspiration (ET) everywhere was more than 1: from 1.1 to 1.35, and for rice systems- 2.65. Drainage outflow to total water supply ratio (D_r/ $B + O_c$) varies usually from 0.18 to 0.56 for cotton fields.

PP of Tadjikistan, where total drainage outflow exceeds the water supply (D_r: Σ B > 1.08), due to expense of great inflow of ground water.

Water balances show, that the vertical drainage on salinizated lands of the region allows to support the irrigation leaching regime in annual cycle and on wet lands to dispose ground water and provide optimal water -salt and nutritious regime. Especially favorable conditions are created within aeration zone of irrigated field. If before VDS introduction in the most of PP because of shallow saline ground water the positive balance is formed with salt influx with ground water, construction and normal maintenance of VDS provides moisture and salt removal from the aeration zone downwards. Volume of descending water runoff from the aeration zone (- D) downwards is from 10 to 1040 (02.02. Kaz.) and from 0 to 5670 -6620 m^3/ha (index 02.04 and 02.37 Uzb.) for cotton fields and for rice systems reaches 13600 m^3/ha for an annual cycle (app. 7). As a result the salt balance of aeration zone almost in all PP is of desalinizing type with a salt removal from 1.5 to 53 t/ha from upper layers.

High effectiveness of VDS in conditions of intensive ground water inflow: ($\underline{P}$ - $\underline{O}$) = 4300 - 4500 m^3/ha, is observed in PP disposed in state farm «Yakkatut» of Besharik district of Fergana province (PP № 02.2 Uzb.). Common and partial water -salt balances of this plot are given on Figure 2.4.

Diagram shows that under VDS operation negative water -salt balance of aeration zone and fine-grained deposits was achieved. Value of desalinizing outflow (-D) in the balance of aeration zone in 1970 -1975 was from 358 to 2959 m^3/ha. Salt removal in 1-m layer is 73.6 t/ha. Aeration zone as well as fine -grained deposits is desalinizated up to depth of 7 -8 m and more, where the salt removal is from 29 to 39.5 t/ha. The outflow through the collector-drainage network (CDN) is from 5.5 to 8.0 th. m^3/ha. Total water supply to total evapotranspiration ratio for these years is 1.04 -1.23.

For conditions of the Hungry Steppe, where geomorphological -lithological conditions are rather heavier, the thickness of the fine-grained deposit is up to 25 m, VDW efficiency can be illustrated as an example (table 2.6). Data show that before VDW construction the existing horizontal drainage with length of 12 -14 m/ha not allowed to provide the project drainability of territory.

Table 2.6

Water-salt balance of top soil loam on pilot plot with vertical drainage in state farm Pakhtaaral

Drainage conditions	Year	Inflow, m^3/ha			Outflow, m^3/ha			Moisture stock change, m^3/ha			Ground water inflow or outflow, m^3/ha	Accumulation (+), or removal (-) of salts, t/ha	
		precipitation	water supply and losses for filtrat.	total	evaporation and transpiration	drainage outflow	total	in ground water	in unsaturated zone	total		dry residue	chlorine
Before vertical drainage system (VDS) putting in operation	1961	2535	5540	8075	8118	137	8991	288	90	378	596	+6.6	1.2
	1962	2481	6568	9049	9920	151	9071	576	-150	426	510	+7.0	1.2
	1963	2595	6986	9681	9578	189	9768	128	180	308	496	+7.0	1.2
	1964	3707	6163	9870	9785	210	9995	-48	60	12	137	+4.10.6	
Under VDS operation	1965	2113	8122	10235	8486	98	8584	-72	-80	-152	-1803	-6.8	-1.3
	1966	2540	7645	10185	7046	124	7170	-256	-210	-466	-3481	-18.7	-3.9
	1969	5652	7253	12905	8394	765	9159	-88	-235	-323	-3423	-20.0	-3.6
	1971	2515	10872	13387	7505	1001	8506	-144	-271	-415	-5291	-15.35	-3.2
	1973	2127	10308	12435	7551	962	8513	-	-668	-668	-4590	-21.55	-4.0
	1975	1799	7570	9370	8083	-	8245	-	-152	-152	-1430	-5.3	-0.9

Construction and maintenance of VDS from 1965 gave possibility to create: high drainability, provided the ground water overflow from top fine-grained deposits to captured layer up to 3 - 5 th. m^3/ha; irrigation leaching regime (in vegetation period O_r =7200 -8400 m^3; in winter period from 2500 to 7800 m^3/ha) with ratio (B + O_c): E_{Tb} =1.15 -1.28. Under this regime annual salt removal was provided from all top fine-grained deposits in amount of 10 -21 t/ha.

In large systems vertical drainage also had high efficiency, for example, construction and maintenance of VDS with number of wells 250 in Bukhara province (Table 2.7). Before 1965 the existing open drainage with length of 8.5 m/ha provided abstraction of 500 -600 m^3/ha of shallow ground water (1.0 -2.0 m).

Due to VDS construction and improvement of territory drainability farms could regulate ground water level within necessary limits (2.5 to 3.2 m). Such level allowed to implement irrigation leaching regime with norm of 6.0 -6.5 th. m^3/ha (vegetation) and with leaching norm from 2.5 to 4.0 th. m^3/ha (in winter). Leaching regime coefficient (B + O_c/ET_b) was from 1.01 to 1.25, that provides negative type of water -salt balance is in zone of VDS introduction with removal of 7.6 - 9.3 t/ha from active thickness (Table 2.7). Under these conditions drainage outflow was from 3.1 to 4.8 th. m^3/ha.

Considerable strengthening of irrigated lands drainability, creation of negative type of water -salt balance with assistance of introduction of vertical drainage were successful also in other large systems, parameters of which are given in Table 2.9. There are 230 wells in Kuva district on area of 26.6 th. ha; Bayautsk and Shuruzyak massifs have 313 wells on area of 117.1 th. ha; in Arys-Turkestan massif of Chimkent province there are 504 wells on area of 52.4 th.ha, etc.

However, in recent years on some objects of the VDS deterioration of well maintenance, discharge reduction as well as worsening of irrigated water quality and water supply reduction were registered. For example, in Kagan district of Bukhara province by 1986 -1988 age of the majority of wells is 15 -25 years. Actual discharge reduced down to 18 l/s against initial 25 -25 l/s; specific water supply net for vegetation period is 4.8 -6.2 th. m^3/ha under irrigation water salinity 0.85 - 1.47 g/l; norms of winter -autumn leaching also decreased to 1.5 - 2.0 th. m^3/ha against 33 -4.0 th. m^3/ha, which took place before 1980 -1985.

Total drainability on horizontal and vertical drainage decreased to 1930 -2260 m^3/ha against initial 5240 -6085 m^3/ha. Because of all above mentioned salt balance of the Kagan district territory was equal almost to zero (total - 1 -1.5 t/ha), that caused slow restoration of soil salinization (Table 2.8).

Similar picture is observed also in SyrDarya province (object 02.30 Uzb.), on VDS system of Pakhtaaral district (object 02.11 Uzb.), Djetisay and Kirov districts (02.9 Uzb.), where along with the water supply annual norm reduction deterioration of VDS maintenance and well discharge reduction are registered. During the last years the water -salt balance on these objects was positive with salt storage from 3 to 8 t/ha (App. 7).

Table 2.7

Water-salt balance of active exchange thickness in zone of vertical drainage introduction in Zerafshan valley (Bukhara province)

Balance components	Water, m^3/ha		Salt, t/ha	
	1969-1970	1970-1971	1969-1970	1970-1971
<u>Inflow:</u>				
Precipitation	1226	1328	-	-
Seapage from canals	1588	1665	7.368	6.292
Water supply	9366	8295	6.397	5.711
Underground inflow	2561	3307	-	-
TOTAL:	**14714**	**14595**	**13.765**	**12.003**
<u>Outflow:</u>				
Total evaporation	7637	8049	-	-
Outflow through horizontal and vertical drainage	6085	5237	18.082	14.554
Underground outflow	2604	1421	4.984	5.081
TOTAL:	**16326**	**14770**	**23.066**	**19.635**
Difference	**-1612**	**-184**	**-9.301**	**-7.632**

Table 2.8

Actual common water-salt balance of area drained by vertical drainage in Kagan district Bukhara province

Water-salt balance components	1986 - 1987						1987 - 1988					
	vegetation		non-vegetation		year		vegetation		non-vegetation		year	
	m^3/ha	t/ha	m^3/ha	t/ha	m^3/ha	t/ha	m^3/ha	t/ha	m^3/ha	t/ha	m^3/ha	t/ha
INFLOW												
seapage from canals	1379	6.14	182	2.72	561	8.87	379	0.42	182	0.201	561	0.62
water supply	4987		2197		7184		5332	5.89	2346	2.59	7678	8.48
precipitation	321	-	1708	-	2029	-	597	-	1394	-	1991	-
TOTAL	5687	6.14	4087	2.72	9819	8.87	6308	6.31	3992	2.79	10230	9.10
OUTFLOW												
evapotranspiration	6158	-	774	-	6931	-	6558	-	738	-	7296	-
outflow throgh vertical drainage	503	1.54	276	8.85	850	2.60	623	1.91	689	2.11	1312	4.02
outflow through horizontal drainage	704	4.44	339	1.66	1079	6.47	598	3.59	352	2.11	950	5.7
underground outflow	556	0.64	240	0.28	796	0.91	585	0.64	258	0.28	843	0.93
TOTAL	7957	6.62	1629	2.79	9656	9.98	8364	6.14	2037	4.50	10401	10.65
BALANCE	-2270	-0.48	3258	-0.05	163	-1.11	-2057	0.17	1854	-1.71	-203	-1.55

2.2.5. Regulation of soil water -salt regime within aeration zone and top fine-grained deposits

In the process of vertical drainage system maintenance on the territory of all pilot plots the high drainability of top fine-grained deposits was achieved. If at the initial state under existing horizontal drainage the average annual drainage modules were 0.02 -0.07 l/s/ha (600 -2240 m^3/ha), after introduction of VDS these indicators considerable increased. In Fergana valley average annual drainage modules reached 0.18 -0.24 l/s/ha (in Besharik and Kuva districts), in Hungry Steppe (in state farm «50 years of Uzbekistan», «Pakhtaaral», etc.) 0.14 - 0.28 l/s/ha. Indicators characterizing drainability conditions, ground water level and salinity regulation, ground water level lowering rate, water-salt regime of soils on all PP and large systems of VDS before and after well construction are given in App. 8.

It is worth to note, that drainage modules during autumn - winter leaching exceed by 1.5 -2 times average annual values. In rice systems drainage modules achieve 0.32 -0.52 l/s/ha.

Vertical drainage systems built on pilot plots allowed to regulate ground and artesian water levels by change of ground water abstraction volume, creating different ground water overflow rate. Latter is closely connected with top fine-grained deposits permeability and head gradient.

By researches was determined that with increase of top fine-grained deposits conductivity (T) and a head gradient (Δ h = H - h) the dramatic growth of ground water lowering rate is observed (Figure 2.5). Latter depending on the top fine-grained deposits permeability is described by formula:

$$V = 0.0031^{2.7} \quad \text{with } \Delta h \le 1.0 \text{ m, and}$$
$$V = 0.007^{3.25} \quad \text{with } \Delta h \ge 1.5 \text{ -2.0 m}$$

Due to the imperfect existing horizontal drainage, especially in the districts having artesian ground water and sandy soils, this type of drainage does not give expected effect, although slightly slows down reclamation state deterioration. For example, PP territory in state farm «50 years of Uzbekistan» and «Besharik», which disposed in zone of strengthened ground inflow from outside from 1.5 -1.8 (in Hungry Steppe) to 3.5 - 5.0 th. m^3/ha (in Fergana valley). Data from previous tables on water -salt balance show, that in conditions of Vakhsh valley of Tadjikistan, the ground water inflow from outside is up to 10 -11 th. m^3/ha per year (PP 02.1 Tadj.).

Due to imperfect irrigation and, especially, drainage network in all plots, ground water is shallow (0.6 -1.8 m). In turn, shallow saline ground water (from 5 to 40 g/l and more) caused increase of total evapotranspiration from their surface and led to soil salinization of aeration zone.

Drainability increase of territory with VDS introduction enabled to low ground water level everywhere with rate from 2 - 2.5 (Sardoba and Shuruzyak massifs) to 3.5 - 4.0 cm./day (north-western part of Hungry steppe), and under higher permeability (Fergana valley or Bukhara province) up to 10 -15 cm/day (App. 8).

The most important factor is that VDS enabled to regulate depth of ground water over periods of a year in optimal way for concrete water-economy conditions taking into consideration agricultural measures implementation.

According to data of multi-year field researches the peculiarities of the most optimal support of ground water level are characterized over year seasons:
- September - November is a period of inconsiderable rainfalls, limited water diversion, high evapotranspiration from irrigated area and common ground water level abatement. In this period vertical drainage lows ground water level to 3.5 - 4.5 m for free capacity creation in soils for autumn -winter leaching implementation with the biggest desalinizing effect;

-December-February - period of maximum water diversion and leaching implementation, highest rainfall, dramatic reduction of evapotranspiration and, therefore, rise of ground water level up to 1.0 - 1.5 m, and under insufficient drainability - quite often irrigated lands water logging. In this period operational organizations usually provide regular operation of VDS with maximum well discharge for leaching water exhaustion and ground water regulation within 1.0 -1.5 m;

- March -May - period of maximum water diversion and canals closing, considerable rainfall, intensive evapotranspiration. Objective of drainage is to reduce ground water level down to 2 - 2.25 m for decrease of physical evapotranspiration from soil surface to prevent salinization restoration and optimal conditions provision for pre-sowing measures;

-June -August - maximum water diversion for vegetation irrigations, big losses of moisture for evapotranspiration and transpiration and common rise of ground water table During this period vertical drainage allows to support this table within 2.6 -3.0 m and to avoid salinization restoration.

Typical schedules of ground water level fluctuation within a year for cotton state farm are given in Figure 2.6 for conditions of Fergana valley; for rice farm in Figure 2.7 (for conditions of Kzylkum massif of Chimkent province of Kazakhstan) and for Vakhsh valley of Tadjikistan in table 2.9.

Table 2.9

Dynamics of area distribution with different depth of ground water (Vakhsh valley)

Depth, m	1957, summer, before irrigation		1966, summer, under irrigation		1969, summer, under irrigation	
	ha	%	ha	%	ha	%
0.0 -0.5	5.4	1.4	-	-	-	-
0.1 -1.0	37,6	9.4	-	-	-	-
1.0 -2.0	300.0	75.0	19	4.7	30	7.5
2.0 -3.0	40.0	10.0	89	22.2	23	5.8
3.0 -5.0	17.0	4.2	133	33.2	224	56.8
5.0 -10.0	-	-	124	31.0	74	18.5
more than 10.0	-	-	35	8.8	49	12.2

Usually in ground water regime two rises are noted - in summer and autumn -winter period under influence of leaching irrigations. Under rice cultivation in summer table rises up to earth surface and connects with water surface in checks, and in spring-winter goes down to 2.5 -3.0 m.

Thus, VDS allows to manage depth of ground and artesian water in optimal diapason from 1.5 to 4.5 m (App.8). In many pilot plots and large systems of VDS due to well operation in scientific-based regime semi-automorphic meliorative regime is provided, that allows to implement leaching regime of irrigation and autumn-winter leaching successfully.

Desalinizing discharge of infiltrating water varies from 1040 to 5670 m^3/ha and salt removal is 5 -50 t/ha a year, that allows to desalinate not only soils but also superficial layers of ground water.

Data of Appendix 8 show, that for 5 -7 years of the VDS operation multi-fold desalinization of ground water is observed to 2 -6 g/l in comparison with initial value of 10 -50 g/l.

But, at the same time, during last years in several PP and large systems of VDS because of discharge (pumping capacity) decrease the rise of ground water level is observed. And limited water use leads to decrease of water supply and this, in turn, leads to decrease of water supply to fields and reduction of leaching part as well as autumn -winter leaching norms.

All this affected water -salt balance, which in several PP became negative with prevailing salt income at expense of surface water over its removal with annual influx 3-6.8 t/ha of salt to aeration zone. For example, state farm Navoyi of SyrDarya province (PP 02.18. Uzb), large systems of VDS in SyrDarya province (02.30. Uzb.).

But, in general, normal operation of VDS on PP and in large systems allowed to decrease ground water salinity to big extent, that is well shown on an example of Shuruzyak and Pakhtaaral massifs, where vertical drainage started to be introduced since 1965 -66 and water supply regime was of a leaching type (table 2.10).

Table 2.10

Dynamics of ground water salinity in large VDS of the Hungry Steppe

Massifs	Number of wells	Average of ground water salinity, g/l							
		1952	1958	1966	1974	1978	1984	1985	1986
Shuruzyak	212	7.9	8.07	6.71	5.11	4.82	3.05	2.71	2.76
Sardoba	151	13.85	12.21	11.65	9.88	8.68	8.68	4.66	4.81
Pakhtaaral	325	8.37	8.34	7.83	5.2	3.82	3.82	4.27	4.93

Dynamics of soil salt regime on the background of vertical drainage

Soil salt regime on all objects was formed appropriately to tendency of water-salt balances of aeration zone, groundwater and common balance. As it is described in chapter 2.2.4, almost on all experimental-production plots and large systems multi-year irrigation leaching regime was kept on level (**$B+O_c/E_{TB}$**) - 1.1 to 1.35, that on the background of well operating vertical drainage provided formation of negative water-salt balance with removal of 5-50 t/ha of salt.

Above mentioned values of irrigation and leaching norms in annual cycle and keeping of negative water-salt balance on the background of vertical drainage system allowed to improve gradually meliorative state of all objects considered (appendix 8).

Analysis of soil water-salt regime dynamics over vertical drainage system objects, being placed in SyrDarya river upper reaches shows the following tendency of processes.

On pilot plot, being placed in Chu valley of Kyrgyzstan, soil salinity degree was various - from non-saline and slightly saline to strongly saline in complex with salt spots, salinity type is sulfate-sodium-calcium, sometimes with soda spots.

During alfalfa sprinkle irrigation by DA Rosa 3 or DM Fregat with irrigation norm 6980-7060 cu. m/ha and autumn preventive irrigation by depth 1400-2100 cu. m/ha negative water-salt balance of aeration zone was provided with annual salt removal of 6 t/ha under joint operation of vertical and horizontal drainage. Irrigation regime of fodder crops was kept by frequent gifts from 4 to 13 and keeping soil moisture from 70 to 90 % of full field water capacity. Under such irrigation leaching regime

$$\left(K = \frac{B + O_C}{ET} = 1.26 \right)$$

significant reduction of toxic salt content was found in top 1-meter layer of soil; in layer of 0-20 and 0-60 cm strongly saline soils did not remain, thickness to 2.0 m was desalinized. And groundwater salinity does not change much and was 2.4-26.9 g/l comparing with initial 3-30 g/l. Toxic salt content decreased from 0.463 to 0.161 % in 0-1 m layer. In order to keep groundwater table not lower than 2 m from land surface duration of pumping in vegetation period should be more than 100 days.

In next water-economic region (Fergana valley) based on data of presented projects and summary fulfilled before (Kh.Yakubov "Saline lands reclamation on the background of vertical drainage", 1990) the following peculiarities of vertical drainage system operation were found.

Zone of wide spreading of vertical drainage covers lands of Kuva, Tashlak, Bagdad and Kirov rayons of Fergana oblast. Natural conditions of this zone are more favorable than in Hungry steppe, for example. In Kuva and Tashlak rayons vertical drainage is constructed in zone of intensive ground inflow with shallow slightly saline groundwater. Irrigated lands of these rayons, as usual, are represented by non-saline, but over mallowed soils with groundwater depth of 0.5-2.0 m. So, vertical drainage wells here are constructed for underground inflow interception and optimal soil moisture providing under minimum of water supply to irrigated fields. Pumped groundwater is slightly saline (1-3.0 g/l) and is used for agricultural crops irrigation.

In Bagdad and Kirov rayons vertical drainage systems are constructed in zones of groundwater intensive seepage with high underground inflow from outside. Here groundwater also has shallow groundwater table (0.5-2.0 m), closely to land surface, but have increased salinity (3-5 g/l in Bagdad and to 10-15 g/l in Kirov rayon). Bagdad rayon lands are represented by non-saline and slightly saline soils and Kirov rayon - slightly and medium saline. Therefore, vertical drainage task in these rayons is creation of optimal area drainability for complex of agrotechnical measures on soil desalinization as well as groundwater interception and use for agricultural crops irrigation.

Captured aquifer is represented here by flaky gravel-pebble deposits with thickness from 8-12 to 25-40 m and more. They have higher conductivity > 500 m^2/day and K_f=25-40 m/day. Top fine-grained deposits have negligible thickness, seldom reaching 20 m and are represented by soils with high K_f=0.25-0.7 m/day. Top fine-grained deposit conductivity changes widely ($\hat{O}_z$=12-34 days, in average 24 days); groundwater table lowering rate under vertical drainage operation is very high - 0.15-0.22 m/day.

Groundwater is connected with captured aquifer water and characterized by high intensity of overflow, which reaches W>0.4 m/day.

Soils of top fine-grained deposits have the better indicators of water and salt availability than in Hungry steppe: water availability coefficient M=0.09-0.11 and salt availability 0.72-1.12.

Easily soluble salts in soils of these rayons of Fergana oblast are mainly concentrated in aeration zone that is usual for areas with artesian groundwater. Salinity type is sulfate and sometimes - chloride-sulfate. Dry residue value fluctuates within 0.4-3.2 % and chlorine-ion - within 0.015-0.8 % of soil dry mass.

At present time on lands of Kuva, Tashlak, Bagdad and Kirov rayons more than 533 wells with depth within 20-60 m and capacity within 8-90 l/s were constructed and operated. Systems efficiency varies within 0.5-0.7. System serves totally 43.2 th ha of lands. Volume of annual pumping of groundwater is equal to 4.5-5.5 th cu. m/ha, that provides on irrigated areas groundwater table regulation within 1.8 (spring) – 2.8 m (autumn). Average annual groundwater table in multi-year period fluctuates within 2.0-2.4 m.

In considered rayons vertical drainage system is supposed for intensification of area drainability where only open horizontal drainage was used before with specific length 30-45 m/ha. However, because of intensive underground inflow, which value reaches 3.5-6.5 th cu. m/ha, horizontal drainage did not provide groundwater depletion on water-logged lands and increased evaporation caused salt accumulation in aeration zone soils.

Desalinization of these lands was fulfilled by means of irrigation leaching regime in annual cycle. In vegetation period leaching depths were 1.8-3.0 th cu. m/ha. Relation between water supply together with rainfalls and total evaporation is 1.1-1.45. So drainage outflow value changed within 5.8-10.3 th cu. m/ha. More 50 % of drainage outflow was disposed by vertical drainage system.

Under such water supply volume on the background of joint operation of vertical and horizontal drainage on irrigated lands negative water-salt balance was obtained everywhere with salt removal within 2.5-3.0 t/ha and in certain rayons up to 12.5 t/ha (table 2.11).

Characteristic for this pilot plot of vertical drainage system is area of state farm Yakkatut of Besharyk (ex Kirov) rayon of Fergana oblast. On this experimental-production plot in the result of vertical drainage system long operation areas with groundwater salinity higher than 3.0 g/l were reduced from 79 to 29 %. Non-saline lands area in 1970 was 138 ha (20.4 %) and in 1980 – 386 ha (57 %). Medium saline lands area was reduced from 250 to 30.4 ha (45 %). Soil desalinization in 1-meter layer was obtained: on dry residue – from 2.0 to 0.6 %, on chlorine-ion – from 0.05 to 0.01-0.015 %. Relation ($B+O_c/ET$)=1.04-1.23. Annual salt removal was from 6 to 12 t/ha. In research period desalinization encompassed not only aeration zone but top fine-grained deposits to depth 7-8 m and more. Dynamics of soil desalinization over experimental-production plot on the background of vertical drainage system for multi-year period is reflected on example of stationary point # 6 (dr. 2.8).

Table 2.11

Water-salt balance dynamics for territories drained by vertical drainage systems in Fergana province

Water-salt balance components	Unit	Kuvah district		Tashlak district		Bagdad district		Kirov (Besharyk) district	
		1976	1987	1976	1987	1976	1987	1976	1987
Water supply, B	m^3/ha	6551	7065	7209	6637	8476	9270	8279	7712
	t/ha	5.25	4.90	4.69	4.01	5.93	5.93	5.43	5.01
Precipitation	m^3/ha	1789	3472	1789	3472	1141	1616	1141	1616
O_c	t/ha	0.716	1.22	0.716	1.22	0.456	0.65	0.456	0.65
Seapage from	m^3/ha	3627	3482	3882	3130	4564	5215	3401	3556
canals, $Ф_к$	t/ha	2.12	2.08	2.33	1.88	2.74	2.19	2.04	2.31
Total evaporation, ET_c	m^3/ha	8171	8477	8286	8747	7940	8150	7800	8050
Difference between	m^3/ha	1951	6677	3530	6155	4977	6506	3100	4120
groundwater inflow and outflow, $\underline{П}$ - $\underline{С}$	t/ha	0.78	2.67	1.41	2.46	1.99	2.66	1.24	1.65
Outflow through	m^3/ha	5803	11316	8040	10011	10377	14400	7712	8950
collector-drainage network, $Д_р$	t/ha	9.75	19.24	13.02	17.02	16.60	23.9	21.09	20.14
Groundwater salinity	m^3/ha	-156	0	84	636	84	51	400	4
changes, $\Delta W_{гр}$, $\Delta C_{гр}$	t/ha	-0.089	-8.47	-3.88	-6.81	-5.48	-12.47	-12.52	-10.52

In SyrDarya river middle reaches vertical drainage wells are widely introduced in Hungry steppe and Arys-Turkestan massif of Kazakhstan. In Hungry steppe more than 1660 vertical drainage wells were constructed with general capacity of 72.4 cu m/s. The most part of Hungry steppe has high thickness of top fine-grained deposits with low water permeability (K_f=0.03-0.15 m/day). Researches showed that in top fine-grained deposits thickness during geological development of landscape significant initial easily soluble salts, which total quantity fluctuates from 0.5-0.7 to 3-5 th t/ha, were accumulated. On watershed plots and, especially, regional non-drained parts of basin, salt stocks were distributed on whole profile for all depth of top fine-grained deposits with several characteristic salt maximum. Characteristic profiles of salt distribution and distinguished rayons over the area are shown above in section 2.2.1.3.

According to desalinization complexity and drainage technique Hungry steppe can be divided into large regions (Kh.Yakubov, L.Skorobogatova, 1980).

The first region includes flooded plain massif with area of 57.2 th ha with two-layer aquifer where high permeable saturated horizon is covered with top fine-grained deposits to depth of 3-5 m with low thickness. Here constructed open drainage provided groundwater outflow (drainage modulus 0.14 l/s/ha) on the background of leaching regime (annual water supply to area is 12-13 th cu. m/ha) that allowed to support irreversible process of desalinization with salt removal of 13-15 t/ha per year.

The second region – is the north-east and north-west parts of Hungry steppe – vertical drainage development zone. It includes Shuruzyak, Sardob, Bayaut, Central massifs of the Republic of Uzbekistan, Djetysay and Pakhtaaral rayons of Chymkent oblast of Kazakhstan.

Total region area is 396.6 th ha. Estimation of desalinization complexity of these lands, i. e. water-salt regime management in the north-east and the north-west parts of Hungry steppe is shown in the tables 2.12 and 2.13.

Table data show that geofiltration, hydraulic and soil-meliorative conditions in the north-east part of massif are very complex. Soils are characterized by high content of easily soluble salts from aeration zone to top fine-grained deposits basement: dry residue value is from 0.5 to 4.5 % of dry soil weight and chlorine-ion – 0.03-1.2 %; soils have mostly decreased water- and salt availability: M=0.06-0.08; L=1.8-3.0.

The north-west part of Hungry steppe is represented by flaky soils of light and middle loam and sandy loam. Complexity of desalinization of soil top fine-grained deposits lands of this region is middle. Water and salt availability is much better then in the north-east part. Easily soluble salt content fluctuates within 0.5-1.8 % on dry residue and within 0.03-0.3 on chlorine-ion. From depth 12-15 m soils are almost desalinized.

For these lands reclamation, located in command zone of Kirov main canal of Hungry steppe, irrigation leaching regime on the background of vertical drainage was used as basic method by means of operational leaching by norm 2.5-5.0 th cu. m/ha (on average 3.0-3.5 th cu. m/ha) and vegetation irrigation by norm 5.0-5.5 th cu. m/ha for the north-west and 5.5-6.5 th cu. m/ha for the north-east part. Then total water supply (water supply + precipitation) to irrigated field will be, appropriately, 10.5-12.0 and 12-13 th cu. m/ha per year. So in annual cycle leaching regime was provided with coefficient 1.15-1.25.

Water-salt balance dynamics of aeration zone, groundwater and top fine-grained deposits, composed before and after vertical drainage system introduction on lands of the north-east part of Hungry steppe, is shown on example of Shuruzyak massif in the table 2.14.

Table 2.12

Assessment of top soil desalinization complexity
in North-East Golodnaya steppe

Factors group	Massifs, administrative rayons		
	Shuruzyak, (Voroshilov, Gulistan, Syrdarya rayons)	Sardoba (Komsomol rayon)	Bayaut (Bayaut rayon)
1. <u>Geofiltration</u>			
Topsoil thikness	20-30	25-40	15-45
Soils and profile	flaky: medium and heavy loam, clay, sandy loam	cleavage: medium and heavy loam	flaky: loam, sandy loam, clay slowed down
Top soil permeability m/day K_n	0.05-0.07	0.03-0.05	0.05-0.1
Captured layer characteristic- $T=K_в.M_в$, m^2/day	sandy graverl-pebble deposits with nigh permeability T>1500	highly permeable sand T> 300	Sand-gravel pebble T= 100-5000
Overflow from above factor $B = \sqrt{\frac{Tm_n}{K_n}}$, m/day	B > 750	B > 300	B = 200-400 seldom before 1200
Topsoil resistance $\Phi_z = \frac{\Sigma m_{n\ cp}}{K_{i\ cp}}$, day	> 400 seldom 100-200	> 500, seldom 300-400	150-200
II. <u>Hydraulic</u>			
Lowering rate, cm/day	2-2.5	1.5-2.0	2.0-2.5
Overflow intensity h=H=1, $W = K_ф \frac{h - H}{m_n}$, cm/day	slowed down 0.0025-0.003	very slowed down 0.0025	slowed down 0.0025-0.005

Factors group	Massifs, administrative rayons		
	Shuruzyak, (Voroshilov, Gulistan, Syrdarya rayons)	Sardoba (Komsomol rayon)	Bayaut (Bayaut rayon)
III. <u>Soil - meliorative</u>			
Salt distribution charater	saline unsaturated zone	all topsoil thickness	all topsoil thickness
Salinization type	chloride-sulfate, sulfate	chloride-sulfate	chloride-sulfate, sulfate
Salinization degree dry residue chlorine -ion	 <u>1.8-3.5</u> 0.04-0.5	 <u>2.0-4.5</u> 0.07-1.2	 <u>0.5-4.0</u> 0.03-1.0
Water availability coefficient (M)	0.06-0.08	0.06	0.06-0.08
Salt availability coefficient (L)	2.8	1.8-3.0	1.4-3.0

Table 2.13

Assessment of topsoil desalinization complexity in North-West Golodnaya steppe

Factors group	Massifs, administrative districts	
	Pahtaaral	Djetysay and Kirov
1. <u>Geofiltration</u>		
Topsoil thickness	15-40	15-30
Soils and profile	flaky: medium and heavy loam, clay, sandy loam	flaky: medium and heavy loam, clay, sandy loam
Top soil permeability m/day $\hat{E}_n$	0.1-0.12	0.1-0.15
Captured layer characteristic- $\grave{O}=\hat{E}_{\hat{a}}.\grave{I}_{\hat{a}}$, m^2/day	highly permeable sand	highly permeable sand
Overflow from above factor $\hat{A} = \sqrt{\frac{\grave{O}m_n}{\hat{E}_n}}$, m/day	$\grave{O}$ = 500	$\grave{O}$ = 500
Topsoil resistance $\hat{O}_z = \frac{\Sigma m_{n\ ñð}}{\hat{E}_{i\ ñð}}$, day	$\hat{A}$ = 150-450	$\hat{A}$ = 150-400
II. <u>Hydraulics</u>		
Lowering rate, ñm/day	2.5-3.0	3-3.5
Overflow intensity h=H=1, $W = K_{\hat{o}} \frac{h - H}{m_n}$, cm/day	moderate 0.0025-0.006	moderate 0.003-0.007
III. <u>Soil - meliorative</u>		
Salt distribution charater	all topsoil thickness	all topsoil thickness
Salinization type	chloride-sulfate, sulfate	chloride-sulfate, sulfate
Salinization degree		
dry residue	<u>0.5-1.2</u>	<u>0.6-1.8</u>
chlorine - ion	0.03-0.2	0.04-0.3

Factors group	Massifs, administrative districts	
	Pahtaaral	Djetysay and Kirov
Water availability coefficient (M)	0.08	0.08
Salt availability coefficient (L)	1.2-1.8	1.2-1.8

Table 2.14

Ground water and unsaturated zone water - salt balance dynamics within the topsoil (0-25) on irrigated lands of Shyruzyak massif (after L.A. Skkrobogatova)

Balance elements	YEARS							
	1962	1964	1970	1973	1977	1979	1983	1986
Water balance								
inflow, m^3/ha								
precipitation	2730	3010	2666	2510	4950	4130	2190	1853
water supply	7920	9340	10516	8900	7180	7940	7890	7082
inflow from collector drainage system	-	-	200	650	750	640	1000	1663
filtration	1230	1080	1198	1140	1000	1000	1100	-
lateral inlow	280	280	280	600	500	500	500	800
TOTAL	**12060**	**13710**	**14860**	**13800**	**11560**	**14380**	**12680**	**11398**
Autflow:								
evapotranspiration	8300	8700	8000	7540	8100	8000	7840	7074
drainage m^3/hà	3780	4820	7200	6370	6080	6170	4850	5780
including:								
Ñollectore	1600	2150	2820	2480	2250	2060	1440	972
horizontal	2180	2670	1070	210	260	260	220	250
vertical	-	-	3310	2680	3570	3850	3190	3630
TOTAL	**12080**	**13520**	**14935**	**14068**	**11860**	**14180**	**14170**	**11926**
± Δ W	-20	+190	-340	-110	-300	+200	+40	-528
ground water table	1.67	1.57	2.28	2.50	2.05	2.10	2.34	2.45
$Î_ï$ =($Ä_ã$+$Ä_â$) - Ï ± Δ W	1900	2580	3760	3180	3530	3650	2900	2552
module Å, l/señ/hà	0.05	0.08	0.14	0.13	0.12	0.13	0.10	0.08
Salt balance								
Salt influx, th/hà:								
water supply	6.3	7.9	9.6	10.0	11.0	11.8	12.0	8.30
drainage	-	-	0.6	1.7	1.9	1.6	2.4	3.50
lateral inflow	0.1	0.1	0.12	0.14	0.14	0.14	0.14	0.28
TOTAL	**6.4**	**8.0**	**10.3**	**11.8**	**13.0**	**13.5**	**15.4**	**12.08**
removed, t/hà:								
horizontal drainage plus collectors	10.0	12.5	10.2	6.6	6.0	3.8	3.5	1.75

Ñ	-	-	19.9	18.5	18.0	20.0	17.3	15.22
TOTAL	**10.0**	**12.5**	**27.3**	**21.9**	**21.8**	**23.5**	**21.4**	**16.97**
Salt removal from topsoil, t/ha	3.6	-4.5	-17.0	-10.1	-8.8	-10	-6	-4.9
Â : ÅÒ	(1)	1.09	-	1.43	1.18	1.1	1.27	1.24
water expenses for 1 t salt removal m^3/t	2080	2060	620	890	815	794	1300	1450

Data of the table 2.14 show that on Shuruzyak massif lands before vertical drainage construction negligible negative balance with salt removal from top fine-grained deposits 3-4 t/ha per year. After vertical drainage system introduction into operation desalinization rate are intensified with salt removal from 4.5 t/ha (1964) to 17.0 t/ha (1970).

Similar character of water-salt balance was noted on lands of Sardob and Bayaut rayons: before vertical drainage system introduction on these lands water-salt balance was positive with salt accumulation 5-10 t/ha, after vertical drainage system introduction it changed to negative, desalinization rate is 3-6 t/ha per year.

Intensive salt removal from aeration zone and groundwater salinity lowering (appendix 8), resulted in irrigated lands meliorative state improvement. So, according to data of soil-salt survey of Uzgiprovodkhoz, 1977 on Shuruzyak massif non-saline and slightly saline area increased by 2.8 times and reached 59.2 th ha (87 %) against 21.6 th ha in 1958. Salts, medium and strongly saline soil areas were reduced to 9 % against 66 % in 1958 and 33 % in 1966 (table 2.15).

On Sardob massif, where water supply to irrigated fields was lower than on Shuruzyak one, lands desalinization proceeded more slowly (table 2.16).

Table 2.15

Land salinization degree dynamics on Shuruzyak massif, ha/per cent

Year	Salinization degree				Fallow lands and settlements	Total
	non-saline and slihtly saline	medium	strong	salt		
1952	31880	7100	13100	14700	1300	68000
	46.5	10.3	19.3	21.9	2.0	100
1958	21600	15200	15100	14400	2100	68400
	32	23.0	22.0	21.0	2.0	100
1966	44400	12300	7300	2600	2.2	68400
	65	18.0	10	4.0	3.0	100
1977	58945	2969	2152	1582	2156	68404
	86.2	4.5	3.1	2.3	4.0	100
1982	49725	11975	3875	-	2829	68404
	73	17	6	-	4	100
1988	37827	25720	2121	-	2829	68404
	55.3	37.6	3.1	-	4.0	100

Table 2.16

Land salinization degree dynamics on Shardoba massif, ha/per cent

Year	Salinization degree				Others	Total
	slight	medium	strong	salt		
1958	6543	3714	9233	9356	1728	32504
	26.2	11.4	28.4	28.8	6.0	100
1966	9104	4108	3357	13300	1181	32352
	28.2	16.9	10.3	42.2	4.4	100
1974	11413	3357	4165	10737	2680	32352
	25.4	10.3	12.7	33.3	8.3	100
1978	14137	4596	4689	2617	3235	32352
	44.0	14.2	14.5	19.0	8.3	100
1982[б]	22506	71736	3500	4252	-	37432
	60.1	19.2	9.3	11.4	-	100
1988	20138	17069	225	-	-	37432
	53.8	45.6	0.6	-	-	100

By 1978 there were rather large areas of medium and strongly saline lands (28.7 %) and salts (19 %). By 1988 salts areas totally disappeared and only 0.6 % (225 ha) of strongly saline lands remained; non-saline lands areas increased to 54 % against 26 % in 1958.

On lands of Pakhtaaral rayon, where top fine-grained deposits are composed of more light soils, having relatively high water- and salt availability, lands desalinization proceeded faster. Here since 1952 till 1966 lands salinization proceeded horizontal drainage did not provide groundwater and salt disposal. Vertical drainage system introduction everywhere begun in 1966-1967, provided negative water-salt balance and optimal conditions for desalinization measures with provided salt removal from top fine-grained deposits from 10 to 21 t/ha per year. All this caused increase of non-saline and slightly saline land areas to 95.8 % of irrigated area in 1977; salts disappeared, medium and strongly saline lands were reduced in area (table 2.17).

On results of water-salt balances, prepared for different massifs of Hungry steppe, where vertical drainage system was widely introduced, generalized schedule of dependence of salt removal from aeration zone on leaching regime value was drawn (dr. 2.9). Schedule data show that for providing negative balance with salt removal from 5 to 25 t/ha relation between total water supply and total evaporation should be at least 1.05-1.25.

Characteristic profiles of easily soluble salts and different ions content within whole top fine-grained deposits for considered massifs in multi-year cycle are shown at dr. 2.10-2.12.

Similar lands desalinization rate under irrigation leaching regime on the background of well operating vertical drainage for period since 1968 till 1974 was kept on lands of Djetysay and Kirov rayons of Chymkent oblast of Kazakhstan, that is reflected on example of salts profiles in collective farm Lenin of Djetysay rayon at dr. 2.13.

However, beginning since 1981 aggravation of vertical drainage system operation conditions started, leaching irrigation norms lowered and irrigation water salinity grew worse. On some vertical drainage systems medium and strongly saline soils area increased at expense of non-saline and slightly saline lands: on example of Pakhtaaral massif this is reflected in the table 2.17.

Table 2.17

Lands dynamics on salinization degree on Pakhtaaral massif, ha/per cent

Years	Salinity degree				Lakes and marshes	Total
	non-saline and slightly saline	medium saline	strongly saline	salts		
1952-1956	41751	7628	6871	1580	400	58230
	71.8	13.0	11.8	2.8	0.680	100
1965-1967	25277	14145	5790	12223	794	58230
	43.4	24.0	10	21	0.3	100
1977	55770	-	2460	-	-	58230
	95.8	-	4.2	-	-	100
1981	37717	4375	313	-	-	42400
	89.0	10.3	0.7	-	-	100
1982	23734	6898	10366	1417	-	42400
	56	16	24	4	-	100
1983	23054	7042	9007	3302	-	42405
	55	16	21	8	-	100
1986	25120	11070	6460	410	-	43050
	58.3	25.7	15.0	1.0	-	100

In Arys-Turkestan massif, where 504 vertical drainage wells are functioning, lands, which are subjected to salinization, are placed mainly in Bugun rayon; in farms of Turkestan rayon lands are desalinized.

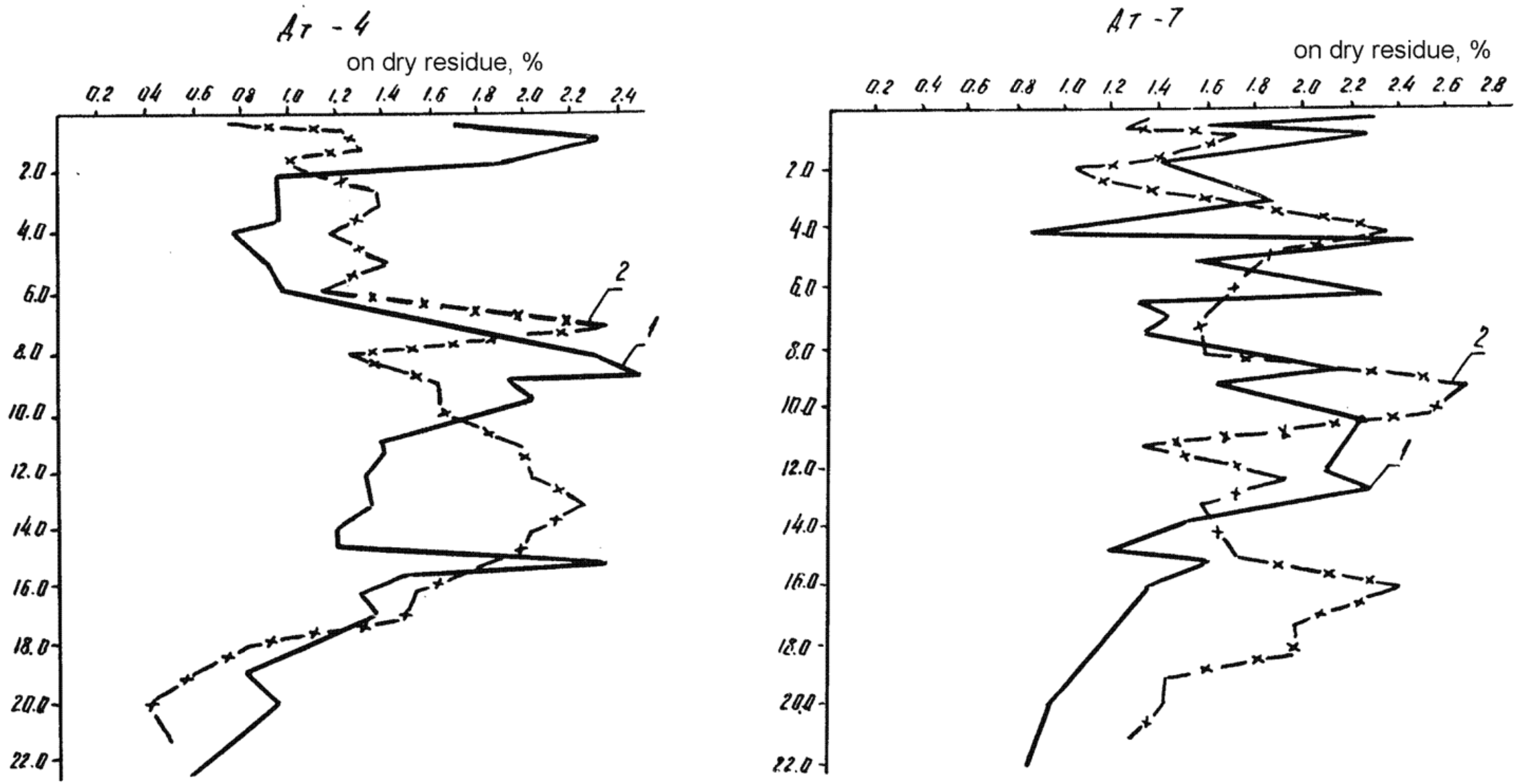
According to salinity type lands of Bugun rayon belong to slightly and medium saline; content of dry residue is 0.2-0.5 % and main reason of soils salinization is absence of irrigation leaching regime and insufficient area drainability. Vertical drainage system construction allowed: regulate groundwater table from 1-2 to 2.5-3.5 m; reduce inflow volume and lower piezometric head within 0.1-0.3 m below groundwater table. On irrigated lands with cotton crop irrigation leaching regime was started to be applied with coefficient $(B+O_c/ET)=0.96-1.12$. Salt stocks in aeration zone were reduced on 10-60 t/ha and easily soluble salts content on dry residue decreased to 0.12 %, i. e. soils are practically desalinized.

For this massif measures are developed on intensification of groundwater withdrawal for efficient combination of surface and groundwater resources and redistribution of surface water among rayons and farms. So, for dry years regime of vertical drainage systems pumping is set, which is recommended to be used with workability coefficient 0.6-0.72. It is determined that pumped water use (salinity is within 0.5-1.5 g/l) for irrigation in volume of 49.8 mln cu m per year allowed to reduce water off - take from Turkestan canal and transport them into areas, locating downstream and by means of that to increase land water supply.

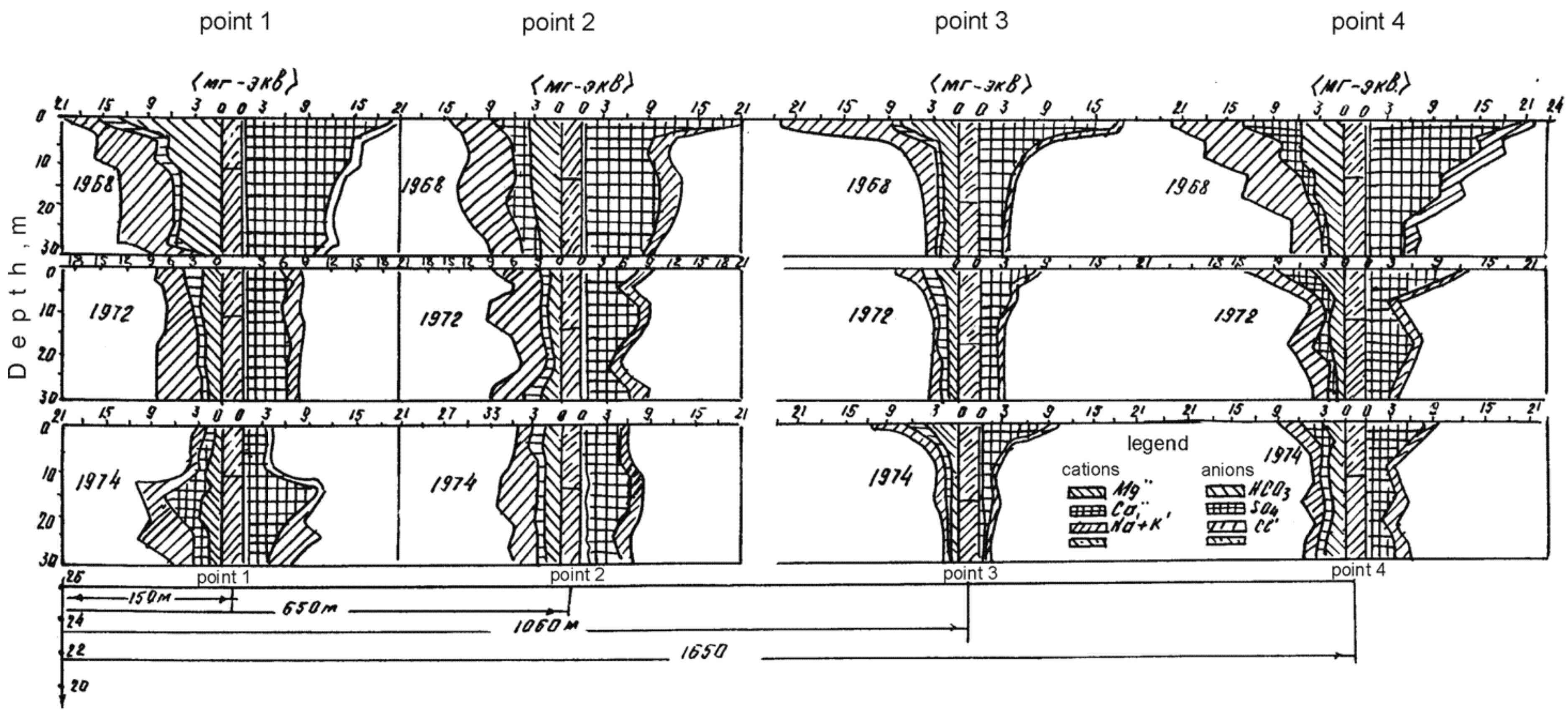
For SyrDarya river lower reaches basic zone of vertical drainage system spreading is Kyzylkum massif, being located below Chardara water reservoir. Vertical drainage system in Chardara area was started to be constructed in 1969. Since 1978 its construction was started on lands of the 2nd turn of development and by 1980 at least 275 wells functioned with total well discharge of 11.0 cu m/s.

In the result of researches of vertical drainage system effectiveness under top fine-grained deposits with low thickness it is found that their high water conductivity negatively influences on groundwater automorphous regime, when infiltration becomes intensive. According to that for considered conditions semi-hydromorphous meliorative regime is recommended in vegetation period and automorphous – in non-vegetation period.

In conditions of Kyzylkum massif for optimal meliorative regime formation and lands desalinization it is necessary to organize vertical drainage system operation regime in the following way: for cotton-growing farms to provide average annual workability coefficient is 0.6-0.7 and pumped water volume for gross area 2.6-2.9 th cu. m/ha; for rice-growing farms workability coefficient 0.65-0.75 and pumped water is 3.0-3.8 th cu. m/ha per year (for certain farms to 6.7 th cu. m/ha; for stock-breeding farms average annual workability coefficient is 0.55-0.65 and pumped water 2.5-7.45 th cu. m/ha.



Dr. 2.12. Soil salinity changes in dynamic points Дт - 4 and Дт - 7 Sardoba massif.
1 - salt stock by spring 1971; 2 - salt stock by autumn 1981.



Dr. 2.13. Easy solvable salts stock dynamics within the unsaturated zone (plot **N** 2), collective farm "Lenin" Chimkent oblast.

Negative water-salt balance on this area with salt removal of 3-5 t/ha is provided under irrigation leaching regime with common water supply ($B+O_c$) at least 10.0 th cu. m/ha, under relation ($B+O_c/ET$) at least 1.3-1.45 and relation between drainage outflow and water supply ($D/\Sigma B$)≥0.26-0.3 (dr. 2.14).

For this zone characteristic variation of salt regime dynamics is shown in the table 2.18 and dr. 2.15.

Table 2.18

Lands desalinization dynamics of state farm Dostyk of Kyzylkum massif on the background of vertical drainage system

Soil salinity area	1978		1979		1983	
	ha	%	ha	%	ha	%
Non-saline	57.0	4.3	947.6	70.5	550	41.5
Slightly saline	914.0	68.9	250.5	18.7	614	46.2
Medium saline	332	25.0	128.9	10.8	163	12.3
Strongly saline	24	1.8	-	-	-	-
TOTAL	1327	100	1327	100	1327	100

Vertical drainage systems in AmuDarya river basin

For AmuDarya river upper reaches vertical drainage system effectiveness is characterized by results of tests, being conducted in collective farm "Safarov" of Khatlon oblast, Vakhsh valley. Here geomorphological conditions, lithology are simplier than in Hungry steppe. Top fine-grained deposits thickness is within 6-7 m and permeability is 0.025-1.0 m/day. But initial soil-meliorative conditions are aggravated – before development beginning 72 % of area was occupied by salts, 15 % - by strongly saline soils with content of chlorine-ion up to 0.2-0.4 % and only 13 % corresponded to non-saline and slightly saline lands.

Here on the background of vertical drainage irrigation leaching regime was kept by norm of 18-21 th cu. m/ha, extra-irrigation by norm 2-3 th cu. m/ha. In the result negative salt balance of area was provided with 33 t/ha salt removal.

Total outflow on vertical drainage system was within 10-16.4 th cu. m/ha and on horizontal drainage within 1580-5960 cu. m/ha, that is caused by high ground inflow, about 10.3 th cu. m/ha. Vertical drainage system allowed to regulate groundwater on 87 % of area on 3 m level and lower.

As the result of seasonal negative water-salt balance whole fine-grained thickness was managed to be desalinized to 0.01-0.03 % on chlorine-ion.

Soils desalinization dynamics on experimental-production plots over Vakhsh valley is shown in the table 2.19 and characteristic profiles at dr. 2.16.

Table 2.19

Areas with different salinity before and after development
(vertical drainage system experimental-production plot in
Vakhsh valley of Tadjikistan)

Soil	Salinity degree on chlorine, %	Before development		After development		Meliorative effect, ha
		ha	%	ha	%	
Non-saline	< 0.03	18	4.5	198	49.5	+180
Slightly and medium	0.03-0.2	15	3.9	122	30.5	+107
Strongly	0.2-0.4	79	19.7	40	10	-39
Salt	0.4-1.0	184	46.0	40	10	-144
Strongly salt	> 1.0	104	26.0	-	-	104

In AmuDarya river middle reaches vertical drainage was widely applied in Bukhara oblast, where in Vabkent, Bukhara and Kagan rayons 250 wells were drilled, providing reclamation of 5.19 th ha of land. Each well serves on average in Vabkent rayon 260 ha, in Bukhara rayon - 193 and Kagan rayon - 185 ha of lands. Well discharge varies within 40-45 l/s in Vabkent rayon and 25-30 l/s - in Kagan and Bukhara rayons.

Vertical drainage introduction zone in these rayons, comparing with Fergana valley and Hungry steppe, is represented by non-artesian and sub-artesian aquifer complexes, consisted of two-layer deposits of quaternary period - top fine-grained deposits of low thickness (to 15 m), which is underlain by gravel-pebble rocks with permeability 40-45 m/day. On desalinization complexity top deposits belong to comparatively simple category. In the table 2.19a geomorphological, hydraulic and soil-meliorative characteristics of top fine-grained deposits are represented according to their desalinization complexity.

Table 2.19a

Assessment of top soil desalinization complexity
in Bukhara province

Group of factors	Massifs, administrative districts: Bukhara, Kagan, Vabkent
1. Geofiltration	
Topsoil thickness, m	8-15
Soils and their texture	flaky: light, medium loam and sandy loam
$K_ф$ top soil permeability, m/day	0.5-1.0 and higher

Group of factors	Massifs, administrative districts: Bukhara, Kagan, Vabkent
Characteristic of captured layer - $T = K_{\text{в}} \cdot m_{\text{в}}$	T = 300-1000
Factor of overflow from above $B = \sqrt{\frac{T \cdot m_n}{K_n}}$, m/day	B = 24-250
Top soil resistance $\Phi_z = \frac{\Sigma m_n \cdot \text{свз}}{K_{\text{п свз}}}$, day	$\Phi_z = 20$
II. <u>Hydraulic</u>	
Groundwater lowering rate, cm/day	0.1-0.25
Overflow intensity h-H = 1, m/day $W = K_{\text{п}} \frac{(h - H)}{m_n}$	high W > 0.5-0.6
III. <u>Soil-reclamation</u>	
Salt distribution character	superficial up to 1.0 m
Salinity type	chloride-sulfate and sulfate
Salinity degree, %	
<u>dry residue</u>	<u>1.2 - 2.2</u>
CL	0.05-0.82
Water availability coefficient (M)	0.1-0.12
Salt availability coefficient (L)	0.75

Top fine-grained deposits also have good indicators of water and salt availability: M=0.1-0.12, L=0.75-1.5.

Soil salinity is superficial: easily soluble salts are concentrated mainly in active zone - up to 1.0 m. Salinity type is sulfate and on salts and strongly saline soils - sulfate-chloride.

In Bukhara oblast vertical drainage is constructed for creation of optimal area drainability.

Before vertical drainage construction (1964-1965) groundwaters were shallow (1-2 m) and highly mineralized (5-7 g/l and more), that resulted in lands secondary salinization. Open horizontal drainage, represented mainly by collectors with specific length 8.46 m/ha and actual depth 2-3 m, because of inopportune mechanical cleaning, overgrown and silted and could not provide lands drainability (500-600 cu m/ha per year).

Due to area drainability improvement by means of vertical drainage by April land areas with groundwater table 1.4-1.5 m were reduced to 15-20 % and with groundwater table 1.5-2 and 2-3 m were reduced to 27 and 40 %, appropriately. Land area with groundwater salinity to 5 g/l reached 85-90 % (table 2.20).

Table 2.20

Groundwater table depth distribution under vertical drainage
in Bukhara province

Year	Area, ha / %	Groundwater table depth, m				
		0-1	1-1.5	1.5-2.0	2.0-3.0	> 3
			Vabkent district			
1976	8812	-	100	810	4672	3230
	100		1.1	9.2	53.0	36.7
1977	10374	-	-	1000	5388	3986
	100			11.5	53.0	36.5
1978	10212	-	-	1856	6356	2000
	100			18.2	62.2	19.6
1979	9176	-	1048	2844	3704	1580
	100		11.4	31.0	40.4	17.2
			Bukhara district			
1976	20708	-	3440	6163	9800	1300
	100	-	16.6	29.8	47.3	6.3
1977	20260	-	3436	4236	9198	3400
	-	-	17.1	22.1	45.8	15.0
1978	10290	1000	2260	4360	10770	1900
	100	11.1	11.1	21.5	53	9.4
1979	20148	1080	6764	6756	5404	144
	100	5.4	33.6	33.5	26.8	0.70
			Kagan district			
1976	23557	173	7098	9014	4697	2575
	100	0.7	30.1	38.2	19.9	11.0
1977	23557	-	475	11125	7717	4239
	100		2.0	47.2	32.7	17.9
1978	23557	405	6360	7077	9425	289
	100	1.7	27	30	40	1.2
1979	23557	1696	4966	9083	6843	969
	100	7.2	21.0	38.6	29.0	4.1
1988	23557	-	-	469	20334	2754
	100	-	-	1.99	86.32	11.69

In autumn on irrigated lands groundwater table was at depth of 2.7-3.2 m. Such range of the level distribution allowed to carry out irrigation leaching regime with irrigation norm 6.0-6.5 th cu m/ha and leaching norm 2.5-3.0 th cu m/ha for slightly saline, 3.0-4.0 th cu m/ha for medium saline and to 6.0 th cu m/ha for strongly saline lands.

Leaching regime value ($B+O_c/EC$) in Vabkent rayon was within 1.03-1.25; in Bukhara rayon - 1.01-1.21; in Kagan rayon - 1.21-1.23.

As the result of irrigation leaching regime on lands, reclaimed by vertical drainage in Bukhara oblast, negative water-salt balance was formed with salt removal on Vabkent rayon - 5.13; on Bukhara - 5.46 and Kagan - 9.5 t/ha. Drainage outflow was 4.8; 3.9 and 3.1 th cu m/ha, appropriately (table 2.21).

Water-salt balance of irrigated field aeration zone was formed in another way. Here in non-growing period due to winter-spring leaching irrigation and rainfalls intensive desalinization of aeration zone proceeds everywhere and in growing period - negligible accumulation of salts was observed. But in annual cycle aeration zone salt balance is formed negatively with salt removal to 11 t/ha.

In the result of provision optimal pumping regime, negative water-salt balance on irrigated lands, salt movement became more dynamic than on non-irrigated lands; in latter total salt content is 2-5 times more;

- groundwater salinity on intensively irrigated lands was 1.2-3.0 g/l;
- salt removal from active thickness of top fine-grained deposits by means of drainage in 1970 was 18 t/ha and with regard to ground outflow - 23 t/ha; in 1971, appropriately, 14.6 and 19.6 t/ha;
- areas of non-saline and slightly saline lands increased permanently. By 1971 they grew by 10 times comparing to 1960, when vertical drainage system was absent.

But for the last years in vertical drainage system of Bukhara oblast aggravation of exploitation conditions is noted. Therefore, for Kagan rayon, where situation is the same, on the base of forecast calculations of common and partial water-salt balances specific recommendations were developed on meliorative regime improvement and corrected regime of vertical drainage system operation, which provides:

under water supply to irrigated field 8600 cu m/ha per year;

- obtaining pumping volume to 2280 cu m/ha per year;
- groundwater table regulation in vegetation period within 2.10-2.66 m; in spring - 1.8-2.45 m; in autumn - 2.7-2.85 m; appropriately, total evaporation lowering from irrigated fields;
- annual reduction of salt common stocks in aeration zone to 89.4 t/ha.

Forecast calculations results are represented in table 2.22.

So, vertical drainage system constructed allowed to regulate groundwater and shallow water table which was additional source of water availability increase. Area high drainability providing and irrigation leaching regime application allowed to regulate water-aerial, recharge and salt regime of soils within optimal limits; sustainable desalinization is obtained in aeration zone and in whole top fine-grained deposits.

2.2.6. Variation of salinity and chemical composition of pumped water under long-term operation of vertical drainage system

Variation of salinity and chemical composition of pumped water is one of the principal indicators, characterizing top fine-grained deposits soils desalinization and intensity of water and salt exchange between groundwater and artesian water of captured horizon.

In process of vertical drainage system operation salinity and quality of water pumped from captured horizon abruptly change. Variation rate of water salinity and quality depends on many conditions, in particular:

Table 2.21

Initial and attained common water-salt balance under vertical drainage
in Bukhara province

District	Years	Unit	Water-salt balances elements												
			inflow					total	outflow					total	balance
			precipitation	water supply	filtration	vertical drainage	collector-drainage water		evapotranspiration	vertical drainage	horizontal drainage	release	inflow minus outflow		
Vabkent	initial 1964-1965	m^3/ha	1090	5586	2680	-	-	9356	8213	-	626	-	517	9356	-
		t/ha	-	3.68	1.76			5.44	-		2.35		1.26	3.61	+1.83
	1976-1978	m^3/ha	1400	8630	3729	280	104	14143	8022	2325	2480	292	394	13513	+630
		t/ha	-	6.64	2.95	0.89	0.34	10.82	-	8.05	6.57	0.28	1.05	15.95	-5.13
	1987	m^3/ha	1991	8788	2635	-	-	13414	7237	1170	643	1318	-	10368	+3046
		t/ha	-	10.06	3.03			13.08	-	4.45	1.59	1.56		7.7	+5.4
Bukhara	initial 1964-1965	m^3/ha	1090	6121	1667	-	-	8879	-	-	540	-	60	600	600
		t/ha	-	4.06	1.11			5.17			2.11		0.41	2.52	+2.65
	1976-1978	m^3/ha	1397	7639	2999	244	88	12347	8166	1369	2529	629	143	12836	-489
		t/ha	-	7.6	3.02	0.59	0.38	11.59	-	3.96	11.96	0.73	0.41	17.05	-5.46
	1987	m^3/ha	1991	9910	1856	-	-	13757	8167	2413	53	1485	-	12118	+1639

District	Years	Unit	Water-salt balances elements												
			inflow					total	outflow					total	balance
			precipitation	water supply	filtration	vertical drainage	collector-drainage water		evapotranspiration	vertical drainage	horizontal drainage	release	inflow minus outflow		
		t/ha	-	11.1	2.0			13.18	-	6.61	-	1.64		8.25	+4.91
Kagan	initial														
	1964-1965	m^3/ha	1090	6401	1377	-	-	8868	8405	-	463	-	-	8869	-
		t/ha	-	4.24	0.91			5.15	-		1.8			1.8	3.3
	1976-1978	m^3/ha	1396	5538	2565	237	75	9811	6881	1560	1501	216	-	10158	-347
		t/ha	-	4.68	2.24	0.82	0.53	8.27	-	5.34	12.22	0.21		17.77	-9.5
	1987	m^3/ha	2024	6542	1315	-	-	9881	6778	884	1238	981	-	9881	-
		t/ha	-	7.05	1.42			8.47	-	2.13	6.49	1.09		9.71	1.24

Table 2.22

Foreseen water-salt balances of Kagan district under high water availability level within non-growing period

Water-salt balances elements	Growing period		Non-growing period		Per year	
	m^3/ha	t/ha	m^3/ha	t/ha	m^3/ha	t/ha
Common balances						
Inflow						
precipitations	252	-	1138	-	1390	-
water supply	4500	4.64	2780	3.0	7280	7.64
filtration from fields	1051	1.02	553	0.6	1604	1.62
filtration from canals	663	0.64	434	0.47	1097	1.11
Total	**6466**	**6.3**	**4905**	**4.07**	**11371**	**10.37**
Outflow						
evapotranspiration	5873	-	818	-	6691	-
vertical drainage	1257	8.12	1026	5.8	2283	13.92
horizontal drainage	666	4.30	537	3.03	1203	7.33
surface release	779	0.76	417	0.45	1196	1.21
Total	**8575**	**13.18**	**2799**	**9.28**	**11374**	**22.46**
Balance	**-2108**	**-6.88**	**+2106**	**-5.21**	**0**	**-12.09**
Irrigated field unsaturated zone balance						
precipitations	252	-	1138	-	1390	-
water supply	5400	6.44	3200	3.72	8600	10.16
filtration	342	-	194	-	536	-
evapotranspiration	6754	-	817	-	7572	-
surface release	809	0.91	480	0.55	1289	1.46
$\pm W_a(\Delta C^o)$	-1393	+5.8	+1393	-94.2	0	-89.4
$\pm$ g (Cg)	+346	-8.92	-3946	-144.0	-3600	-152.32
	S^a_n=0.35	S^a_n=0.35	S^a_n=0.64	S^a_n=0.35	S^a_n=0.64	S^a_n=0.35

- initial content and composition of easily soluble salts in top fine-grained deposits;
- profiles of salt stock distribution in top fine-grained deposits;
- characteristic of top fine-grained deposits (conductivity, salt availability, etc.);
- rate of water exchange between groundwater and captured horizon;
- volume of groundwater inflow and regime of its chemical composition;
- initial salinity and salt composition of ground and shallow water;
- level of vertical drainage system operation, as well as desalinizing measures (character of leaching and irrigation leaching regime).

In appendix 9 variation of pumped water salinity is given over all represented pilot plots depending on natural-economic, geomorphological-lithological, hydrological-soil-meliorative conditions of objects.

Results, represented in appendix 9, show that in dependence of desalinization complexity of top fine-grained deposits and other above mentioned original factors, under vertical drainage system exploitation on individual experimental-production plot gradual salinity lowering was noted, on other plots - pumped water salinity increased.

In Chu valley, where top fine-grained deposits differ with high permeability of sediments and initial salinity of groundwater fluctuates within 3-30 g/l, easily soluble salt content was 0.5-1.2 % on dry residue with soda spots, only negligible variation of water salinity was observed (02.1 Kyr).

In SyrDarya river upper reaches in Fergana valley conditions, where top fine-grained deposits are represented by simplier categories of soil desalinization, pumped water salinity is subjected to fast changes. Range of pumped water quality variation depends on easily soluble salt content in top fine-grained deposits.

On wells, being located within Tashlak and Kuva rayons, where top fine-grained deposits are represented by non-saline soils with fresh groundwater (to 1.5 g/l), stable type of pumped water salinity change is formed with negligible fluctuation in process of vertical drainage long-term operation: within 0.3-0.5 g/l (02.17 Uz, appendix 9).

On lands of Kirov (Besharyk) rayon, where in top fine-grained deposits sufficient stocks of easily soluble salts are contained, salinity of pumped water by means of vertical drainage system changes quickly. In this zone wells depending on initial salt stocks in top fine-grained deposits, two types of change of pumped water salinity are formed:

- intensive-uneven. This type of change of pumped water quality is observed on massifs where in aeration zone of top fine-grained deposits big stocks of easily soluble salts are concentrated. In these conditions stop of certain quantity of wells operation and starting their operation result in abrupt change of pumped water salinity: in the beginning of operation period it increases during 6-7 years and then decreases. After long cessation of system operation starting operation causes secondary growth of pumped water salinity;

- moderate uneven with less range of fluctuation (0.3-0.5 g/l). This type of change of pumped water salinity is formed in conditions of negligible salt stocks in top fine-grained deposits.

On wells of Bagdad rayon depending on salt stock in top fine-grained deposits two forms of pumped water salinity change are observed:

- long moderate increase of salinity, formed in conditions of sufficient content of easily soluble salt in aeration zone;

- stable negligible change of pumped water quality which is formed by wells, being placed on desalinized fresh soils.

Within SyrDarya river basin middle reaches according to pumped water salinity change several characteristic types can be distinguished.

In old zone of Hungry steppe according to character of salt stocks distribution profiles in top fine-grained deposits, formation and hydrochemical regime of groundwater of captured horizon, as well as water-physical properties (fine-grained deposits desalinization complexity) three large regions above mentioned.

1. The north-east part of Hungry steppe - Shuruzyak and partially Bayaut massifs, with area 85-90 th ha and initial water salinity of captured horizon from 1.2 to 3.5 g/l (sometimes higher). Salinity type is hydrocarbonate or chloride-sulfate. Basic content of easily soluble salts is distributed in aeration zone. Groundwater salinity is high in top layers (10-15 g/l and more) that exceeds pumped water salinity by several times.

Multi-year observations of variations of pumped groundwater salinity and chemical composition showed that in conditions of intensified groundwater inflow from outside (1.5 th cu m/ha per year) during system operation gradual growth of pumped water salinity proceeded.

On Shuruzyak massif for 20 years of vertical drainage system operation pumped water salinity increased from 0.8-1.5 to 2.5-3.7 g/l on dry residue and from 0.2-0.4 to 0.5-0.8 g/l on chlorine-ion (dr. 2.17). More intensive growth of salinity is found in wells, being placed directly on irrigated fields, while on wells, being located near large canals, its values almost do not change. So, salinity of water from the well # 1, being located in 50 m from Shuruzyak inter-farm distributor for 20 years of operation almost did not change. Moreover, in these wells abrupt lowering of pumped water salinity is observed after each their long stopping (10-15 days).

With regard to researches data, duration of pumped water salinity growth in conditions of Shuruzyak massif is 13-15 years, after that firstly stabilization comes and then slow reduction of removed salt amount is found.

2. Central part of Hungry steppe - Sardob and Karoy sinks with area about 50 th ha with initial groundwater salinity of captured horizon 4.5-8.0 g/l. Salinity type is sulfate-chloride and chloride-sulfate. Groundwater inflow from outside is absent. Initial groundwater salinity either coincides or significantly exceeds (by 4 times) salinity of pumped water. Easily soluble salts are distributed here evenly along whole profile of top fine-grained deposits and their content changes within 2.5-3.5 % on dry residue. According to desalinization complexity top fine-grained deposits belong to very complex category, moisture and salt exchange proceeds here very slowly. In this zone 3 types of pumped water salinity changes are distinguished:

- slow salinity lowering. This type of pumped water quality change is formed on old-irrigated massifs under close groundwater and captured horizon water salinity and under relatively low level of system operation (workability coefficient is 0.4-0.5);

- stable - without special change of pumped water salinity. It is formed on old-irrigated massifs under low level of vertical drainage system operation (workability coefficient is 0.2-0.3). In similar conditions water exchange between ground and shallow water is so slowed down that salt quantity, removed from top fine-grained deposits into captured horizon, does not cause pumped water salinity change;

- salinity increase. This type is met on old irrigated lands with relatively low salinity of captured horizon water under normal level of systems operation (workability coefficient is 0.6-0.7). In particular, on Sardob massif these lands are placed near inter-farm canals, operated for long period (more 25-30 years).

3. The north-west part of Hungry steppe - Pakhtaaral, Djetysay and Kirov rayons of Chimkent oblast with gross area about 175 th ha. Captured water salinity changes widely within 3.5-7.0 g/l and more. The lower salinity corresponds to wells, being located near SyrDarya river and higher salinity - to Karoy sink. Salinity type is sulfate. Initial salinity of groundwater mostly coincides or exceeds pumped water salinity, that is characteristic for zones, where groundwater is formed basically due to irrigation water infiltration. Desalinization complexity of top fine-grained deposits belongs to simple categories. Here 2 types of salt distribution along profile are observed: even distribution of salt stocks over all thickness of top fine-grained deposits and profile with 2 maximums of salt accumulation: in aeration zone and on depth from 6-7 to 10-12 m.

Within this zone of Hungry steppe the following peculiarities in pumped water salinity change are determined:

- stable type, formed in conditions of old-irrigated lands, when salinity of groundwater and captured horizon water coincide. It includes wells, being placed in Pakhtaaral and Djetysay rayons farms. Exception are wells, operated on Sardob and Karoy sinks area;
- stable increase of salinity. It corresponds to lands with low salinity of groundwater in initial state, but having certain easily soluble salt stocks on top fine-grained deposits. Such type is met in wells, being placed near Kyzylkum and Karoy sinks.

Arys-Turkestan massif, where 504 vertical drainage wells are operated on area 52400 ha, is characterized by high conductivity of top fine-grained deposits and slightly saline soils with dry residue 0.2-0.5 % and low initial groundwater salinity within 2-5 g/l. In this zone hydrochemical regime of pumped water is formed according to stable type - water stays almost fresh - 0.5-1.5 g/l, seldom increasing to 2.5 g/l under vertical drainage system operation (02.1 Kaz, 02.2 Kaz and 02.14 Uz).

In SyrDarya lower reaches - on Kyzylkum massif about 275 of vertical drainage wells are operated in conditions of low thick (0.1-11 m) top fine-grained deposits, having increased conductivity. Easily soluble salts are distributed here on soils surface with content of dry residue within 0.3-1.0 %. Initial groundwater salinity is low - from 2 to 5 g/l. Complexity of top fine-grained deposits desalinization belongs to very simple category, therefore pumped water salinity under long operation of systems remains almost invariable - on level of initial value equaled to 0.8-17.0 g/l. Only in certain wells on rice systems groundwater with salinity within 1.0-3.5 g/l was observed, which remains stable for operation period.

In AmuDarya river upper reaches - in Vakhsh valley top fine-grained deposits are represented by medium and strongly saline soils with easily soluble content within 2.5-3.0 % and relatively low conductivity of soils, groundwater salinity is increased - 10-15 g/l and more, i. e. this zone could belong to complex category of desalinization.

In wells, being placed in this zone, increase of pumped water salinity is to 10.4 g/l against initial 6.0 g/l during operational period.

Characteristic regime of vertical drainage system operation, variation of pumped water salinity and chemical composition for this zone are shown in tables 2.23 and 2.24.

Table 2.23.

Vertical drainage system operation duration and abstracted water volume, th,m^3

Years	vertical drainage system - 1(VDS)		vertical drainage system - 2(VDS)		vertical drainage system - 3(VDS)		Total	
	duration	water volume	duration	water volume	duration	water volume	duration	water volume
1964	68	665	267	2882	306	3402	641	6949
1965	108	1006	163	1649	137	1390	408	4045
1966	173	1527	167	1643	158	1457	498	4627
1967	120	964	232	1890	129	1067	481	3921
1968	205	1563	226	1771	261	2468	692	5803
Total	674	5725	1055	9836	991	9784	2790	2345

Table 2.24

Drainage effluent salinity (VDS-2) and drain discharge during the leaching

Month	Discharge, l/sec	Salinity, g/l						
		Dry residue	HCO_3	Cl	So_4	Ca	Mg	Na
December	111	5,80	0,24	1,53	2,23	0,39	0,74	0,33
January	118	7,80	0,25	1,56	3,60	0,39	0,41	1,62
February	128	8,60	0,24	1,58	4,05	0,44	0,44	1,72
March	132	10,40	0,18	1,59	4,83	0,49	0,53	1,35
April	135	8,58	0,07	1,91	3,84	0,63	0,26	1,87
May	136	4,88	0,24	1,71	1,61	0,09	0,36	0,83
Jun	136	6,89	0,28	1,93	2,55	0,48	0,48	1,17
July	136	6,29	0,33	1,78	2,20	0,56	0,33	1,08

In AmuDarya river middle reaches - in Bukhara oblast, where 250 of vertical drainage wells function on area of 52.0 th ha, conditions of top fine-grained deposit desalinization are simplier, here easily soluble salts are accumulated in top 1.0 m active layer. Groundwater salinity is within 1.2-10 g/l, sometimes up to 40 g/l.

In some wells in this zone stable type of hydrochemical regime is observed, salinity stays close to initial, equaled to 1.5-3.0 g/l (02.31 Uz).

On lands with increased salinity pumped water salinity increase is found during 13-15 years of operation and then stabilization comes. So, in Kagan rayon of Bukhara oblast in some wells salinity growth was found from 1.0-3.0 g/l to 3-8 g/l (02.40 Uz, appendix 9).

Generalization of represented field researches on investigation of pumped water hydrochemical regime under vertical drainage wells long operation as in experimental-production plot conditions, so on large systems, shows that three periods can be distinguished in pumped water quality formation:

a) salinity increase;
b) relative stabilization;
c) salinity decrease.

2.2.7. Water abstracted use for irrigation and leaching

In 1966-1986 within Uzbekistan, Kazakh part of Hungry steppe, in Arys-Turkestan massif, as well as SyrDarya lower reaches about 500 of vertical drainage wells and more than 9.0 th of wells for water are constructed and used, main part of which operate in dry year. Only by means of vertical drainage wells annually about 2.8 km^3 of water (at level of 1990) is pumped and in perspective it is possible to obtain volume up to 6.64 km^3 per year (table 2.25).

On the most part of Uzbekistan, Kyrgyzstan areas in Arys-Turkestan and Kyzylkum massif and SyrDarya low reaches of Kazakhstan pumped water salinity fluctuated within 0.3-3.0 g/l. In previous chapter multi-year dynamics of pumped water salinity is shown on all represented experimental-production plots and large vertical drainage systems. Data show that of 28 objects, represented in the region, in 18-20 objects pumped water salinity is retained stable at rate of 0.8-2.0 g/l for all period (15-25 years) of vertical drainage system operation.

That is, in majority of them pumped groundwater salinity is within the limits, permissible for irrigation and leaching and only in certain areas, such as Sardob, Central massifs (02.04 Uz, N.Kalyuzhnaya) and the north-western rayons of Hungry steppe (02.12 Uz, 02.7 Uz), Khatlon oblast of Tadjikistan (02.1 Tad) it reached 5-7 and seldom 10-12 g/l.

Estimation of pumped water quality in wells, used in large vertical drainage system, is fulfilled by means of different local and foreign methods shows fitness of them for usage in order to conduct irrigation and leaching (table 2.26). From this table is evident that in many rayons vertical drainage development and pumped water use for irrigation and leaching does not create dangerous situation of sodification. Especially as, if respect that it is used only during short period (3-4 months) and the rest time it is disposed outside.

But possibility of saline water use, including groundwater, should be proved by field tests for conditions of specific object with regard to natural-economic peculiarities. In conditions of Central Asian republics certain experience of ground and shallow water application is obtained for agricultural crops irrigation and saline lands leaching.

In 1965-1970 in the state farm Pakhtaaral of Hungry steppe SANIIRI conducted researches on saline (4-6 g/l) pumped water use for cotton irrigation and saline lands leaching on area of 50 ha. Initial content of easily soluble salts in root zone was from 0.6-0.8 to 1.2-2.0 % on dry residue and 0.08-0.13 % on chlorine-ion. Salinity type is chloride-sulfate.

<u>Results of field researches on pumped water use for leaching</u>

Leaching was conducted from October 12 to December 20 in three gifts by total norm 7600 cu m/ha. For the first and the second irrigation by norm 3600 and 2000 cu m/ha pumped water was used, which salinity was 4.5 g/l. The third irrigation was conducted by irrigation norm 2000 cu m/ha, taking into account rainfall 680 cu m/ha it was 2680 cu m/ha. Before leaching groundwater table was 3.5-3.8 m and after its conduction raised to 1.2-1.5 m.

For leaching period (October) and before sowing (April) drainage modulus on the plot changed within 0.2-0.3 l/s/ha. In result of leaching soils were desalinized to depth of 1.5-2.0 m (table 2.27).

The following peculiarities were noted in dynamics of groundwater salinity under influence of leaching. After the second leaching gift groundwater salinity increased to 19.3 g/l against usual 6-7 and after the third gift it decreased to 13.4 g/l (table 2.28). This is connected with salts washing out from aeration zone.

So after leaching conducted in aeration zone (2.0-3.5 m) salt stocks are retained yet, which could cause salinity restoration under unfavorable conditions. Therefore, in next years autumn-winter leaching was continued for total desalinization of aeration zone soils and top layer of groundwater with pumped water use.

<u>Test result</u> of cotton irrigation with pumped water.

Pilot plot with area of 5.6 ha was splitted in 3 parts: on the first one pumped water was used with salinity 5.5-5.8 g/l on dry residue, including 1.2-1.3 g/l of chlorine-ion; on the second part - mixed water with total salinity 3.0-3.8 g/l (0.6-0.8 g/l on chlorine-ion); on the third part (control) - cotton irrigation with irrigation water, having salinity 0.65-0.75 g/l (fresh). Agromeliorative complex (initial conditions) was similar for all parts. According to this scheme test was conducting for 4 years.

Table 2.25

Vertical drainage development and perspective of abstracted water use

Province	vertical drainage by 01.01.86.				vertical drainage in perspective			
	number of wells-	capacity m^3/sec	flow, mln m^3		number of wells-	capacity m^3/sec	flow, mln m^3	
			total	flow which could be used			total	flow which could be used
1	2	3	4	5	6	7	8	9
Andijan	279	7.2	286.5	-	580	40	864	328
Fergana	768	19.0	514	-	840	20	432	216
Namangan	115	2.6	96	-	315	15	324	162
Tashkent	157	5.8	114.8	-	152	11	238	119
Djizak	144	2.6	33.2	-	300	10	200	20
Golodnaya steppe[x]	2000	53.2	1063	-	2102	107	2310	810
Samarkand	81	1.5	20.5	-	140	7	151	76
Bukhara[x]	445	13.6	157	-	728	26	562	280
Kashkadarya	358	7.0	85	-	763	23	497	215
Karakalpakstan	-	-	-	-	155	5	108	54
Total	**4391**	**108.8**	**2434**	**1590**	**7540**	**280**	**5832**	**2488**
Arys-Turkestan massif Chymkent province	504	3.5	95.0	95	600	10	270.5	200
Syrdarya low reaches Kyzylkum massif	275	11.0	298	290	350	20	540	450
Total	**5170**	**123.3**	**2827**	**1975**	**8490**	**310**	**6642.5**	**3138**

Note: [x] In total number of wells in Syrdarya oblast some wells from Golodnaya steppe are included, the same is done for wells from Navoy to Bukhara oblast.

Table 2.26

Assessment of abstracted water quality in Uzbekistan

Methods and criteria	Golodnaya steppe				Fergana valley	Bukhara province
	Shuruzyak massif	Bayaut massif	Sardoba massif	North-Western part		
CL/SO_4 (SANIIRI method)	0.3-0.65	0.35-0.7	0.3-0.97	0.45-0.8	0.07-0.6	0.15-0.35
Antipov-Karatayev's method: $K = \frac{\text{ч}Ca + \text{ч}\,Mg}{\text{ч}Na \,.\, 0.23 \,.\, S} > 1$	1.13-1.4	0.27-1.5	0.17-0.7	0.44-1.4	0.15-4.5	1.05-3.3
Budanov's method: $K = \frac{SS \,.\, \text{в}}{Ca + Mg} > 4$	4-5	4.3-5.5	4.6-6.5	4.4-5.3	3.05-5.0	2.5-3.4
Mozheiko and Vorotnikov's method: $K = \frac{Na \,.\, 100}{Ca + Mg + Na} < 66\ \%$	55-60	55-70	59-73	53-72	24-37	19-25
$NaSAR = \frac{}{\text{Ц}\,\frac{Ca + Mg}{2}} < 8\text{-}10$	4.5-8	4.8-10	12.3-25	8.1-21.5	2-4.5	1.36-5.0

Methods and criteria	Golodnaya steppe				Fergana valley	Bukhara province
	Shuruzyak massif	Bayaut massif	Sardoba massif	North-Western part		
Kelly and Libich (USA): $K = \frac{Na}{Ca + Mg} > 1.0$ or	1.30-1.65	1.4-1.75	1.5-3.0	1.6-2.5	0.35-0.55	0.23-0.5
$K = \frac{Mg}{Ca + Mg} . 100 < 60$ %	50-62	55-65	31-50	45-85	48-60	42-50
Irrigation coefficient (after Stebler) $K > 2$	2-6	2-8	0.5-2.0	0.5-6	4.5-18	2-14

<u>Note</u>: in formulae чCa, чMg, чNa - mg-equivalent of cations' concentration;
S - water salinity, g/l. If SAR < 10 - water is good; if SAR = 11-20 - satisfactory.
After Stebler: if Ê< 2 - water is less satisfactory, Ê = 2-6 - satisfactory, Ê = 6-18 - water is good.

Table 2.27

Soil salt regime dynamics under irrigation by saline water

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Horizont м	salt concentration on chlorine-ion, % of soil mass (average from 6 points)				
	initial	after tact I	after tact II	after tact III	salt concentration change compared with initial one, %
0.0-0.2	0.126	0.026	0.022	0.017	-86.6
0.2-0.4	0.092	0.042	0.033	0.018	-80.5
0.4-0.6	0.079	0.077	0.054	0.025	-68.4
0.6-0.8	0.069	0.089	0.060	0.034	-50.7
0.8-1.0	0.066	0.082	0.064	0.048	-27.3
1.0-1.2	0.064	0.074	0.071	0.048	-25.0
1.2-1.4	0.054	0.066	0.080	0.057	5.5
1.4-1.6	0.054	0.063	0.069	0.055	1.8
1.6-1.8	0.052	0.063	0.076	-	-
1.8-2.0	0.050	0.051	0.086	-	-
2.0-2.5	0.044	0.054	-	-	-

Table 2.28

Ground water salinity changes under irrigation by saline water

Salt composition	water salinity, g/l			ground water upper salinity after each tact leaching, g/l		
	abstracted	irrigation	ground water	I	II	III
Salt amount	5.13	0.68	7.35	13.3	19.3	13.4
	1.30	0.04	0.62	2.5	3.3	1.8
	2.40	0.36	3.16	6.4	9.3	6.4

Water-physical properties of soils are similar to the plot, where saline lands leaching was conducted. On all sections annually autumn-winter leaching was carried out by norm 3400-4000 cu m/ha (with irrigation water). In the vegetation period in 2-3 irrigations (July-August) by total norm 3000-3200 cu m/ha (with pumped water). Total annual water supply, including precipitation, was 9.0-10.0 th cu m/ha, of which 7.0-7.5 th cu m/ha was spent for evaporation and transpiration, the rest - for infiltration.

In general water-salt balance of sections, where irrigation water and mixed water with salinity appropriately 0.7 and 3.3 g/l was used for cotton irrigation and irrigation regime with total annual water inflow of 9.0-10.0 th cu m/ha, prevents salinity restoration and provides gradual desalinization of soils. In order to obtain this result under use of pumped water only it is necessary to increase water supply in vegetation period up to 3500-4000 cu m/ha (net). Groundwater table should be kept on depth 2.5-3.0 m, otherwise salinity restoration will happen.

At the same time theoretical calculations show that under irrigation water salinity 3-4 g/l for prevention of salinization it should be supplied within 4400-7200 cu m/ha (under groundwater salinity 12 g/l) and within 6100-9400 cu m/ha (under groundwater salinity 16 g/l) depending on groundwater table.

Positive result under pumped water use, having salinity to 3.0 g/l, was obtained in tests, conducted in the state farm Yakkatut of Fergana oblast (02.24 Uz, T.Bekmuratov). Here is found that under pumped water use with salinity up to 3.0 g/l, groundwater table is to be regulated within 2.5-3.0 m. In this case optimal water-salt regime is obtained under irrigation norm of 6325-6700 cu m/ha (net field).

In experiments, conducted in conditions of low thick top fine-grained deposits ($M_п$=2-10 m) of Kyzylkum massif, is found, that without additional measures on prevention of salinization and sodification of soils pumped water with salinity up to 3.0 g/l may be used for irrigation. On Kyzylkum massif of 275 wells more than 60 % has salinity of water lower than 2.0 g/l. Total capacity of these wells is 6.0-6.8 cu m/s (M.Djurayev, 1990; 02.14 Uz). Optimal water-salt regime is obtained under irrigation norm 8.5-10.0 th cu m/ha, that meets requirements of irrigation leaching regime on vertical drainage system background. On the other hand, groundwater table is recommended to be regulated within 1.9-2.6 m in vegetation period and 2.1-3.4 m in non-vegetation period.

In general, over the region there are many tests on saline shallow and groundwater use (including collector-drainage), results of which are generalized in direction III of report and in special papers of N.Reshetkina and Kh.Yakubov (1978), A.Usmanov and oth. (1981), F.Rakhimbayev and oth. (1978), V.Dukhovny, N.Khodjibayev (1974), M.Yakubov (1988) and many others.

In given works it was determined by researches that under high drainability loam soils can be irrigated with water, containing 4.0 g/l of salt, light soils can be irrigated with water, which salinity is 6.0 g/l. Runoff should be 10-20 % of water supply. In tests available it was found that pumped water use for irrigation in conditions of light soils according to structure does not effect agricultural crops yield capacity and, as usual, it is not lower than in control variant (irrigation with ditch water). In middle-loamy soils difference in crop yield capacity under drainage water use could be 3-5 c/ha depending on soil-meliorative conditions and agrotechnical methods.

So, theoretical study on estimation of ground pumped water properties and multi-year field tests on their use for irrigation and leaching confirm prospectivity of such water application.

2.2.8. Meliorative-ecological processes management by means of vertical drainage and selection of optimal irrigation meliorative regime

Meliorative measures, effecting soil formation (irrigation, leaching and drainage), mainly influence directly water-salt regime of soils and groundwater. Big ecological significance of reclamation, in the first turn, is systematic scientifically grounded increase of soils fertility, irrigation water productivity and their resistance to negative phenomena.

The basic positive components of water inflow into soil under conditions of arid zone irrigation are water supply, precipitation and groundwater. Water expenses are mostly for evapotranspiration and outflow of infiltration water from soil layer downward.

Changing irrigated lands water regime (soil moisture and surface water) meliorative measures influence on change of not only soil but climatic and hydrogeological conditions (surface and groundwater regime).

Management of irrigated areas meliorative-ecological processes is possible by means of changing composition and relation between positive and negative water components, that in result will define type of water and related to it salt regime, i. e. soil-meliorative regime.

In principle, on irrigated lands 4 types of meliorative regime can be created (hydromorphous, half-hydromorphous, half-automorphous and automorphous), characterized by different groundwater regime, its participation in soil formation, plant feeding, specific structure of common and partial water-salt balances.

In the table 2.29 basic indicators of meliorative regimes under different types of soil profile are shown. They are applied for drainage operational period. In meliorative period in the majority of cases groundwater table should be kept some what deeper and irrigation leaching regime should be conducted.

All types of meliorative regimes, depending on meliorative state of lands, can be leaching, periodically leaching and non-leaching.

Selection of one or other developed meliorative regime should be based on deep and detailed analysis of geomorphological, hydrogeological, soil-agronomical and meliorative conditions, allowing to define soil formation tendency and further outline complex of technical and agrotechnical measures for keeping and regulation of regime chosen.

For directed regulation of soil meliorative regime it is necessary to determine relations between average state (water, aerial, salt and water recharge state of root zone thickness), regulating factors (water supply, drainage, agrotechnical methods, etc.) and their interrelations indicator (growth and development of crop cultivated). At the same time, there is rather certain water-salt regime of root zone, corresponding to biological requirements of this agricultural crops development (reference). Therefore, the main task is to regulate water inflow, including salts from the different sources, to retain chosen water-salt regime of root zone and means for its obtaining (irrigation, drainage, etc.) were it is the most profitable. Similar task can be solved by means of analysis of formation and expenses of certain components of water-salt balance.

While ground of large regions reclamation with the help of systematic drainage lateral groundwater inflow and outflow may be excluded from calculation. As basic equations of water-salt balances are shown in section 2.2.4. of given report, so equation of water-salt balance of aeration zone and groundwater should be considered closely.

In simplificated kind (without account of inflow and outflow) water balance of aeration zone is the following:

$$\Delta \mathbf{W_a} = \mathbf{O_c} + \mathbf{B} - \mathbf{E\text{т}_п} \pm \mathbf{g}\,, \ \mathrm{m^3/ha}$$

Table 2.29

Reclamation regime and main criteria of meliorative well being under different types of soil profile

Type of reclamation regime	Type of soil profile					Water balance elements ratio		
	regular sand deposits (thin- and medium grains, barkhan) [1 - â]	sandy-loam, loam deposits (0.5-1.0 m) on sandy and pebble deposits [1 - a]	regular light and medium loam [2-á], [3-a], [2-â], [3-â]	sandy loam, sandy underlaid by heavy loam and clay [3-á], [4-á]	heavy loam, clay [4-a], [4-á]	ÅÒâ / ÅÒï	Qn / Â+Ô	$Î_{ð}$ + $Î_{ñ}$ / $ÅÒ^{ê}_{n}$
Groundwater depth from surface, m								
Hydromorphous	0.6-1.2[õ] / 0.9-1.5	0.6-1.2 / 0.9-1.5	0.6-1.8 / 0.6-2.1	0.6-1.2 / 0.9-1.5	- / -	0.5-1.0	0.30	1.05-1.1
Half-hydromor-phous	1.2-1.5 / 1.5-1.8	1.2-1.5 / 1.5-1.8	1.8-2.5 / 2.1-2.8	1.2-2.0 / 1.5-2.3	- / -	0.2-0.50	0.30	1.05-1.1
Half-automor-phous	1.5-2.2 / 1.8-2.5	1.5-2.2 / 1.8-2.5	2.5-3.5 / 2.8-4.2	2.0-2.5 / 2.3-2.8	1.5-2.5 / 1.8-2.8	up to 0.20	0.30	1.05-1.1
Automorphous	deeper 2.2 / 2.5	deeper 2.2 / 2.5	deeper 2.5 / 4.4	deeper 2.5 / 2.8	deeper 2.5 / 2.8		0.30	1.05-1.1

Explanations:
$ÅÒ_{ã}$ - share of groundwater contribution to agricultural crops water consumption, m^3/ha; $ET^{â}_{ï}$ - evapotranspiration during growing period, m^3/ha;
$Q^{Î}_{ï}$ - share of drainage outflow forming at expense of surface infiltration (for example, under Ï, Î, Ð equal to 0 (vertical drainage) it equals
$Q^{Î}_{ï}$ = $Ä_{ã}$+$Ä_{â}$; Â+Ô - water supply and losses from canals, m^3/ha; $ÅÒ^{ã}_{ï}$ - evapotranspiration from irrigated field per year, m^3/ha; $Î_{ð}$ - water supply to irrigated field, m^3/ha; $Î_{ñ}$ - precipitation, m^3/ha; [1-â] - type of soil profile;
* - above- groundwater depth during vegetation of cotton field; beneath - the same for lucerne.

where $B = O_р + B_{вр} + B_{КДС} + (1 - L)\ Ф_{в/х} - C_п$,

for areas with systematic vertical drainage under $\psi = 1$ (areas of experimental plot systems) balance of groundwater of top fine-grained deposit may be described as:

$$\Delta W_{гр} = \quad . \Delta h = \pm g - Д_г \pm Q_п$$

Under systematic horizontal drainage groundwater balance is the following:

$$\Delta h = \pm g - Д_г \pm P,$$

$\pm g$; $Д_г$; $Q_п$; P influence of groundwater table.

Mark in $\pm Q = Д_г + Q_п$ и $\pm Q = Д_г + P$, as in both cases they influence groundwater table from beneath. Positive sign (+ Q) means predomination of inflow from beneath over outflow.

Water exchange of aeration zone with groundwater may be found in the simplier way from the following equation:

$$\pm g = \pm \quad . \Delta h \pm Q$$

Under consideration of different options of combinations of signs Q and Δh for each case sign of water exchange between aeration zone and groundwater (in comparison with aeration zone) and its maximum value are defined.

Obtaining known meanings $\pm g$, $\pm W_a$ under the different combinations ET $(B+O_c)$ and, with regard to soil moisture energetic ideas, sources of formation and expenses of certain balance components are calculated for all options.

Meliorative regimes formation

Hydromorphous meliorative regime is formed under permanently shallow groundwater, when their capillary fringe actively participate in soil formation. In natural conditions hydromorphous regime is typical for lower river terraces, flooded plains and seaside deltas, as well as pre-mountainous slopes with artesian rising shallow groundwater in zones of seepage and dissipation. In conditions of low drainability salt regime of hydromorphous soils is formed positively and soil salinization is observed. Under high drainability meadow soils are formed on fresh groundwater. In semi-desert and desert soil zones under low natural drainability of lands hydromorphous meliorative regime with stable favorable conditions for plants growth and development can be created only on the background of well-operated artificial drainage.

One of the specialties of hydromorphous soils salt regime is positive salt balance in vegetation period (often in substantial volume). So, soils desalinization is carried out mainly in non-vegetation period.

Researches, conducted by scientists (SANIIRI, etc.) in hydromorphous regime conditions, showed that on strongly saline lands on the background of well-operating drainage under irrigation norms 6000-7000 cu m/ha and leaching norms 4000-5000 cu m/ha for 2-3 years it is possible to desalinize lands totally. But at the same time negligible deviations because of irrigation leaching regime application on these lands even under high drainability can cause salinity restoration. Therefore, hydromorphous meliorative regime should be appointed only in zone of seepage of fresh groundwater or in rivers flooded plains.

Automorphous meliorative regime is formed in conditions of deep groundwater, when it does not participate in soil formation.

On irrigated lands similar regime can be formed as on the background of high natural drainability, so under artificial drainage (for example, by means of vertical drainage).

On these lands under available now irrigation technique (on furrows) it is difficult to regulate of volume water infiltration from fields and for keeping optimal moisture of top soil irrigation water has to be over spent. Here leaching regime is formed periodically in aeration zone (at the expense of groundwater infiltration recharge in the vegetation period and in periods of plentiful winter-spring rainfalls) that allows to gradually desalinizing soils profile.

If natural or artificial drainability is absent on lands with initial automorphous regime, gradual groundwater recharge proceeds due to infiltration water and groundwater table slow rise. The same situation is observed in all new developed lands of Central Asia, in particular, Karshi and Djizak steppes. Lithilogical cross section of top 20 meter layer is represented here by diverse thickness of rocks: from light loam and sandy loam to heavy loam with sand and clay interlayers. Under natural automorphous meliorative regime water supply to irrigated field (precipitation and water supply) during the year is spent mostly for evapotranspiration and less - for recharge of aeration zone and groundwater moisture storage (Kh.Yakubov et al.). Infiltration into groundwater proceeded in summer - in period of mass irrigation and partially in the non-vegetation period, when there was high precipitation. As drainage was absent, it led to groundwater table raise on average on 2 m per year under initial 13-16 m and the secondary soil salinization, though on irrigated field leaching regime $(B+O_c/ET)=1.3-1.4$ was kept annually.

In these conditions for formation of really negative salt balance artificial drainage is to be constructed, which would provide disposal of descending desalinizating overflow from aeration zone, sustainable groundwater table at optimal depth.

At present time there is no practical experience of creation of soil formation automorphous regime by means of artificial drainage on old irrigated lands. However, on areas with relatively low thick top fine-grained deposit (6-8 m), reclaimed by systematic vertical drainage, due to formation around deep-water wells plots with soils automorphous meliorative regime are created.

For example, vertical drainage system experimental-production plot is located in Kirov rayon of Fergana oblast (02.24 Uz, T.Bekmuratov, 1983), where around certain wells on distance of 50 m plots with automorphous meliorative regimes, with deep groundwater table to 4.5-5.2 m under land surface were created.

As under automorphous meliorative regime and available technique and technology of irrigation, unproductive losses for infiltration are inevitable so prospective of this meliorative regime can be decided only after perfection of irrigation technology, which introduction will provide minimal volume of percolation.

Half-hydromorphous regime is formed in conditions of shallow groundwater table. In natural conditions these are low river terraces and river deltas with fresh and brakish groundwater, seaside plains. Under lands reclamation this type of meliorative regime can be formed in other geological-geomorphological conditions, in particular, in conditions of artesian groundwater recharge and insufficient drainability.

Half-hydromorphous regime was created on experimental-production plot of the state farm Pakhtaaral (02.7 Uz, 02.11 Uz) before vertical drainage construction (1961-1965). Specific length of open collector-drainage system in the state farm was 6.9 m/ha. In the farm in considered period groundwater was on the depth of 1.5-2.8 m. Moisture storage in layer of 0-20 cm before irrigation was 72-83 % of full field capacity (FFC) and in horizon of 20-40 cm - 80-100 % of full field capacity, that is moisture in soil was not observed. Lower 40 cm water storage much exceeded full field capacity.

On lands of the state farm extra infiltration during irrigation, exceeding water lack, promoted groundwater table rise and evaporation intensification.

Under low drainability of lands and practiced in these conditions irrigation norms 1500-2000 cu m/ha and leaching irrigation in autumn-winter period by norms 2000-2500 cu m/ha, common water-salt balance was formed as positive with annual salt influx of 6-7 t/ha.

Therefore, lands meliorative state here aggravated from year to year. Cotton crop yield capacity decreased for several years from 38.5 to 19.6 c/ha. In these conditions for soils meliorative regime improvement artificial vertical drainage system was constructed.

Typical example of soils optimal half-hydromorphous regime creation is vertical drainage experimental-production plot in Kirov rayon of Fergana oblast (02.24 Uz). Here in artesian groundwater conditions under intensive vertical drainage system operation half-hydromorphous regime was mostly provided. In vegetation period on the most part of area groundwater table fluctuated from 1.88 to 2.45 m, on average per year from 2.03 to 2.75 m and on the background of irrigation leaching regime here since 1970 till 1975 water-salt balance tendency and lands meliorative state were sufficiently improved (see section 2.2.4), providing by that cotton crop yield capacity 38-45 c/ha.

Half-automorphous meliorative regime is formed under relatively deep groundwater table and differs with the less participation in soil formation, than under half-hydromorphous regime. In natural conditions these rayons of ancient deltas, seaside and proluvial plains, often with saline groundwater and deep salts soils. On vertical drainage background half-automorphous regime can be formed practically in any hydrological conditions.

Example of half-automorphous regime is for conditions of the state farm Pakhtaaral on vertical drainage system experimental-production plot - after system starting operation.

In half-automorphous regime water storage before cotton irrigation in 0-20 cm layer lowers more than in half-hydromorphous regime and fluctuates within 12.6-16.9 %, 0.6-0.8 of FFC. In layer of 0.2-0.4 m they are 15.7-19.1 % (0.77-0.94 of FFC).

Results of calculation of water balance elements structure formation under half-automorphous regime showed that during vegetation period evapotranspiration was formed due to water supply and partially at the expense of aeration zone and groundwater storage. Water supply is totally spent for evapotranspiration, that caused negligible water recharge of root zone from groundwater and creates low salt accumulation in soil for season. However, preventive leaching of lands in autumn-winter period and rainfalls provide lands desalinization.

On lands with half-automorphous regime in the state farm Pakhtaaral of Hungry steppe cotton crop irrigation by norm 3200-3500 cu m/ha and leaching by norm 2560-3000 cu m/ha on slightly and medium saline soils, 5000-6000 cu m/ha on strongly saline ones provided favorable meliorative processes. Half-automorphous regime advantage was reflected in fact that in the first half of vegetation under high physical evaporation from soil surface groundwater share in common evapotranspiration is very low.

In total under half-automorphous meliorative regime unproductive losses are reduced and irrigation water is used more fully, drainage outflow volume is reduced, as well.

Similar results are obtained on all large vertical drainage systems, where groundwater table was regulated by half-automorphous regime: in winter-spring period - within 1.5-2.0 m, vegetation - 2.6-3.0 m and autumn period - 3.0-3.5 m. Therefore, under modern level of irrigation technique while designing vertical drainage system the best of all is to create soil half-automorphous meliorative regime. When irrigation technique will be developed, providing management of irrigation water expenses for infiltration, the best of all is to form automorphous meliorative regime on the background of vertical drainage.

Analysis and generalization of multi-year results of field researches on all objects, actual water-salt balances and formed meliorative regime over represented pilot plots of vertical drainage system allowed to develop rational parameters of meliorative regimes, which are represented in table 2.30, for different natural-economic conditions of Uzbekistan and South Kazakhstan.

2.2.9. Active zone of water and salt exchange under drainage systems operation

One of undesirable ecological consequence of "unlimited wide-scaled" development of irrigated farming in Central Asia, begun in 50s and 60s, is significant water resources shortage and sharp aggravation of all rivers flow quality in the region and especially SyrDarya and AmuDarya. The basic provider of ingredients in river trunk is collector-drainage outflow, formed on irrigated lands. Almost all Aral Sea basin regions participate in process of pollution from upper to low reaches of rivers. However, according to ingredients "delivery" they differ each other depending on natural-economic conditions and drainage parameters, but they are salts providers.

Under lands artificial drainage characteristics of water complex and drainage parameters supposes water exchange zone formation. The main factors, which influence water exchange zone formation are aquifer thickness, soil cleavage and impermeable layer position. Formation of active influence zone under drainage operation is effected not by its depth but drain spacing. According to theoretical solutions under systematic drainage operation with alternation of field drains and collectors under drain spacing **B=3T** (**T** - aquifer thickness) whole thickness of aquifer participates in drainage outflow formation independently on drain depth. When drain spacing is reduced, drainage influence on the depth of water exchange zone formation decreases. As field drains alternate with collectors, whole thickness of aquifer takes part in drainage outflow formation. When impermeable layer is close to land surface under systematic drainage, whole thickness of aquifer complex participates. At the same time intensity of drainage modulus formation (outflow) depends on drainage depth, which creates head gradient, i. e. water exchange in system between aeration zone and groundwater zone. N.Khodjibayev and Ya.Neyman, basing on results of design and field researches give for soils, prevailing in Central Asia, the following values of active influence zone under groundwater influence:

- in light soils (silty sands and sandy loam K_f=0.5-2.0 m/day) - h=50-100 m;
- in middle soils (light loam and middle loam K_f=0.5-1.0 m/day) - h=50-100 m;
- in heavy soils with permeability K_f=0.1 m/day, h=10-30 m,

h - drainage operation influence zone.

According to V.Bobchenko data in homogenous aquifer extension of filtration flows with availability 90 % is restricted by depth equaled to 1/6 of drain spacing, under **m=(6-30)t** filtration flows extent lower drain level on depth of **m<3t**. So, under drains spacing 300 m filtration flows remove salts from depth of 50 m and under h= 30m from depth of 5 m, where **m** - aquifer thickness, **t** - drain depth.

In pilot projects, represented in IPTRID register, there is certain information on zone of active water and salt exchange, obtained on the background of close horizontal drainage. In AmuDarya lower reaches, represented by flaky soils on big depth (100-150 m) with top fine-grained deposit 3.0-3.5 m with sub-artesian groundwater on the background of close drainage with depth 2.5-3.0 m and drain spacing 250-300 m drain influence extents up to 50 m (02.20 Uz).

Table 2.30

Parameters of optimal meliorative regimes recommended for different natural-economic conditions of Uzbekistan and South Kazakhstan

Soil-meliorative and hydrogeological conditions	Reclamation regime (recommended)	Groundwater depth within a year				Abstracted water volume to water intake ratio, %	water supply exceedance over total evaporation, %	Agricultural crops water consumption at expense of groundwater, %
		X - XI	XII - II	III - IV	VI - VIII			
Heavy.Medium and strongly saline lands over the area of 50 % with groundwater salinity more than 10 g/l, m = 20-25 m, $K_ф$ = 0.1 m/day	half-auto-morphous	3.5-4.5	1.4-1.5	2.2-2.7	2.7-3.5		25-30	2-12
Golodnaya steppe						35-40		
Fergana valley						50-80		
Medium. Medium and strongly saline lands over the area of 30-50 %, m = 15-30 m, $K_ф$ = 0.1-0.2 m/day	half-auto-morphous	3-4	1.4-1.5	2-2.5	2.5-3.0		20-25	5-15
Zarafshan oasis						30-35		
Fergana valley						40-50		
Karshi steppe						30-35		

Soil-meliorative and hydrogeological conditions	Reclamation regime (recommended)	Groundwater depth within a year				Abstracted water volume to water intake ratio, %	water supply exceedance over total evaporation, %	Agricultural crops water consumption at expense of groundwater, %
		X - XI	XII - II	III - IV	VI - VIII			
Light. Medium and strongly saline lands over the area of less 30 %, $K_ф$ = 0.2 - 4 m/day Fergana valley Zarafshan oasis	half-hydro-morphous	2.5-3	1.4-1.5	1.8-2.4	2.4-2.5	35-45 30	15-20	20-40

Note: m - top soil thickness, m.
$K_ф$ - top soil permeability coefficient, m/day.

After Kalantayev data (02.1 Turk and 02.2 Turk) in conditions of limited water of aquifer on the background of close drainage on depth of 3.0 m with zero gradient under L=250-300 m active water exchange zone changes within 20-35 m.

On rice crop drainage system, located in AmuDarya lower reaches in conditions of flaky soils with thickness of more than 150-200 m on the background of close drainage with depth of 2.5-3.0 m, under drain spacing L=200-350 m under rice crop irrigation filtration flows are spread on depth to 100-110 m (A.Nabiyev, 02.25 Uz).

On pilot object 02.35 Uz (G.Baturin) which is located in conditions of proluvial-alluvial deposit of removal cone in the southern part of Hungry steppe under low impermeable layer with depth of 15-20 m on the background of close horizontal drainage on depth of 2.8-3.5 m under L=250-300 m active water and salt exchange zone was 16-17 m and it corresponded to piezometers depth. In the same farm (state farm # 6), but in other pilot (02.27 Uz), where aquifer thickness was spread to depth of 200-250 m, under similar parameters of close horizontal drainage active water and salt exchange zone changed within 45-110 m and, finally, in conditions of Chu valley, where lithology of plot is represented by flaky deposits, active water and salt exchange zone under close horizontal drainage operation was 10 m, i. e. it corresponded to information obtained by means of piezometers. Approximately the same situation of active water and salt exchange zone formation is observed on vertical drainage system background. So, water and salt exchange zone formation depends, on the one hand, on space between wells, on the other hand, on vertical drainage system destination (local drainage or systematic). In any case, under systematic drainage the whole thickness of aquifer takes part in drainage outflow formation and under local vertical drainage and thick aquifer its top part participates in outflow formation. However, on vertical drainage system background formation groundwater participate more intensively in drainage outflow than on close horizontal drainage background and depends on inflow from outside. The larger systematic drainage area, the less the share of water supply at the expense of external inflow. In vertical drainage system, such as old zone of Hungry steppe with area of 350-400 th ha, practically, drainage outflow is formed due to surface water supply, given to the fields and irrigation systems.

After A.Soyfer data in local vertical drainage system during its exploitation zone of pumping effect is spread to depth of 1.5 h (hell depth). With regard to SANIIRI observations pumping depth influence depends on character and aquifer thickness. In two-horizon water complexes with limited thickness the whole thickness of aquifer participates actively in filtration flow formation.

In conditions, when large area is covered by systematic vertical drainage, where aquifer thickness reaches 150-250 m and more, pumping active effect zone plays big role increasing groundwater share in drainage outflow. Due to groundwater share increase in drainage outflow in conditions of artesian aquifers salt flow grow as well (dr. 2.18).

From data of dr. 2.18 it is obvious that in conditions of non-artesian and low head aquifer salt removal volume from irrigated lands, practically, is the same as for horizontal, so for vertical drainage, that proves equal influence on active water and salt exchange zone formation systematic vertical drainage operation in case of large massifs or regions, the whole aquifer thickness takes part in filtration flows (active zone) formation, as under close horizontal drainage background, so under vertical drainage. Nevertheless, different types of drainage participation intensity in salt flow formation is different: in vertical drainage system it is more intensive, than in horizontal drainage. At the same time under operation of both (close horizontal drainage and vertical drainage system) salt exchange intensity is found, different.

Drainage salt outflow intensity mainly depends, on the one hand, overflow volume from aeration zone to groundwater (g); on the other hand, on salt stocks and their distribution in top fine-grained deposit thickness, as well as ground and shallow water salinity. In drainage salt outflow formation ground and shallow water salinity changes on to depth is very important. In this direction during 1965-1980 SANIIRI defined that geomorphologic particularities of irrigated area in Central Asia (pre-mountains, river inter-mountain valleys, alluvial plains, removal cones, sinks between cones, low deltas and high river terraces) in combination with conditions of groundwater regime formation and thermal regime of soils, as well as balance of surface and groundwater, define principal differences of initial salt stock and profile, as soil layer, so underlain, top fine-grained deposit soils. Over irrigation rayons 6 types of salt profiles were defined in top fine-grained deposit on depth of 20-30 m, which determine drainage salt outflow intensity under development of irrigation and reclamation of lands (dr. 2.19).

The I type. Non-saline profile for all thickness of quaternary deposits. Similar type of salt profile corresponds to upper plots of removal cone, mountainous, pre- mountainous, upper and partially middle river terraces. Lithology of these rayons is represented from surface by top fine-grained deposit of low thickness (1.0 m), underlain by gravel-pebble deposits. Conserning hydrogeology, this is zone of groundwater intensive transit with deep groundwater table. Surface and ground water exchange is intensive due to high water losses, as from canals, so from irrigated fields. On this area salt exchange is practically absent and it does not participate in the region salt flow.

The II type. Strong salinity of top layers of soils (to 2.0-2.5 m), downward soil is almost desalinized. In some regions, as Khorezm oasis, Zerafshan valley, Kyzylkum massif, only soil layers to 1.0 m are saline. Similar type of surface accumulation of basic salt mass is formed in low river teraaces, tail parts of removal cones, inter-mountain plains, alluvial plots of river deltas, with top fine-grained deposits (3-25 m), which is underlain by gravel-sandy deposits. Area is characterized by weak natural drainability with relatively shallow initial position (3.0-3.5 m after irrigation) (Shuruzyak-Sardob massif of irrigation, old zone of Hungry steppe, Kyzylkum massif of South Kazakhstan, Khorezm oasis, etc.). Groundwater are mainly artesian (Central Fergana, old zone of Hungry steppe) or sub-artesian (Khorezm oasis, Tashauz oblast). There are non-artesian aquifer complexes, such as Zarafshan oasis (Zarafshan river middle reaches), the northern and southern zones of Karakalpakstan, Kyzylkum, Toguz-Chiyli massifs, etc.

In pointed geomorphological-hydrogeological regions groundwater table is shallow - 1.5-2.5 m, groundwater salinity is various: on irrigated lands - 3-5 g/l; on non-irrigated and fallow lands is very high - to 40-50 g/l. In Khorezm oasis groundwater salinity to depth 25-30 m is relatively low- 3-4 g/l and with depth it growth up to 15 g/l.

According to water exchange intensity pointed geomorphological-hydrogeological regions, where the II type of salt profile is formed, belong to the group of water exchange high category and is defined by top fine-grained deposits conductivity. Water exchange volume between aeration zone and groundwater is determined by water supply volume and losses from irrigation canals. Drainage outflow is formed due to shallow water overflow and groundwater head.

Intensity of salt exchange and drainage salts outflow depends on salt content in top fine-grained deposits and overflow volume from aeration zone and top fine-grained deposits. On the most part of area vertical drainage system and combined horizontal drainage, intensified by vertical drainage system are developed.

The III type. Non-saline profile of limited depth (to 1.0-1.5 m) with abrupt increase of salt content to 5-8 m and then its stock lowering in lower layers - deep salts soil. This salt profile corresponds to deluvial-proluvial plains and deposits between channels before irrigation development. Salt stocks in 1-meter layer are less than maximum permissible value and change within 30-150 t/ha, in 3-meter layer - to 1600 t/ha and in 20-meter layer - to 2000 t/ha. Lithology of pointed geomorphological structures are represented, mainly, by one-layer complex of deposits from low permeable soils with interlayers and lenses of small- and fine-grained sands and sandy loam. Area, where the III type of salt profile is formed, is weakly drained or non-drained in natural conditions. Groundwater table before irrigation usually is relatively deep: 5-10 m and deeper. Groundwater is saline. Salinity changes widely from 10-15 to 25-40 g/l. In these regions during irrigation secondary salinization proceeds, mainly due to saline water rise. Examples are the south-eastern and south-western parts of Hungry steppe, sinks between cones, group of rayons of Fergana valleys, Djizak-Lomakin region.

Water exchange intensity between aeration zone and groundwater is moderate and depends on water supply volume and drainage workability. Intensity of salt exchange and drainage salts outflow is moderate and sometimes very high and depends on salt stocks in upper part of quaternary deposits and water exchange volume between aeration zone and groundwater (desalinizating discharge - g). Regions with formation of the III type of salt profile are one of basic salt providers during lands irrigation.

The IV type. High salt content in top layers of soil with their stocks increase downward the profile to the depth of 12-15 m. Salt stocks in 1-meter layer exceed by 3-4 times permissible values for usual plant growth and change within 350-500 t/ha. Salt content in 3-meter layer reaches 600-700 t/ha and in 20-meter layer - up to 1500 t/ha. Similar type of salt profile is usually formed in tail parts of small rivers removal cones, in lake deposits of SyrDarya and AmuDarya river deltas. Lithology is represented, mainly, by one-layer complex of deposits and in some places (seldom) by two-layer as tongue-shaped lenses and small- and fine-grained sands interlayers. Area, practically, has no drainability. Groundwater table is shallow (2-3 m) and has high salinity to big depth (10-50 g/l). Soils are half-hydromorphous and half-automorphous.

Water exchange intensity between aeration zone and groundwater is determined by water supply volume and drainage modulus. Before 1990 it was moderate to high (1500-3000 cu m/ha). Last years intensity lowered and transferred to category of insufficient. Salt exchange intensity and drainage salt outflow are high because of salt stocks removal from deep layers.

The V type. Non-saline from land surface to 1.5-2.0 m with gradual increase of salt content downward. Salt stocks in 1-meter layer change within 30-50 t/ha, 3 m - 90-150 t/ha and in 20 m thickness - to 3000 t/ha. Similar type of salt profile corresponds to irrigated massifs within central and border part of alluvial plain and inter-mountain depression (Hungry steppe), deposits between channels in river deltas (Karakalpakstan). Lithology of the area, where the V type of salt profile is formed, is represented by one-layer and in some places by two-layer of quaternary deposits. Area in natural conditions is not drained. Before irrigation groundwater table was everywhere deep - 5-10 m, shallow and groundwater salinity are high 15-50 and 5-10 g/l, appropriately. During irrigation everywhere rise of saline groundwater and intensive secondary salinization of soils are observed.

Intensity of water exchange between aeration zone and groundwater before 1990 was high - to 2.0-2.5 th cu m/ha, which lowers last years. Salt exchange and drainage salt outflow very high due to salt stocks removal from lower layers.

The VI type. Even high salt content in all layers, salt stocks within 0-1.0 m - 500 t/ha, 0-3 m - to 1150 t/ha and 0-20 m - 4000 t/ha. This type of salt profile corresponds to tail plots of removal cones, sinks between cones, big bowls within inter-mountain depressions, lake deposits in large river deltas (removal cones and sinks between cones in Fergana valley; the south-eastern and the south-western parts of Hungry steppe; central part and Sradob-Karakaroy bowl of Hungry steppe; lake deposits of the northern zone of Karakalpakstan). In pointed morphological structures lithology is represented, mainly, by one-layer aquifer complex and in some places by two-layer. Area is, practically, without flows. Groundwater salinity to the big depth is high: from 10-15 to 60-70 g/l.

Intensity of salt exchange and drainage salt outflow is very high due to salt influx from aeration zone, as well as from lower layers.

So, of 6 zones with various salt profiles, which define drainage salt outflow intensity, the II zone of geomorphological structures, represented by superficial salinization, belongs to the easiest category with salt content minimum in top fine-grained deposit. Here basic salt mass is concentrated within 0-1; 0-2.5 m, beneath - soils and groundwater have negligible salt content. At present time area, represented by the II type of salt profile, is covered, mainly, by vertical drainage systems and open drainage. Vertical drainage systems are developed widely in conditions of two-layer and multi-layer deposits, top fine-grained deposit with thickness of 8-30 m, which has close hydraulic relations with deep artesian aquifers. There are following similar zones: Central Fergana, old zone of Hungry steppe (including its central part) of Uzbekistan and Kyzylkum, Teren-Uzyak, Zhana-Kurgan and Chiyli massifs, as well as Arys-Turkestan massif of South Kazakhstan. Over Zarafshan river basin - middle reaches, part of irrigated area of Bukhara and Navoi oblasts, over AmuDarya river basin and part of Karshi oblast area. Open horizontal drainage serves lands, represented by aquifer with top fine-grained deposit with thickness to 5-8 m, with very close hydraulic relations with aquifers downward.

Open horizontal drainage is operated on flooded plain massif of Fergana valley, Hungry steppe of the Republic of Uzbekistan, as well as irrigated lands part of SyrDarya river delta and on AmuDarya river basin irrigated lands of Khorezm oasis, lands within deposit between channels of the northern Karakalpakstan, Tashauz and Chardjou oblasts of Turkmenistan. Character feature of lands reclamation of this zone is that in regions of operation of vertical or horizontal drainage, soils desalinization acceleration is obtained, groundwater and drainage outflow desalinization (table 2.31). In these regions duration of ecological-meliorative processes stabilization under irrigation leaching regime lasts within 2-3 years, during which groundwater salinity lowers to 2-5 g/l and drainage outflow to 3-5 g/l is observed. For example, drainage systems of flooded plain massifs of Central Fergana, Hungry steppe, Khorezm oblast and other regions (dr. 2.20-2.23).

In regions, where vertical drainage systems are applied during their long-term operation (25-30 years and more) growth of pumped water salinity does not exceed 0.3-0.5 g/l against initial value, excluding vertical drainage systems, which are located in the north-western part of Hungry steppe, where increase value reached 1.0-1.5 g/l (dr. 2.24). Similar inertness of pumped water salinity rise is explained by relatively negligible salt stocks in top fine-grained deposits, which participates in drainage salt flow formation. Because of relatively low salinity (0.5-3.0 g/l) of pumped water, it is used everywhere for land irrigation and leaching. Therefore, in the regions of vertical drainage system application salt removal outside irrigated area, mainly, is carried out by intervals in period from vegetation watering cessation to the beginning of leaching and after it. Besides that, vertical drainage system allows to solve easily drainage water utilization, releasing it to canals, being constructed on land surface. This is one of vertical drainage advantages.

Table 2.31

Zone of active water and salt exchange changes in area of vertical and horizontal drainage depending on character of salt stock distribution

Indicators	Type of data	Zone of vertical drainage		Zone of horizontal drainage	
		superficial salinization	deep salinization (top soil)	superficial salinization	deep salinization (top soil)
Groundwater table lowering rate, cm/day	initial achieved	1.5-3.0 4-10	0.5-2.5 3-10	0.08-2.7 4-2.5	0.5-6.0 3-2
Drainage outflow, m^3/ha per year	-	2500-7880	4500-5670	2400-22000	2800-15000
Salt removal rate, t/ha per year	-	7-60	4-80	4-26	6-30
Zone of active water and salt exchange, m	water exchange salt exchange	25-100 3-15	up to 100 18-20	8-110 1.5-10	10-110 10-50
Groundwater salinity, g/l	initial achieved actual	5-50 1.2-6.0 1.2-3.0	5-25 3-6 3-5	3-60 3-15 3-5	5-60 6-30 5-10
Drainage effluent salinity, g/l	initial achieved actual	0.45-15.0 0.45-3.0 0.5-3.0	1.4-15.0 1.5-8.0 2-5	2-20 1.5-5.0 1.5-4.5	5-50 5-20 6-15
Object location		Fergana valley Golodnaya steppe Bukhara province Kyzylkum and Arys-Turkestan massifs, Leninabad province (02.24, 02.33, 02.4, 02.18, 02.30, 02.11, 02.13, 02.14, 02.10 Uz) and (02.1, 02.2, 02.3 Kaz) 02.1 Tad	Golodnaya steppe Uzbekistan and Kazakhstan (02.19, 02.27, 02.30, 02.36, 02.37, 02.7, 02.9 Uz)	Karakalpakstan, Khorezm, Bukhara, Fergana, Syrdarya provinces Kyzylkum and Arys-Turkestan massifs, Ashkhabat province (02.1, 02.2, 02.8, 02.7, 02.23-02.25 Uz), (02.2, 02.6 Kaz), (02.1, 02.2 Tur)	Golodnaya steppe Uzbekistan and Kazakhstan (02.12, 02.14, 02.20, 02.27, 02.28, 02.29, 02.30 Uz)

The III, IV, V, VI types of salt profiles, characterized by huge salt stocks, are basic sources and areas, represented by such profiles, critical zone of salt provision in drainage outflow formation in Aral Sea basin.

Practically all irrigated areas, represented by these four types of salt profiles, are drained by open and close drainage systems and only within small areas, where IV and V types of salt profiles are formed, vertical drainage is introduced. Due to huge salt stocks, concentrated within big thickness of soils in geomorphologic structures, where III-IV types of salt profiles are formed, ecological-meliorative processes continue for long term - several dozens of years. For example, there are the south-east and the south-west massifs in new irrigated zones of Djetysay-Karakaroy sink, Hungry steppe, Charykul sink in Karshi steppe and irrigated massifs of sinks between cones in Fergana valley, as well as areas, which are placed within lake deposits in the northern Karakalpakstan, where drainage outflow salinity is rather high - 6-12 g/l and more (table 2.31). These massifs are introduced in agricultural rotation in 60s and 70s. So, under lands reclamation important role in salt masses mobilization belongs not to drainage types, but to salt stocks in soils and their distribution within active influence zone. In connection with that under forecast calculations of drainage outflow salinity should be done with respect to salt stocks distribution within not only aeration zone, but lower layers as well.

2.2.10. Technical and economic comparison of effectiveness of water-salt processes regulation and selection of the optimal drainage types for saline land reclamation

Pilot studies on forming and control of the soil water-salt regime and the environmental-reclamation processes under drainage operation showed high reclamation and technical-economic effectiveness of perfect drainage types under given hydrogeologic, soil and reclamation conditions. Zone of effective use for any drainage type depends on lithology, groundwater head and the latter hydraulic links with shallow water.

Vertical drainage system (VDS) showed high reclamation effectiveness in area represented by two- or multi-layer sediments with artesian and sub-artesian waters covered by surface fine-grained soils and having good hydraulic links with lower aquifers. Practically all the pilot plots (Socialism, Besharyk, Kagan, Bukhara state farms in Uzbekistan; Dostyk, Pahtaaral, Maktaly, Boyarkuduk, Kommunism, Ikan state farms in Kazakhstan and the plots located in the Vaksh valley of Tadjikistan) as well as regional VDS' (in Pahtaaral, Dzetysai, Kirov districts, in Kzylkum, Turkestan, Terenuzyak, Yanakurgan schemes of Kazakhstan, in old zone of Hunger steppe, Central Fergana, in Bukhara, Kagan, Vabkent, Gijduvan districts, in part of Karshi steppe of Uzbekistan, most part of the Chu valley of Kyrgyzstan) are operated under mentioned hydrogeological conditions.

Horizontal drainage is used under more complex hydrogeologic, soil and reclamation conditions as compared with VDS. Soils have lower permeability of 0.01-0.3 m/day and uniform distribution of big amount of salts within the zone of active water exchange reaching 3.5-5.0 th.t/ha for 20 m layer (the most part of new irrigated area in Hunger steppe: state farms N^o 5 and 6; Niyazov collective farm in Fergana province; Leningrad and Isfara collective farms in Chardjou province of Turkmenistan and others). Plots with subsurface horizontal drainage (SHD) are represented by two- and multi-layer sediments, covered by thin low permeable soils, and are located in the Khorezm province, Karakalpakstan (Uzbekistan), lower Syrdarya (Kazakhstan) and the Chu valley (Kyrgyzstan).

Indicators of perfect drainage effectiveness for all the plots are given in Appendix 10. Generalized information is given in table 2.32. Under mentioned natural-economic conditions regular operation of perfect drainage types in all the plots and large schemes allowed to:

- increase the land use efficiency from 95 to 96% with SHD and to 99% with VDS;
- increase the drainability through maintaining the stable drainage depth and control the rate of water table decrease - water table regulation ranged from 2 to 2.8 m with SHD and from 2 to 5 m with VDS (average values);
- increase soil desalinization rate by 1.25-1.3 times with SHD and 1.5-2.0 times with VDS under optimal reclamation regime;
- save water through better reclamation regime, eliminate 10-25% run-off with SHD and 15- 40% with VDS;
- reduce and keep groundwater salinity at 3-4 g/l even in the plots where it was 14-50 g/l;
- establish optimal conditions for increasing soil productivity and crop yields. Practically in all the plots and schemes over 3-4 years cotton productivity was increased by 5-12 c/ha. Irrigation water productivity accounted for 0.35-0.57 kg/m^3 with subsurface drainage against initial values of 0.2-0.37 kg/m^3, while it was 0.35-0.6 kg/m^3 with vertical drainage against initial 0.25-0.35 kg/m^3 (control plot). Thus, under perfect drainage types operation irrigation water productivity increased and varied within FAO recommended values of 0.4-0.6 kg/m^3 (for cotton);

Table 2.32

Indicators of meliorative and technical-economic efficiency of perfect types of drainage

Indicators	Type of drainage	
	close horizontal	vertical
Land use efficiency, %	95-96	98-99
Land drainability improvement by means of stable depth of drainage, prevention of surface release and groundwater lowering acceleration, %	15-25	25-35
Diapason of ground water table regulation, m	2,0-2,8	2,0-5,0
Reclamation period duration, year	5-8	3-4
Acceleration of coil desalinization rate through optimal meliorative regime establishing (increasing free volume of soil)	1,25-1,3	1,5-2,0
Water saving through surface release elimination %	10	15-20
Water saving at expense of better meliorative regime creation and desalinization rate increase, %	15-25	25-40
Specific water expense per yield unit, m^3/c	220-600	200-400
The same for control version	400-800	400-650
Irrigation water productivity, kg/m^3		
The same for control version	0,25-0,35	0,25-0,35
The same according to FAO recommendations, kg/m^3	0,4-0,6	0,4-0,6
Specific water expenses on 1tn salt removal, m^3/tn:		
in upper reaches	530-688	
	(900-A.d)	300-400
in middle reaches	220-320	220-250
in lower reaches	470-650	350-400
Drainage construction cost, soum/ha (prices of 1996)	63000[x)]	22000[xx)]
Operational costs, soum/ha (1996 prices)	258-330	350-380

Note:
x) close horizontal drainage construction cost for 200 ha under specific length l=50 m/ha equalsto 13 mln soum;
xx) 1 vertical drain construction cost with command area 200 ha and depth 60 m is 4,4 mln soum

- specific water expenses per unit yield account for 220-600 m^3/c with SHD and 200-450 m^3/c with VDS.

After statistical processing of obtained information from old irrigated lands of Hunger steppe the following relationships of cotton productivity growth with drainability coefficient and leaching irrigation regime were established:

$$\frac{Д_{гор} + Д_{вер}}{О_с + \Sigma В} = К_{др.},$$

$$К_{пр.} = \frac{О_с + \Sigma В - С_б}{ET}$$

These relationships are described by equations given in figures 2.25 and 2.26.

According to those figures high cotton productivity (30-35 c/ha) under complex hydrogeological, soil and reclamation conditions of old irrigated lands, which have artesian and sub-artesian aquifers, is reached with drainability coefficient $\hat{E}_{äð}$ = 0.4-0.5 and leaching irrigation regime $\hat{E}_{ïð}$ = 1.15-1.2. While desalinating soil and groundwater these coefficients can be reduced to 0.3-0.35 and 1.1-1.15, respectively.

For new irrigated lands of Hunger steppe, where SHD is used in the most part under complex drainage area, relationships of cotton productivity with $К_{др}$ and $К_{пр}$ were established as well and are shown in figures 2.27 and 2.28.

Analysis of actual information shows, that each drainage type is sufficiently effective under certain natural-economic conditions and, finally, selection of the most appropriate type is to be based on feasibility study.

Specific value of subsurface horizontal drainage construction in the Republic of Uzbekistan is 63000 soum/ha in prices of 1996 (data of design institute Uzgiprovodkhoz). Value of vertical drainage well construction is 22000 soum/ha. Current operational costs of SHD and VDS are 258-330 soum/ha and 330-380 soum/ha, respectively (table 2.32, data from the hydrogeological-reclamation station in Syrdarya province and the design institutes).

However, for Central-Asian conditions SHD is more preferable than VDS. At the same time, under some hydrogeological and reclamation conditions VDS is preferable regarding control of water-salt regimes and environmental-reclamation processes. VDS enables to regulate the level and rate of groundwater decrease within wide diapason and, hence, to control the rate of water and salt exchange between the aeration zone and groundwater. Besides, VDS allows to control easy drainage water whether it is re-used or disposed outside the irrigated lands, excluding release into river channel.

Conclusions and proposals on direction II, section a) "Control of water-salt regimes and environmental-reclamation processes through drainage systems, leachings and leaching irrigation regime"

1. At present time, in Central Asia 7.95 mln. ha are irrigated, including 5 mln. ha, which are saline or subject to salinization. Saline soils damage agricultural production. Depending on degree and type of salinity this causes yield, water, technical and labor resources losses. Yield losses of salt tolerant crops (as cotton) vary within 15-20% in lightly saline soils, 20-50% in medium saline soils and 50-80% in strongly saline soils. In alkali soils crop perishes. Annual specific norm of water supply to irrigated field for non-saline soils is 20-50% less than for saline one. The same situation is with overspent inputs.

Taking into account above mentioned, irrigated land salinity control is an important issue of irrigated agriculture. Practically all over the world solution of this issue is based on increase of irrigated area drainability through artificial drainage and leachings jointly with advanced agrotechnics and various "accelerators" of leaching and salt removal. As desalinization is based on artificial drainage use, various types and constructions of drainage were widely used in Central Asia while developing new and reclaiming old irrigated lands (for example, horizontal open and subsurface, vertical and combined drainage systems).

Out of total irrigated area of Central Asia 5.2 mln. ha require construction of artificial drainage. Actually, 4.7 mln. ha are under drainage. 174.5 th. km (or 39.4 m/ha) of horizontal drainage (including 145.4 th. km of on-farm one) and 8650 vertical drainage wells in 794 th. ha (average command area of 1 well of 85.5 ha, maximum of 250-300 ha) were constructed by 1996 in this area.

Certain reclamation and economic effect was reached practically in all the regions with artificial drainage, where with its normal operation and leaching requirements observance salt removal ranges from 5-10 t/ha to 50 t/ha under negative water-salt balance. The highest reclamation effect is observed under perfect drainage systems operation. In total in the Aral Sea basin annual drainage outflow accounts for 36-40 km^3 with salt removal of 120-130 mln.ton, most part of which returns to river channels.

However, construction of drainage perfect types, launched in 1960-1985, was stopped last decade in all Central Asian republics due to lack of finances. At the same time, in all the republics, excluding Uzbekistan, drainage systems are, practically, not maintained. Uzbekistan maintains mostly inter-farm collector-drainage network, while on-farm one is neglected. Meanwhile, high effectiveness of perfect drainage types consists not only in improvement of reclamation state of irrigated lands but in irrigation water saving and crop productivity increase as can be seen from collected information.

Direction II of the project "Control of soil water-salt regimes and reclamation-environmental processes through drainage, irrigation and leachings of saline lands" includes primary information from 75 pilot plots located in different conditions of the Aral Sea basin, including 10 projects in large regions (more than 50-150 th.ha) and 7 projects on capital leachings under various drainage types.

Pilot projects (plots) have the following distribution over CAR:
- 41 plots in the Republic of Uzbekistan, including 15 plots with VDS studies;
- 18 plots in the Republic of Kazakhstan, including 14 plots with vertical drainage wells;
- 9 plots in the Republic of Tadjikistan, including 2 plots with combined vertical and horizontal drainage systems;
- 4 plots in Turkmenistan with horizontal drainage;
- 3 plots in the Republic of Kyrgyzstan, including 1 plot with VDS.

Submitted information on drainage projects shows high reclamation effectiveness of drainage perfect types, which consists in:

- drainage outflow management;
- soil water-salt regime and irrigated land water-salt balance management;
- increase of the rate of soil and groundwater desalinization as well as decrease of drainage effluent salinity;
- increase of crop and irrigation productivity;
- water saving;
- increase of farming efficiency on saline soils.

2. Depending on natural conditions, horizontal drainage system is used, mainly, in areas comprised by one-layer low permeable sediments with permeability of 0.03-3.0 m/day. This drainage type was also used in two- and multi-layer sediments with thickness of top fine-grained soils $\leq$ 3-5 m as well as in corrugated relief. Usually, in above soils III-IV types of salt profiles are formed with distribution in depth of huge salt reserves (1.5-5.0 th.t/ha) and high groundwater salinity (15-50 g/l). These factors under drainage operation determine character and duration of environmental and reclamation processes being the main suppliers of salts removed by drainage outflow. Large horizontal drainage systems were developed in new zone of Hunger Steppe, in Karshi, Dzjizak and Sherabad steppes, in lower Syrdarya and Amudarya, Chui valley of Kyrgyzstan, Tedzen and Mary provinces of Turkmenistasn, etc.

Vertical drainage was developed in areas comprised by two- and multi-layer sediments with artesian water under water conductivity (K_p x m) of more than 200-500 m^2/day. This type of drainage was most efficient under conditions, where thickness of top small-grained soils ranged from 10 to 30-45 m and sediments resistance ($\Phi = \sum_{I=1}^{n} \frac{m_i}{K_{\phi i}}$) was 25-700 m. When thickness of top fine-grained soils m$\leq$ 10 m vertical drainage causes irregular decrease of groundwater table and if m $\geq$ 45 m effect of increase of fine-grained soils resistance decreases. Better results of reclamation effectiveness in top fine-grained soils with thickness of m $\leq$ 10 m are obtained under combined drainage. In such conditions mainly I type of salt profile is formed with salt reserve distribution within 1.0-2.5 m. Salt reserves within these layers range from 450 t/ha to 550 t/ha. Lower layers are practically desalinized under influence of groundwater head.

Groundwater salinity in a zone of superficial salinization ranges from 5 to 14 g/l, maximum up to 20 g/l in irrigated lands and 50-100 g/l in fallow lands. Salt reserves in fallow lands account for 1.5-1.750 t/ha.

Vertical drainage was widely developed in Fergana valley, Bukhara oasis, old irrigated zone of Hunger steppe, parts of Karshi and Sherabad steppes as well as in rice schemes of lower Syrdarya in Kazakhstan and command areas of Arys-Turkestan canal.

It should be noted, that with II type of salt profile and superficial salinization environmental and reclamation processes are being stabilized faster and easier, than with III-VI types of salt profile under horizontal and vertical drainage.

3. Efficiency of environmental and reclamation processes control in saline lands depends mostly on drainage parameters (drainage depth, drain spacing, discharge and command area of well), which influence forming of artesian gradient, drainage modulus (drainage salt flow), as well as on soil water-salt regimes and irrigated land balances under inflow of desalinized water.

Drainage parameters in pilot projects range within wide diapason. For subsurface horizontal drainage parameters are the following:

- Syrdarya river basin:

upper reaches - Fergana province: h = 2.5-3.0 m; B = 200-250 m; $L_{spec.length}$ = 40 m/ha;
Leninabad province: h = 2.2-2.4 m; $L_{s.l.}$ = 50 m/ha;
Chui valley: h = 3.5-4.5 m; $L_{s.l.}$ = 20-60 m/ha;
middle reaches - Hunger steppe: h = 2.8-3.5 m; $L_{s.l.}$ = 70-110 m/ha;
lower reaches (Kazakhstan) - h = 1.6 m; $L_{s.l.}$ = 20-110 m/ha.

- Amudarya river basin:

upper reaches - plots in Tadjikistan: h = 1.6-1.8 and 3.5-4.5 m; $L_{s.l.}$ = 38-84 m/ha;
middle reaches - Karshi steppe: h = 3-3.5 m; $L_{s.l.}$ = 55-60 m/ha;
Bukhara province: h = 2.2-2.5 m; $L_{s.l.}$ = 25 m/ha;
lower reaches - Chardjou vilayat: h = 2-2.2 m and 2.5-3 m; $L_{s.l.}$ = 20 m/ha;
Khorezm province: h = 1.5-3.0 m and 1.6-2.7 m; $L_{s.l.}$ = 30-74.0 m/ha;
Republic of Karakalpakstan: h = 1.8-2.5 m; $L_{s.l.}$ = 44-47 m/ha;
regional project: h = 1.8-3.6 m; $L_{s.l.}$ = 30-32 m/ha;
subsurface drainage in rice system in Karakalpakstan: h = 2.0 m, $L_{s.l.}$ = 36.0m.

Available data show that pilot projects located in lower Syrdarya and Amudarya are provided with relatively shallow drains (1.5-2.0 m), while projects located in Hunger and Karshi steppes are provided with deep drains (3.0-3.5 m). Drainage modulus in irrigated lands varies within 0.05-0.3l/sec, depending on application depth and ground inflow, while it is 0.3-0.8 l/sec in rice irrigation system under artesian gradient of 0.5-2.5 m.

<u>Vertical drainage system (VDS)</u>

For VDS wells' parameters vary widely depending on natural conditions (lithology):

- Depth of well ranges from 25 to 50-60 m for plots located in Fergana valley and lower Syrdarya (below Chardara reservoir). Capacity of wells in the plots of Fergana valley ranges from 40 to 100 l/sec under specific discharge of 50-15 l/sec. Command area of one well is 80-150 ha due to large groundwater inflow.
- Depth of well in lower Syrdarya ranges from 30 m to 60 m, Q = 25-50 l/sec, q = 2-5 l/sec. Command area ω = 150-200 ha.

- Depth of well in Hunger steppe ranges from 50 to 80 m, Q = 50-100 l/sec, q = 3-10 l/sec, ω = 150-300 ha.
- Depth of well in Arys-Turkestan canal is 40-60 m, Q = 25-100 l/sec, q = 3-10 l/sec, ω = 80-120 ha.
- Depth of well in Bukhara province and Karshi steppe is 25-60 m, Q = 25-100 l/sec, q = 2-10 l/sec, ω = 100-150 ha.
- Depth of well in Vaksh valley is 40-60 m, Q = 50-100 l/sec and more, ω = 80-100 ha.

Drainage modulus ranges widely (0.05-0.3 l/sec) as well, and depends on application depth and groundwater inflow. The largest values are in Fergana valley and Hunger steppe, where groundwater inflow is prevalent, while the lowest ones are in lower Syrdarya, Bukhara province and Karshi steppe.

4. While solving problems related to control of soil water-salt regimes, irrigated land balances and drainage outflow, issue of water sources for reclaimed area is of certain importance.

In Central Asia sources of water and salt for irrigated area are water supply, precipitation and groundwater inflow, formed by surface waters, and inflow from outside. Out of total annual water inflow the most important role in environmental and reclamation processes formation belongs to water supply, i.e. irrigation norms. Annual irrigation norm (water supply to the pilot plots) varies depending on drainage zone and type.

Data of table 1 show, that annual water supply to the pilot plots does not differ largely by drainage types. In plots with VDS water supply is 10-15% lower than that in plots with SHD. At the same time, annual water inflow to the fields, including precipitation, even under minimum water supply (5.5-6.5 th. m^3/ha), much exceeds total evaporation for all zones and plots and varies within 7.5-9.0 th.m^3/ha. Thus, annual water supply for all zones and plots meets requirements of leaching irrigation regime, i.e.

$$K = \frac{M+O_c}{И+T} \geq 1.0$$

Maximum annual water supply is provided at initial stage (first years) of land reclamation using perfect drainage types, further this amount is reduced. In other words, as soils are being desalinized water supply is decreased. If in the first years of drainage operation coefficient of leaching irrigation regime varied within 1.2-1.3, then further it was 1.1-1.15.

Table 1

Drainage zone	Annual water supply, M (th. m^3/ha)	
	SHD	VDS
Syrdarya river basin		
Fergana	11.2-14.2	8.3-10.4
Chui (conventionally related to the basin)	5.5-7.6	5.5-9.6
Leninabad	9.8-14	-
Hunger steppe	6.5-10.9	6.8-8.9
Kzylkum (cotton)	6.8-10.2	8.0-8.9
Lower Syrdarya (rice)	19-25	22.8
Arys-Turkestan	-	4.5-7.5

Drainage zone	Annual water supply, M (th. m^3/ha)	
	SHD	VDS
Amudarya river basin		
Vaksh	8.8-25	9.1-11.3
Bukhara-Karshi and Chardjou	9.7-13.4	8.9-17
Khorezm (cotton)	7.4-26.5	-
(rice)	22-26	-
Lower Amudarya (Republic of Karakalpakstan)		
(cotton)	6.8-12	-
(rice)	24-38	-

Under mentioned water supply volumes drainage outflow varies by zones and perfect drainage types and is shown in table 2 .

Table 2 shows, that minimum drainage flow both under SHD and VDS is observed in middle reaches of Syrdarya and Amudarya. These include Hunger steppe, Bukhara-Karshi and Chardjou zones and Chu valley as well as Arys-Turkestan canal, where drainage outflow ranges from 1.1-2.0 th.m^3/ha to 4.5-5.0 th.m^3/ha. Maximum drainage outflow is observed in upper and lower reaches, where drainage flow ranges from 5-6 th.m^3/ha to 11-15.6 th.m^3/ha (under vertical drainage). In upper Syrdarya and Amudarya high drainage outflow is formed through considerable water inflow, while in lower reaches - through excessive water supply to rice fields.

Table 2

Drainage outflow changes under perfect drainage types

Drainage zone	Drainage outflow, th. m^3/ha	
	SHD	VDS
Syrdarya river basin		
Fergana	5.1-6.1	6.3-9.2
Chu (conventionally related to the basin)	1.4-1.7	1.7-4.2
Leninabad	3.0-3.5	-
Hunger steppe	1.1-2.8	2.0-4.5
Kzylkum	5-7	2.5-3.5
Lower Syrdarya (rice)	5-10 and more	8-11
Arys-Turkestan	1.6-2.8	1.5-1.7
Amudarya river basin		
Vaksh	2.8-15.2	4.5-6.5
Bukhara-Karshi and Chardjou	2.0-5.0	2.5-5.5
Khorezm	3.7-15.6	-
Lower Amudarya (Republic of Karakalpakstan)		
(cotton)	2.1-6.7	-
(rice)	9-1.7	-

High drainage flow in Fergana valley is explained by large groundwater inflow from outside.

Thus, drainage modulus (outflow) of all the pilot plots, excluding those located in Arys-Turkestan canal and Chu valley, lies within optimal drainability and a bit higher. It provides favorable reclamation conditions for saline lands and, mainly, leaching irrigation regime.

5. Analysis of information on soil water-salt regime and environmental and reclamation processes formation and control shows high reclamation and technical-economic effectiveness of perfect drainage types under certain hydrogeological and reclamation conditions. Zone of drainage effective use is determined by lithology, head of groundwater and their hydraulic links with shallow water. Vertical drainage systems have high effectiveness under two- and multi-layer sediments.

High reclamation effectiveness of vertical drainage system is observed under two- and multi-layer sediments with artesian and sub-artesian water covered by top fine-grained soils and having good hydraulic links with lower aquifers. Practically, all the pilot plots (state farms Socializm, Besharyk, Kagan, Bikhara in Uzbekistan and Dostlik, Pakhtaaral, Maktaly, Boyarkuduk, Communizm, Ikan in Kazakhstan) and those located in Vaksh valley of Tadjikistan and regional systems of Pakhtaaral-Dzjetysai and Kirov district, Kyzylkum, Priturkestan and Terenuzak-Yanakurgangilyan schemes of Kazakhstan, old zone of Hunger steppe, Central Fergana, Bukhara-Kagan-Vabkent-Gizjduvan districts, part of Karshi steppe in Uzbekistan, most part of Chui scheme in Kyrgyzstan as well as Vaksh valley in Tadjikistan have the same conditions. Under these conditions regular operation of VDS in all the pilot plots and large schemes allowed to:

- Create high drainability of command area while providing groundwater overflow from top fine-grained soils to aquifer. Overflow from top fine-grained soils to aquifer varied within 1.5-2.5 th. m^3/ha for Fergana zone, 2.5-4.5 th. m^3/ha for Hunger steppe and 2.5-5.0 th. m^3/ha for Bukhara-Karshi zone. Minimum overflow (up to 1.5-2.5 th. m^3/ha) is observed in Kyzylkum and Arys-Turkestan schemes of Kazakhstan and in Chu valley of Kyrgyzstan. Maximum overflow (up to 5-6 th. m^3/ha) is observed in Vaksh part of Tadjikistan.

- Control groundwater table and artesian waters. The control is provided by groundwater withdrawal (pumping) regulation through changes in capacity of well. Practically in all the plots groundwater table was kept within 1.5-2.0 m in spring, 2.5-3.0 during vegetation and 3.5-4.5 m in autumn and winter before leaching. To the beginning of sowing groundwater table decreased to 1.5-2.0 m. Piezometric head was kept at 0.4-1.5 m below groundwater table. Groundwater table control within above values enables to: exclude wasting soil water before sowing and create optimal conditions for crop sowing, obtain even sprouting; minimize salinity restoration in summer and create free capacity for successful leaching. Exception to this principle of groundwater table regulation are plots located in Kyzylkum-YanaKurgan schemes, where mostly rice and accompanying crops are sowed without “land leaching”;

- Control groundwater table decrease rates and overflow from top fine-grained soils to aquifer. Bounds of groundwater table decrease rates depend on thickness of top sediments and soil permeability. High rate of groundwater table decrease, about 10-200 mm/day, is reached in plots located in Fergana and Bukhara provinces, Chu and Vaksh valleys as well as in lower Syrdarya, where thickness of top sediments varies within 8-12 m and soil permeability is 0.2-0.5 m/day. In lower Syrdarya thickness of top sediments is not more than 3-6 m. Lower rates

of groundwater table decrease are observed in Hunger and Karshi steppes under overflow rate of 2-5 cm/day.
In mentioned areas thickness of top sediments ranges from 15 to 30 m and more and soils are low permeable ($K_{ф} \leq 0.05$-0.15 m/day);

- Control desalinization in aeration zone of top fine-grained soils through creation of free capacity up to 3.5-4.5 m before leaching and control overflow (water and salt exchange) between unsaturated and saturated zones during leaching and vegetation waterings with norms shown in table 1. Desalinization rate depends on initial soil salinity and desalinating discharge in aeration zone, which is determined by difference between water supply, precipitation and total evaporation. Desalinating discharge ranged by plots and large schemes from 1.0 to 5-7 th.m^3/ha. During initial period of drainage system operation there were higher irrigation norms (8-10 th.m^3/ha and more) than in next periods under leaching irrigation regime observance. Coefficient of leaching irrigation regime was $K_{пр} = 1.1$-3.5. Under these conditions in all the plots both annually and within long-term period there was optimal soil water-salt regime with gradual desalinization of aeration zone and groundwater. Salt removal by surveys and fixed points ranged from 20 to 120-130 t/ha and its value depended on initial desalinization and salination discharge. Practically in all the plots medium- and strongly-saline soils became non-saline over 3-4 years.

- Create negative water-salt balance both in aeration zone of fine-grained soils and all over the territory with salt removal of 7-10 and 25-30 t/ha from saturated zone, 50-70 t/ha from small-grained soils and 5-10 and 20-25 t/ha from the area. The higher the ratio of drainage flow to water supply and the initial salt reserve the larger specific salt removal. At the same time, removal of the same amount under artesian waters is related to higher ratio D/W, i.e. water supply volume to the field to drainage outflow, than without artesian waters due to increase of artesian waters share in the flow. The same is tendency of specific salt removal dependence of coefficient of leaching irrigation regime $\frac{M+O}{И+Т}$, which in the plots with VDS varied within 1.1-1.35.
It should be noted, that while desalinizing soil and, mainly, groundwater to 4-5 g/l it is possible to reduce sharply leaching requirements and set them at 1.05-1.1 during irrigation and leaching norms establishment;

- Smooth in all the plots and schemes spotted soil salinity and create even reclamation background. Practically in all the plots and schemes with VDS over 3-4 years of its operation medium- and strongly- saline irrigated lands transferred to non-saline and, partially, slightly saline ones. In state farm "Pahtaaral" over 3-4 years of VDS operation under coefficient of leaching irrigation regime of 1.15-1.20 30% of medium- and strongly- saline lands transferred to non-saline ones.

The same situation is in Pahtaaral district, where VDS was put in operation on 50 th.ha in 1969-1970. Here, in 1975-1977 almost 95% of irrigated lands were non-saline and slightly saline, while groundwater salinity decreased to 3-4 g/l under coefficient of leaching irrigation regime K = 1.1-1.5.

In Shuruzyak scheme with area of about 68.5 th.ha, where thickness of top fine-grained soils is 25-30 m and they are low permeable ($K_a = 0.01$-0.07 m/day) and strongly saline, aeration zone and groundwater were desalinized to 3-4 g/l over 5 years under $K_п = 1.15$-1.3. In other schemes (Fergana, Bukhara, Kzylkum, Vaksh and Chui schemes), comprised by thin top fine-grained soils (8-12 m) under permeability of 0.1-0.3 m/day, period of aeration zone and groundwater desalinization is less than 3 years;

- Reach over 3-4 years in all the plots full desalinization of aeration zone and top fine-grained soils;

- Decrease and smooth groundwater salinity to 3-4 g/l even under high initial values. Under VDS operation in plots located in Shuruzyak scheme (state farm “Socializm”) and in Lenin collective farm of Dzetysai district, where soils are strongly saline (up to 2.5%) by salt sum and groundwater salinity reaches 14-15 g/l, the latter decreased over 3-5 years to 4-5 g/l;

- Decrease and stabilize pumped water salinity. Stabilization depends on initial salinity of fine-grained soils and on deep and shallow water salinity. Decrease of salinity by 0.5-1.0 g/l and then stabilization are observed in plots with salinity within 1.0-1.5 m in fine-grained soils having thickness of 10-12 m, such as plots in Fergana and Bukhara province, Chu and Vaksh valley and Kzylkum scheme. In plots with salinity within 2.5-3.0 m and high groundwater salinity slow increase of groundwater salinity is observed (see data from state farm “Pahtaaral” and 50 years of Uzbekistan). At the same time, in plots with even distribution of salt reserve in depth (VI type of salt profile), with high shallow water salinity (up to 20-25 g/l) and high deep water salinity (up to 10-15 g/l) amount of pumped water is gradually reduced;

- Create optimal conditions to increase soil and crop productivity. Practically in all the plots and schemes over 3-4 years cotton yield was increased by 5-12 c/ha. Specific water expenditures per unit yield ranged from 230-300 m^3/c (state farms Besharyk, Kuva district; Kagan, Bukhara and state farm Pahtaaral, Pahtaaral district, Dzetysai district of Kazakhstan) to 350-400 m^3/ha (Shuruzyak scheme, state farm “50 years of Uzbekistan”) under complex natural conditions.

In all the plots after VDS application relatively high irrigation water productivity has been reached and varied within 0.41-0.57 kg/m^3 against 0.2-0.37 kg/m^3 meeting FAO criterion - 0.4-0.6 kg/m^3. At the same time, after information statistical processing for old irrigation zone in Hunger steppe dependence of cotton yield growth on drainability coefficient $К_{др} = \frac{Д_с+Д}{О_с+\Sigma В}$ and on leaching irrigation regime $К_{пр.р.о.} = \frac{О_с+\Sigma Ф-С_б}{ET}$ was established, which is described by parabola of second degree. Correlation coefficient is 0.77 and 0.81. According to the figures high cotton productivity (30-35 c/ha) for complex hydrogeological-soil-reclamation conditions of old irrigation zone in Hunger steppe with artesian and sub-artesian waters is reached under drainability coefficient and leaching irrigation regime $К_д$ = 0.4-0.5 and $К_{пр.о.}$ = 1.15-1.2, respectively. However, after groundwater desalinization they can be decreased to 0.3-0.35 and 1.1-1.15, respectively.

b) Open and subsurface horizontal drainage is widely used under conditions of one-layer sediments (most part of new irrigation zone in Hunger steppe, Niyazov collective farm in Fergana province, Leningrad and Isara collective farms in Chardzjou province, etc.) or two- or multi-layer sediments covered by thin unpermeable soils (plots located in Khorezm province, Karakalpakstan and Uzbekistan; in lower Syrdarya in Kazakhstan and in Chu valley in Kyrgyzstan) with non-artesian and sub-artesian groundwater. Open collector-drainage system, which was important for reclamation improvement of irrigated lands and intensification of agricultural production in Central Asian republics, but did not meet present requirements of agriculture and, mainly, requirements of irrigation water saving and accelerated soil desalinization under sharp resource deficit, practically was not included into drainage registers, excluding one pilot project - the northern zone of Karakalpakstan, where assessment of effectiveness of existing open drain systems in 500 th.ha was given and recommendations on their efficiency increase were prepared.

At the same time, subsurface horizontal drainage is used under more complex hydrogeological-soil-reclamation conditions as compared with VDS: soils in depth have lower permeability (0.01-0.3 m/day) and even distribution of huge salt reserves in a zone of active water exchange reach 3.5-5.0 th.t/ha within 20 m layer. Drainage zone of subsurface horizontal drainage includes III, IV, V and VI types of salt profile having huge salt reserve and high groundwater salinity, which ranges from 15-20 to 50-60 g/l and more. This is explained by source of secondary salinization during land development and long lasted salt removal to river channels and their pollution.

Under above mentioned conditions subsurface horizontal drainage showed sufficiently high reclamation and technical-economic effectiveness and allowed to:

- Create high drainability of irrigated lands ranging from 0.05 to 0.15 l/sec/ha in Fergana drainage zone, including 0.04-0.075 l/sec/ha in Chu valley, 0.035-0.15 l/sec/ha in Hunger steppe drainage zone and 0.17-0.225 l/sec/ha in lower Syrdarya. In Arys-Turkestan scheme drainage modulus was lower than 0.1 l/sec/ha. In drainage zones of the Amudarya basin drainage modulus is higher than in the Syrdarya basin and accounts for 0.4-0.48 l/sec/ha for upper reaches and 0.05-0.22 l/sec/ha for Bukhara-Karshi and Chardzjou zones. Highest drainage modulus (upper drainage outflow) is in lower Amudarya: it varies within 0.22-0.36 l/sec/ha in Khorezm province, 0.15-0.18 l/sec/ha in Karakalpakstan under cotton cultivation and 2.7-5.1 l/sec/ha under rice irrigation. In total, drainage outflow varies from 30-35% to 60% of annual water supply. Maximum drainage outflow is observed in the plots located in upper and lower reaches of the rivers. In upper reaches drainage outflow is formed mainly by ground inflow, while in lower reaches - by water supply;

- Provide optimal semi-hydromorphous (in lower reaches) and semi-automorphous reclamation regime while keeping groundwater table at 0.7-1.1 of capillary rise, i.e. regulation of groundwater table within 1.5-2.8 m. Depending on drain depth minimum limits (1.2-2.2 m) of groundwater table regulation are observed in plots located in lower Syrdarya and Amudarya under high water supply. Slightly higher limits (1.8-2.8 m) are observed in upper and middle reaches;

- Provide sufficiently high rate of groundwater lowering, ranging from 2-6 cm/day in heavy soils in middle Amudarya and Syrdarya (Hunger steppe, Bukhara, Karshi and Chardzjou zones) to 10-20 cm/day in upper and lower reaches (Fergana province, Vaksh and Chu valleys, Khorezm province, Karakalpakstan and lower Syrdarya);

- Fulfill timely autumn-winter-spring leachings by different norms depending on degree of salinity (3.5-8.0 th.m^3/ha) and, thus, achieve accelerated desalinization of aeration zone (3-4 years) and stabilize over 3-4 years groundwater salinity at 3-4 g/l in plots located in Fergana zone and upper Amudarya. Over 3-5 years in Bukhara-Karshi zone groundwater salinity was stabilized at 4-6 g/l and more. In lower Amudarya and in new irrigation zone of Hunger steppe, where irrigated area includes IV, V and VI type of salt profile with huge salt reserves in 20 m layer and deeper, stabilization at 6-15 g/l occurs over 5-6 years of irrigation under leaching irrigation regime observance. There groundwater decrease and period of stabilization depend on degree of soil salinity and annual water supply norm.

The same situation is observed during drainage outflow decrease and its salinity stabilization. The only difference is that stabilization occurs during longer period. Intensity of drainage effluent salinity decrease in first 2-3 years is quite high and then it becomes lower. At present time, in mentioned areas drainage effluent salinity remains quite high.

- Create in all the plots, including regional, negative water-salt balance. Rate of salt removal both from aeration zone and from irrigated area depends on initial soil salinity, desalinating discharge through aeration zone, expressed conditionally through coefficient of leaching irrigation regime K_{po} = B+O/ET and drainability coefficient K=Д/ΣB.

Salt removal from aeration zone varies from 10 to 110 t/ha (table 2.4 in main text of the report), while for irrigated area it ranges from 5-10 t/ha, under ratio of drainage flow to total water supply to irrigated land Д/B = 0.2-0.3, to 25-35 t/ha, under Д/B = 0.3-0.6. Salt removal from aeration zone depending on coefficient of leaching irrigation regime is characterized by Fig. 2.2. Salt removal ranges from 4-10 t/ha under K = 1.05-1.2 to 20-30 t/ha under K = 1.2-1.6.

It should be noted, that high rate of removal under low coefficient $K_п$ is observed in lower Amudarya (mainly in Khorezm province), while low rate of removal under high coefficient $K_п$ is observed in Fergana valley with artesian waters. During first 2-3 years of irrigation of new lands and reclamation of old irrigated lands intensity of removal is very high, then it slackens. Specific water expenses per 1t salts removed ranges from 90 to 1080 m^3 (table 2.4 in main text of the report).

Average water expenses per 1t salts removed within drainage zones are the following:
Fergana zone - 531-688 m^3;
Hunger steppe - 243-286 m^3;
Upper Amudarya - 487-900 m^3;
Bukhara-Karshi zone - 172-328 m^3 .

- Identify good hydraulic links all over the layer up to impermeable layer and active zone of water and salt exchange under operation of drainage and canals with regard for crop irrigation and leachings. Zone of active influence of water and salt exchange under drainage operation spreads as follows:
Fergana zone -15-20 m;
Hunger steppe -25-30 m;
Bukhara-Karshi zone - 20-25 m;
Lower Amudarya -30-40 m.

In total volume of removed salts share of salts entered from beneath ranges from 23-30% to 45-55% (Khorezm);

- Achieve in all the plots gradual reduction of annual irrigation norms while desalinating soils and, mainly, through reduction of leachings. In all the plots after desalinization of aeration zone and top layer norms of winter-spring leachings decreased to 2.5-4.5 th. m^3/ha against 5-8.0 th. m^3/ha. As a whole, there was the following reduction of annual water supply:

Fergana zone - 14.2-11.0 th. m^3/ha;
Chui valley - 7.6-5.0 th. m^3/ha;
Hunger steppe - 9.0-6.8 th. m^3/ha;
Plots in Republic of Kazakhstan - 10.2-8.1 th. m^3/ha;
Amudarya river basin - 25.3-8.8 th. m^3/ha;
Bukhara-Karshi zone - from 12-13.5 to 9.7 th. m^3/ha in Bukhara zone; 18.3-13.4 th. m^3/ha in Karshi zone; from 26.2 to 17 th. m^3/ha and from 10.5 to 5.5 th. m^3/ha in lower Amudarya;

- Create optimal conditions in order to increase irrigated land and irrigation water productivity. Practically in all the plots with subsurface horizontal drainage over 3-5 years of its operation cotton and rice yields were increased by 5-10 c/ha (excluding Prawda collective farm, where cotton and rice yields were increased by 36 c/ha and 6-14 c/ha respectively). Specific irrigation water expenses for cotton varied within 226-250 m^3/c in upper reaches, 300-450 m^3/c in middle reaches and 450-600 m^3/c in lower reaches. While keeping leaching irrigation regime under SHD irrigation water productivity ranged from 0.35 to 0.537 kg/m^3 (0.2-0.35 kg/m^3 in control plot) against FAO criterion of 0.4-0.6 kg/m^3.

Statistical processing of data from new zone in Hunger steppe (the most complex drainage zone) enabled to determine dependence of yield increase on: salt removal from 1m layer Y = (Δ C); drainability coefficient Y = (D/B) and coefficient of leaching irrigation regime Y = (B+O/ET); these dependencies are described by parabola equation of second degree under correlation coefficients of 0.7-2, 0.74 and 0.75, respectively. These dependencies under complex hydrogeological-soil-reclamation conditions of new irrigation zone in Hunger steppe show, that high cotton productivity of 30-35 c/ha during initial period of land development is reached with drainability coefficient $K_{др}$ = 0.4-0.6 and coefficient of leaching irrigation regime $K_{пр}$ = 1.1-1.2.

Thus, analysis of information provided by direction II"Control of soil water-salt regimes and reclamation processes in saline lands through drainage, leachings and leaching irrigation regime" shows quite high reclamation and technical-economic effectiveness of perfect drainage types.

Indicators of perfect drainage types effectiveness are shown in table 3.

Table 3

Indicators of effectiveness	Drainage types	
	SHD	VDS
Land use efficiency, %	95-96	98-99
Increase of land drainability through provision of stable drainage depth, prevention of surface release and increase of groundwater decrease rates, %	15-25	25-35
Range of groundwater table regulation, m	2.0-2.8	2.0-5.0
Reclamation period duration, years	5-8	3-4
Speeding the soil desalinization through establishment of optimal reclamation regime (increase of soil free capacity)	1.25-1.3	1.5-2.0
Water saving through surface release elimination, %	10	15-20
Water saving through establishment of better reclamation regime and acceleration of desalinization,	15-25	25-40

Indicators of effectiveness	Drainage types	
	SHD	VDS
%		
Specific expenses per unit yield, m^3/c	220-600	200-450
Specific expenses per unit yield in control variant, m^3/c	400-800	400-650
Irrigation water productivity, kg/m^3	0.35-0.57	0.35-0.6
Irrigation water productivity in control variant, kg/m^3	0.25-0.35	0.25-0.35
Irrigation water productivity by FAO	0.4-0.6	0.4-0.6
Actual expenses per 1t salts removed, m^3/t:		
upper reaches	530-688 (900	300-400
middle reaches	220-320	220-250
lower reaches	470-650	350-400
Cost of drainage construction, soum/ha (prices of 1996)	65000*)	22000**)
Operation costs, soum/ha (prices of 1996)	258-330	350-386

Notes: *) - cost of subsurface horizontal drainage construction on 200 ha under specific length L = 50 m/ha is 13.0 mln. soum (data of Uzgiprovodkhoz institute);
**) - cost of 1 vertical drainage well with command area of 200 ha and depth of 60 m is 4.4 mln. soum.

Each type of drainage is effective under certain natural and economic conditions and selection of the most expedient type should be based on feasibility study.
According to data of Uzgiprovodkhoz institute, specific cost of subsurface drainage construction in Uzbekistan is 63000 soum/ha, while for vertical drainage it is 22000 soum/ha. Current operation costs of SHD and VDS, from data of Hydrogeological and Reclamation Station in Syrdarya province, vary within 258-330 and 330-380 soum/ha, respectively.

However, area and scale of SHD use under conditions of Central Asia are slightly wider than those for VDS. At the same time, under certain hydrogeological and reclamation conditions there are more possibilities for VDS to control water-salt regimes and reclamation processes. VDS allows to regulate groundwater table lowering rate in wide range and, thus, to regulate water and salt exchange between the aeration zone and groundwater. Besides, VDS allows to manage easily drainage outflow both under its use and under its disposal outside irrigated lands without release to river channel.

6. Possibility and expediency of aeration zone and groundwater desalinization through operational leachings and optimization of leaching norms and schedule, according to degree of salinity, without capital leachings. Coefficient of leaching irrigation regime is set within a year with regard for precipitation and its value should be determined as (1.2-1.3) ET according to initial salinity at the beginning of land development and reclamation of old irrigated saline land. After desalinization of rooting zone up to maximum permissible concentration (MPC) and desalinization of top groundwater it is expedient to reduce coefficient of leaching irrigation regime down to 1.05-1.1.

7. Discussion about effectiveness of shallow or deep subsurface drainage is pointless. Drainage depth should be determined by hydrogeological-soil-reclamation conditions with regard for collector-drainage outflow utilization. Most pilot plots are provided with deep

drains (2.6-3.5 m). Only plots located in river deltas have drain depth of 1.6-2.5 m. Studies of soil water-salt regime control under "shallow" drainage were conducted in Khorezm province of Karakalpakstan and Kzylkum scheme of Kazakhstan, where thickness of top fine-grained soils is 1.5-5 m, rarely 8 m, underlain by shifting sand, and surface of irrigated lands has slight slopes. This complicates construction of deep drainage and drainage outflow disposal, i.e. its utilization. Practically all the plots worked effectively. However, in plots located in lower reaches with shallow drains water supply to irrigated lands and drainage outflow are 2-3 times higher (water supply to irrigated land by plots 02.1, 02.20 varies within 20-24 th.m^3/ha, while drainage outflow varies within 11350-15100 m^3/ha).

Under equal hydrogeological-soil-reclamation conditions, if collector-drainage outflow utilization is not complicated (i.e. inlet is available), than deep drains must be preferable, which will provide in irrigated lands semi-automorphous reclamation regime. This regime causes more effective reclamation of saline lands with minimum water expenses.

8. Disputes about mobilization of salt masses and zone of active water-salt exchange under different types of drainage (vertical, horizontal) and its parameters (deep or shallow) are pointless.

Under artificial land drainage aquifer characteristics and drainage parameters predetermine formation of active water exchange zone. The main factors influencing formation of water exchange zone are thickness of aquifer, stratified soils and location of impermeable layer. Formation of active water exchange zone under drainage operation is influenced, mainly, by drain spacing under horizontal drainage and by well spacing under vertical drainage, and not by drain depth. In theory under systematic drainage operation with alternating field drains and collectors and drain spacing $B \geq 3T$ (T - thickness of aquifer) drainage outflow is formed within the whole thickness of aquifer irrespective of drain depth. The smaller drain spacing the lower drainage influence on depth of water exchange zone. However, in this case the whole thickness of aquifer takes part in drainage outflow formation, since field drains are alternated by collectors. When impermeable layer is shallow, drainage flow is formed with the whole aquifer system. At the same time, intensity of drainage modulus (flow) formation depends on drain depth, which creates artesian gradient, i.e. gradient of water exchange between aeration zone and groundwater.

N. Khodjibaev and B. Neiman, based on model and pilot studies, give for main soil textures of Central Asia the following values of an area of active influence under horizontal drainage:
- in light soils (sands and sandy loam, $K_ф$ = 0.5-2.0 m/day) h = 50-100 m;
- in medium soils (light and medium loam, $K_ф$ = 0.5-0.1 m/day) h = 30-50 m;
- in heavy soils ($K_ф$ < 0.1 m/day) h = 10-30 m.

In pilot projects zone of active water and salt exchange under subsurface horizontal drainage operation have the following parameters:
- 35-50 m (piezometric observations) in lower Amudarya, comprising stratified soils in depth (100-150 m) with top fine-grained soils (3-3.5 m) and sub-artesian waters, subsurface drainage parameters: depth of 2.5-3.0 m; drain spacing of 250-300 m);
- 20-35 m in middle reaches (Kalantaev data from plots 02.1 and 02.2, Turkmenistan) under conditions of limited thickness of aquifer and subsurface drainage parameters: depth of 3.0 m ; drain spacing of 250-300 m);
- rice drainage system located in lower Amudarya, comprising stratified soils with thickness of more than 150-200 m, under subsurface drainage depth of 2.5-3.0 m.

The same situation is observed in zone of active water exchange under systematic vertical drainage operation and it depends on well spacing, on the one hand, and on artesian waters, on the other. In any case influence of pumping spreads over the whole aquifer system and over the more active first aquifer, where well screens are located. The more command area of systematic vertical drainage, the lower share of outside inflow as, for example in old zone of Hunger steppe, i.e. practically the whole drainage outflow is formed by surface waters. Under such conditions, by SANIIRI data, the whole thickness of the first aquifer takes an active part during formation of VDS filtration flow.

In principle, from the positions of hydrodynamics, drainage types identically influence the zone of active water and salt exchange formation. From practical point of view it is proven by figure. This figure shows, that under non-artesian and sub-artesian aquifers amount of salts removed from irrigated lands varies, according to Ä/B, within 10-30 t/ha both with vertical and horizontal drainage. However, intensity of various drainage types influence on its salt flow formation is different under artesian aquifers: with VDS it is more intensive than with HD. At the same time, both under SHD and VDS intensity of salt exchange is not mainly determined by thickness of the zone of active water exchange, though it plays an important role in salt removal. Intensity of drainage outflow depends mostly on overflow from aeration zone to groundwater (± g), on the one hand, and on salt reserve and its distribution over top fine-grained soils as well as on deep and shallow water salinity, on the other. Distribution in depth of deep and shallow water salinity plays an important role in drainage outflow formation as well.

In this respect more complex soil and reclamation conditions are related to the drainage zone of horizontal drainage, where soils include huge salt reserves (2000-5000 t/ha) and higher groundwater salinity (15-60 g/l) distributed more or less evenly, i.e. they comprise mainly III, IV, V and VI types of salt profile (Fig. 2.19). These salt reserves are the source of drainage outflow formation and determine duration of ground and drainage waters desalinization. On irrigated lands, comprising III, IV, V and VI types of salt profile, ground and drainage water salinity is stabilized over 10-12 years. However, level of ground and drainage water salinity remains quite high (7-12 g/l).

At the same time, drainage zone of VDS comprises mainly II type of salt profile, where soils and groundwater have superficial salinity. Usually, under geomorphological and hydrogeological conditions, where II type is formed, salt reserves (up to 1500 t/ha) are concentrated maximum in 2.5 m layer, below of which soils and groundwater are practically desalinized. Beside this zone VDS is used in small areas, comprising IV and V types of salt profile. Due to light natural conditions of VDS drainage zone ground and drainage water salinity is stabilized over 3-4 years. Groundwater salinity varies within 3-5 g/l, while it is 3-4 g/l for drainage waters (fig. 15). Practically in all the plots and regional pilot projects, where VDS is used, over 15-30 years of its operation slight increase of pumped water salinity was observed, excluding Sardoba scheme in Hunger steppe, irrigated lands of which comprise VI type of salt profile. Due to slight increase of pumped waters salinity, they are used for irrigation and leaching.

Thus, due to complex natural conditions the main source of drainage outflow is drainage zone of horizontal drainage and it is a “critical planning zone”. However, in spite of complex conditions, perfect drainage types are effective for water and salt rational use and management.

However, over last decade reclamation funds and, particularly, perfect drainage types become obsolete, do not meet functional requirements and need to be reconstructed. At the same time, Central-Asian states have no sufficient capital investments to complete reconstruction of perfect drainage types. In this context for the nearest future following reconstruction works can be proposed: drain flushing for subsurface drainage system; well cleaning by pulse method, allowing to rehabilitate well capacity up to 65-80% of initial, for vertical drainage. In partially rehabilitated structures it is necessary to carry out desalinizing works through operational leachings with norms meeting leaching irrigation regime.