A.2. Geomorphological-hydrogeological conditions as factors determining development of ecological meliorative processes and parameters of irrigation-drainage systems

A.2.1. Geomorphological-hydrogeological indicators of the Aral Sea basin

Desert zone of the Central Asian republics is a zone of ancient irrigation. In many classifications the highest taxonomic units are: Turan plain, mountains Pamir, Tyanshang and Turkmen-Khorasan mountain country.

In turn, each taxonomic unit consists of different provinces with correspondent origin (genesis) of sediments, lithology, relief, etc.

According to climatic indicators with respect to geomorphological peculiarities two large ecological-landscape zones are distinguished: desert depression and pre-mountain plain. Geomorphological structures. Including relief formation and lithological features, present complexes of natural conditions, determine surface gradients and territory drainability, i.e. surface and underground flow (runoff) and tendency of ecological-meliorative processes under irrigation.

According to geomorphologic-lithological indicators within the Aral sea basin 7 large landscape-geographic-geomorphological regions (oblasts) which, in turn, are divided into lot of rayons, sub-rayons and sites (fig.1.2.1. and 1.2.2.)

There are 4 rayons within desert depression and 3 rayons within pre-mountain plain.

In desert depression they are:

1. river terraces (middle and lower), slightly drained in natural conditions;
2. alluvial plains, bowls without ground water outflow;
3. sea deltas-without outflow;
4. dry deltas of small and medium rivers;

Within pre-mountain plains they are:

1. river terraces of upper and middle reaches;
2. corrugated pre-mountain plains drained in natural conditions;
3. cones of withdrawal upper part of which is well drained but lower part has not ground water outflow.

Geographic-geomorphological structures of mountain corrugated plains, upper and middle river terraces and cones of withdrawal with good natural drainability could be distinguished as oblasts which do not require complex measures on management of ecological-meliorative processes.

In these rayons main task is water management in order to minimize its losses and prevent degradation (flash and erosion) of soils.

In rayons with medium natural drainability and without ground water outflow complex ecological-meliorative processes develop under irrigation: water logging, secondary salinization, surface and ground water quality aggravation. In this connection for these ecological-meliorative processes management more complex water saving and conservation measures and irrigation and drainage technologies are required.

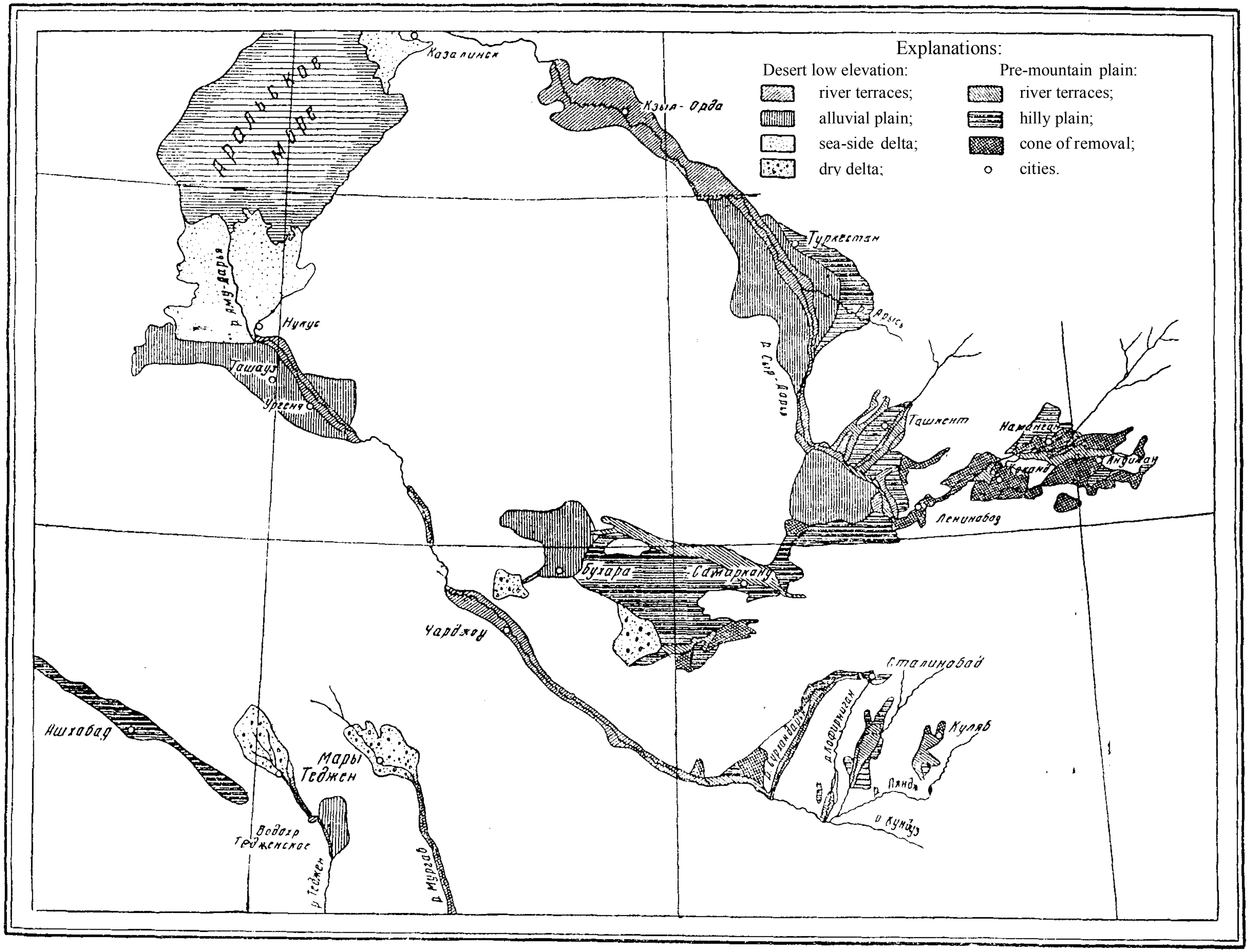

Fig. A.2.1. Landscape zoning of Central Asia

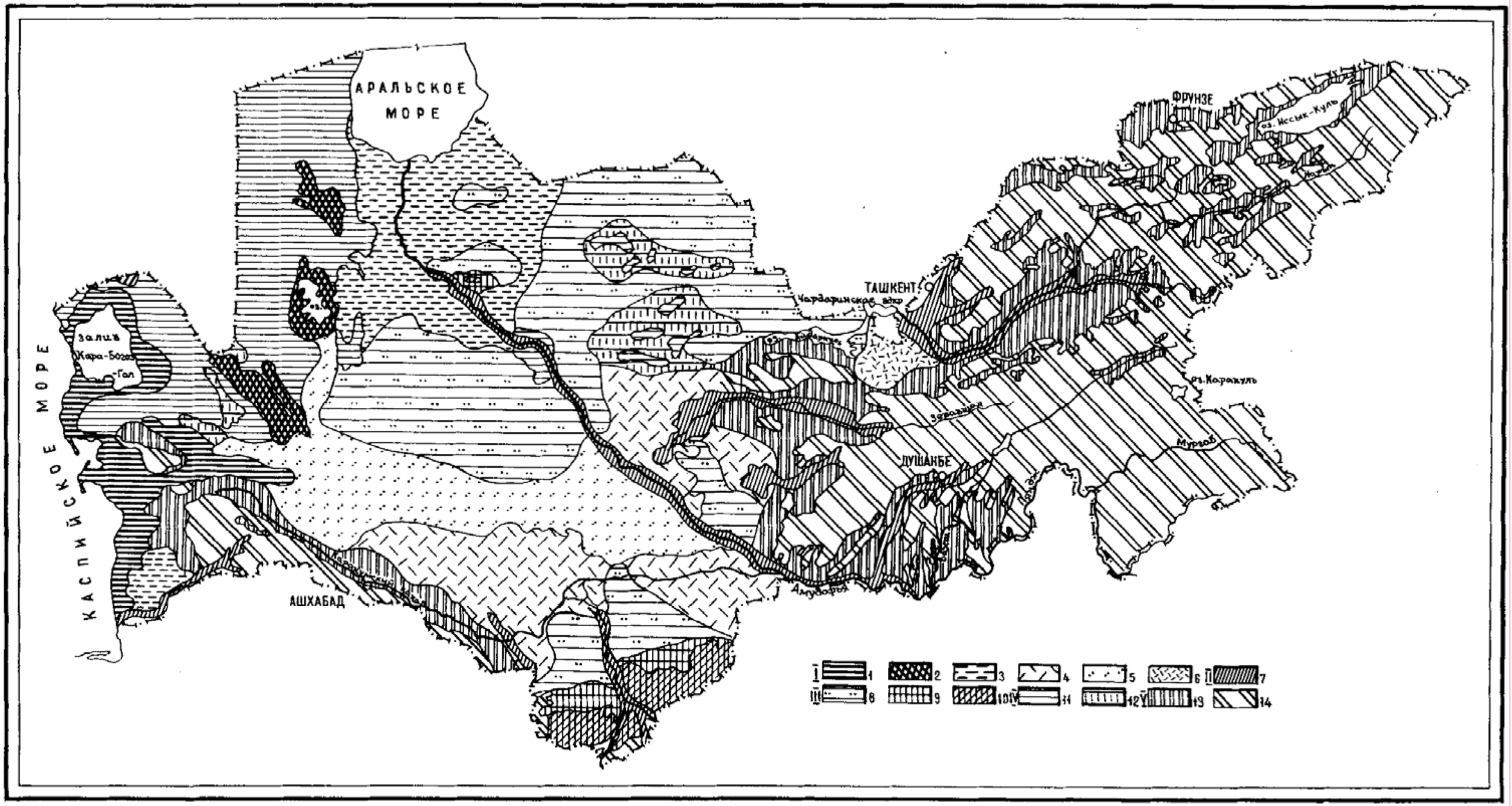

Fig. A.2.2. Geomorphological provinces and genesis of aquifers deposits (Hydrogeological map of Central Asia, Soyuzvodproekt, 1990)

I. Lower accumulation plains; aquifers deposits: 1 - maritime; 2 - lake; 3 - delta alluvial-maritime; 4 - sub-aerial-delta; 5 - ancient alluvial; 6 - alluvial-proluvial.

II. Accumulation terraces in the modern rivers valleys; deposits: 7 - modern alluvial. III. High denudation-accumulation plains: deposits: 8 - eolic-delluvial; 9 - alluvial-proluvial; 10 - eluvial-deluvial. IV. High denudation plateous; deposits: 11 - eluvial-deluvial; 12 - alluvial-proluvial. V. Mountain massives, pre-mountain-mountain and inter-mountain plains; deposits: 13 - alluvial alluvialproluvial; 14 - eluvium and exposures of bedrocks.

A.2.2. Lithological description of main region of irrigated farming development

In the regions of irrigated farming development lithology is very important for distinguishing geomorphological rayons. Each geomorphological rayon or hydrogeological basin with respect to its genesis (alluvial, proluvial, limnic, fluoglacial, etc.) have own regularities in lithology determining conditions of irrigation drainage system operation.

On fig. A.2.3. typical lithological cross-sections for major rayons of irrigation are given.

Mountain plains well drained by rivers fine-grained deposits are underlain by thickness of highly permeable soils. Pre-mountain plains well drained and provided by ground water outflow are presented by fine-grained deposits underlain by coarse disintegrated material.

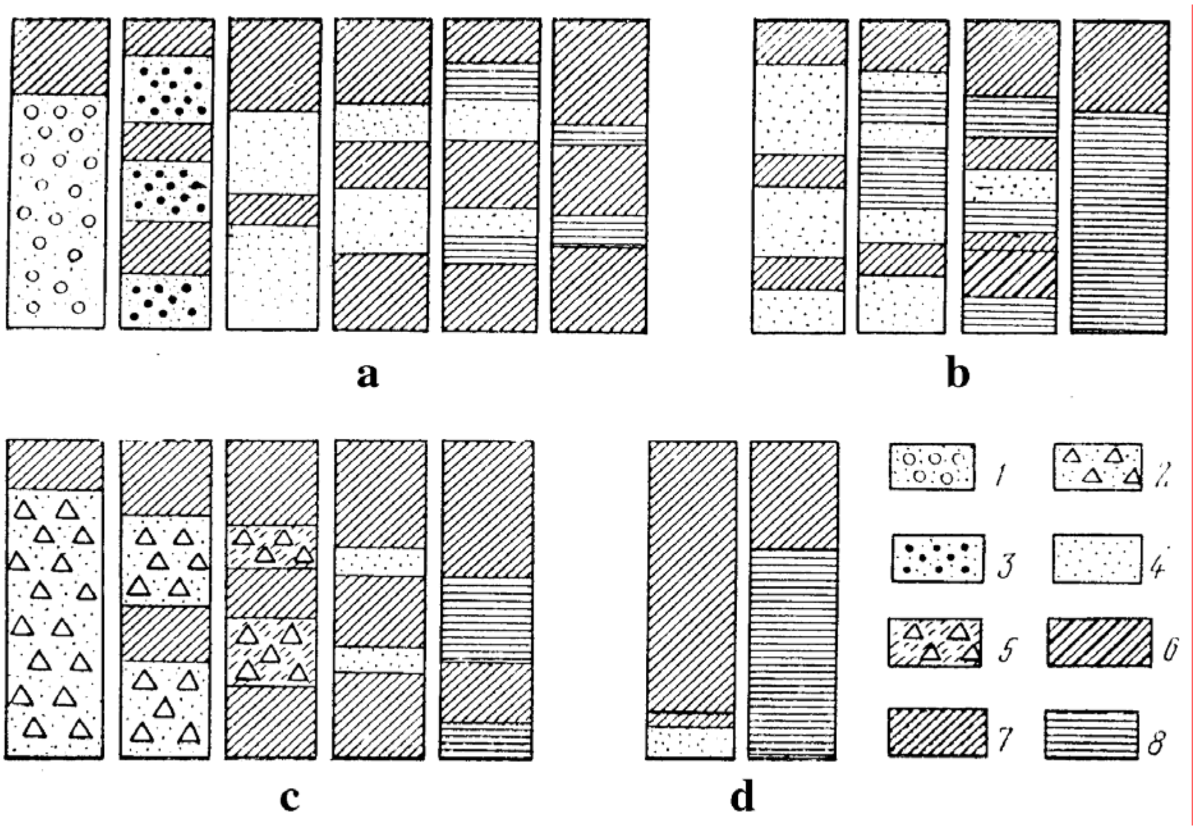

Fig. A.2.3. Genetic rows of typical lithological cross-sections of ground water upper layers (to depth of 70-100 m).
a - alluvial plains; b - pre-mountain plains; c - delta and sea-side low elevations; d - watersheds; 1 - pebbles; 2 – coarse peble with loam; 3 – gravel; 4 - sand; 5 - crushed stone; 6 - sandy loam; 7 - loam; 8 - clay.

For these rayons two genetic types of cross-section are typical: the first is connected with large rivers alluvium (pebble and gravel), the second with provisional streams (desintegrated coarse and fine-grained material).

Lithology of middle river terraces are characterized by fine-grained deposits underlain by sand and gravel. There are not impermeable interlayers close to land surface. Free outflow is provided to natural sinks (rivers, gulleys).

On lower river terraces and secondary drained river cones flacky thickness of fine-grained deposits is underlain by sands of higher permeability. Low hydraulic gradients and soil water-physical properties slow down filtration rate.

Alluvial-proluvial cones of withdrawal and alluvial-proluvial plains are characterized by sharp changes of soil along the profile. On alluvial plains sandy fractions prevail which in lower reaches are replaced by clay and loam. Thickness of cover deposits increases from young to old terraces (from 2-5 up to 25-40 m).

Watersheds are presented by thick loess deposits underlain by fluvioglacial and ancient alluvial sands.

For close to sea lower elevations heavy clayey soils are typical interlaing with small-grained sand. Permanent sedimentats accumulation occures, because rayon is practically without outflow, intensive soil salinization and water logging of substantial area have place.

A.2.3. Hydrogeological conditions of main regions of irrigation

Hydrogeological conditions are complex of indicators characterizing conditions and regularity of ground water formation in natural conditions, expected reclamation inflence and necessary measures providing favorable hydrogeological conditions.

With respect to degree of complexity irrigated regions are divided in to 4 groups:

1. regions with relatively simple conditions;
2. regions of medium complexity;
3. complex region;
4. very complex

On fig. A.2.4. examples of orogenic and platform regions which are characterized by different complexity of hydrogeological conditions are shown

Irrigated regions of platform group with respect to hydrogeological conditions complexity vary from simple to very complex. Depth of regional impermeable layer is low.

Quaternary rocks do not contain gravel-pebble deposits.

Regions with relatively simple hydrogeological conditions are characterized by fresh ground water formation with table deep ground water table (regions 1 - 4 on fig. A.2.4.).

These regions are located mainly in water sheds and are distingnised by intensive natural drainability.

Ground water outflow fully compensates inflow evaporation and transpiration are negligible or absent at all.

Automorphous regime of soil formation is typical under this outflow, soils are non-saline (typical and light grey soils, etc.) and sustainable good meliorative state of lands as provided. Artificial drainage is not required that reduces expenses for reclamation. These lands are very favorable for irrigation. Naturally drained lands also belong to the first groups of regions. Thanks to intensive ground water outflow it is sustainably fresh in spite of shallow water table (regions 5,8,on fig. A.2.4.).This is facilitated as well by intensive ground water inflow which, under substantial outflow, provides good "flushing" of deposits and absence of easily soluble salts within unsaturated zone. Thanks to shallow fresh ground water agricultural crops cover their water requirement at expense of ground water. Meadow -marshy soils,

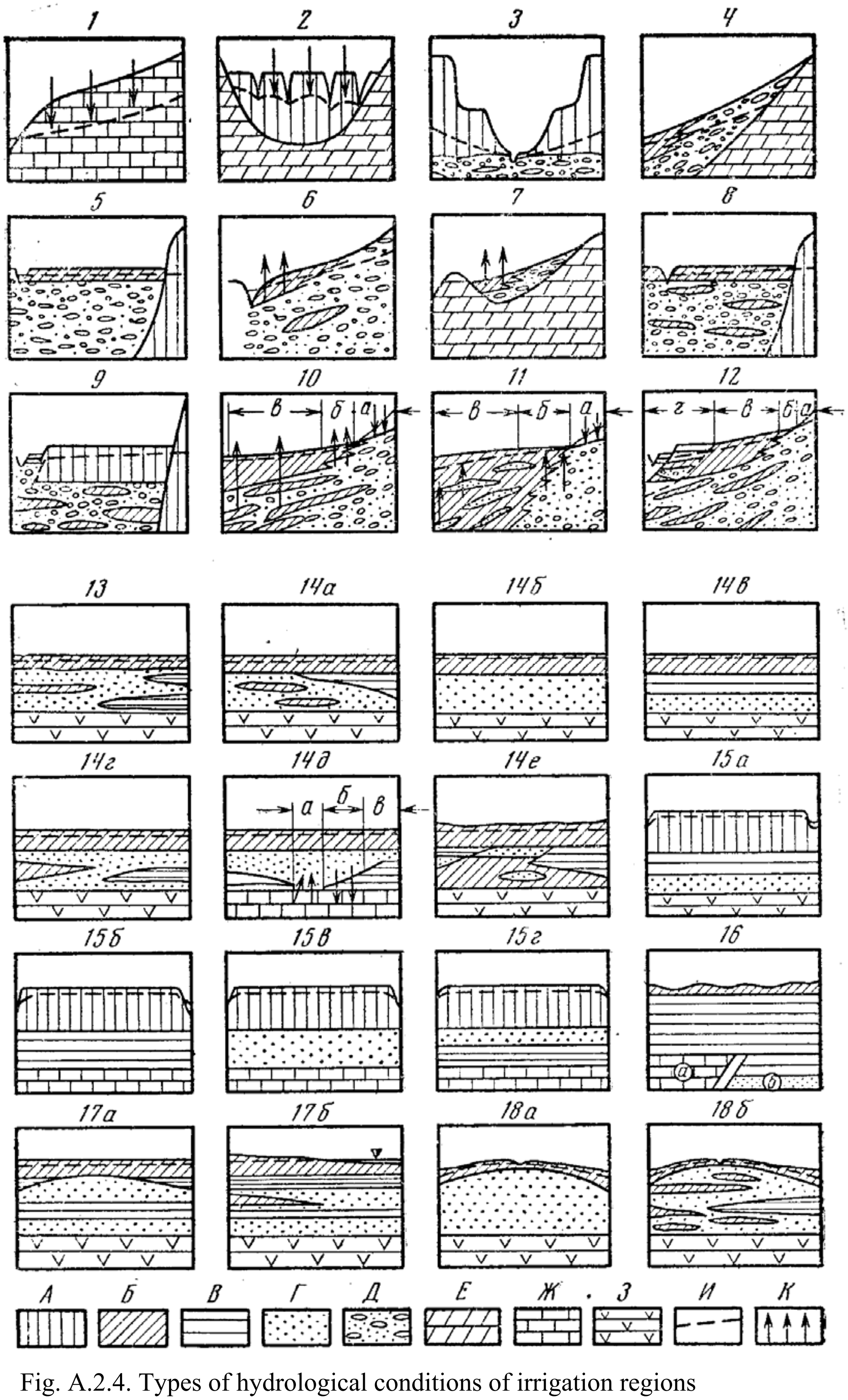

Fig. A.2.4. Types of hydrological conditions of irrigation regions

1-mountain slopes and pre-mountain plains made of flaky bedrock; 2.-

3. deeply corrugated pre-mountain plains;4-rivers cones of removal; 5-low and middle alluvial terraces; 6-imperfeet river cones of removal; 7-depressions between adyrs; 8-upper parts of sub-aerial delts, middle alluvial terraces weakly drained; 9- alluvial terraces very weakly drained; 10-cones of removal constituting pre-mountain plains.

which are formed under these conditions, possess high potential fertility (in case water logging prevention). Soils have sulfate-calcium and carbonate. Magnesium salinity with formation of solid salt horizons (called in Central Asia "shoh or "arzik".

Regions of medium complexity include naturally drained lands where under artesian water influence it is necessary to fight water logging more intensive drainage is needed to compare with the first group regions (regions 6,7 on fig. A.2.4.). Weakly drained regions, where it necessary to fight slightly soil salinity, encompass also naturally weakly drained regions with saline ground water (regions 9,14, a, b, c, d on fig. A.2.4.).

Regions with complex hydrogeological conditions are widely spread within irrigated zone. They are as follow:

- very weakly drained lands without or with weak artesian overflow (regions 9, 13, 14. a, b on fig. A.2. 4.);
- zones of intensive ground water seepage within the cones of withdrawal where strong and very strong artesian overflow occures (regions 10, 12, on fig. A.2.4.).
- lands practically without outflow with weak or without artesian overflow (regions 14, b, e, 15, a, b, c, d on fig. A.2.4.)

In considered group of regions, where ground water of high salinity occures, the main task of reclamation measures is fight with soil salinization on base of ground water regime regulation by the intensive drainage.

Regions with very complex hydrogeological conditions include :

- lands without outflow - practically impermeable (regions 16 on fig. A.2.4.);
- very weakly drained lands with two-layer and multi-layer aquifer and middle or strong overflow from fresh artesian to ground water (region 11 on fig. A.2.4.);
- very weakly drained lands and lands without outflow with two-layer or multi-layer aquifer under complex hydrogeological conditions (regions 17, a, b, on fig. A.2.4.)

Regions of last group require the most intensive drainage to fight with land salinization and leaching irrigations using chemical meliorants (in case of soil sodification). If in the regions with simple hydrogeological conditions expenses for drainage are not necessary, in considered group of regions these expenses achieve 2-3 th. rouble/ha. Annual operational costs are high as well.

For many regions of this group methods of ground water regime regulation for reclamation are not yet developed.

One of the most important hydrogeological indicators of irrigated lands is a natural land drainability. Its indicator is potential value of ground water outflow (expressed in mm of water layer or m^3/ha per year).

Massif natural drainability is defined by its geostructural, geological, geomorphological conditions, relief, ground water inter action with surface water bodies and with artesian water as well. These factors are reflected in geofiltration schemes of irrigated or drained massifs.

The following geofiltration schemes are possible depending on geology:

1. one-layer;
2. two-layer;
3. multi-layer;
4. impermeable.

Under geofiltration schematization for quantitative characteristic of layer parameters it is expedient to use the following quantitative indicators.

Layer permeability with respect to horizontal drainage conditions:

Favorable conditions - permeability coefficient more than 0,5 nm/day,intermediate - 0,1-0,5 and unfavorable - less than 0,1 m/day.

On base of analysis of drain operation under permeability coefficient less than 0,1 m/day their differentiation is expedient on the following groups:

from 0,1 to 0,01 m/day low permeability, from 0,01-0,001 m/day very low permeability and less than 0,001 m/day-extremely low permeability. At the same time along with soil permeability reduction losses for filtration from irrigation canals reduce as well.

For assessment of vertical drainage and ground water intakes operation efficiency and common hydrogeological conditions of the massif one of main parameters is sediments water conductivity. Under two-layer of multi-layer scheme water conductivity of more permeable layer should be evaluated within the following borders:

less than100 m^2/day (unfavorable); 100-200; 200-500; 500-1000; more than 1000 m^2/lay.

Along with water conductivity increase conditions of water-intake and vertical drainage efficiency are being improved.

Important factor of geofiltration schematization is availability and character of links between ground water and under artesian aquifer . It should be distinguished:

1) regions of ground water formation, 2) regions of unit aquifers of ground and artesian waters formation. Under accedance of artesian water head over ground water level and overflow from artesian water to ground one it is expedient to distinguish the areas:

weak artesian recharge-up to100 mm/year; middle-from 100 to 200; strong-from 200 to 300; very strong-more than 300 mm/year.

Natural drainability depends on factors considered as well as geofiltration flows border conditions.

With respect to natural drainability degree certain hydrodynamic zones are distinguished, characterized by different outflow of ground water compared with its irrigation recharge.

From water balance investigations is found that in arid and semi-arid zones under existing land efficiency and furrow irrigation by dravity, irrigation recharge of ground water is near 300-600 mm/year.

Coming from that the following 5 zones are distinguished:

1. naturally intensively drained with potential ground outflow more than 500 mm/year i.e. more than irrigation recharge under any climatic conditions and methods and technique of irrigation;
2. drained-outflow is 300-500 mm/year that corresponds to ground water irrigation recharge in desert and semi-desert regions and accedes recharge in steppe regions;
3. weakly drained-outflow is 150-300 mm/year i.e. it is less than irrigation recharge in desert and semi-desert regions and corresponds to upper limit of recharge in steppe regions;
4. very weakly drained - outflow is 50-150 mm/year i.e. significantly less than recharge in desert and semi-desert regions and close to lower limit of ground water recharge in steppe regions;
5. practically without outflow-outflow is less than 50 mm/year, i.s. much less than ground water irrigation recharge under any climatic conditions.

Along with ground outflow under shallow decreaseground water its discharge for evaporation and transpiration grows that leads to ground water salinity growth and salt accumulation in soil and unsaturated zone. Geomorphological conditions of distinguished hydrodynamic zones are presented in table A.2.1.

Irrigated lands can be located in all zones of natural drainability. But only near 20 % of irrigated lands are characterized by intensive natural drainability where stable deep ground water table takes place and artificial drainage is not necessary. The same area is occupied by naturally drained zone with stable fresh ground water, where drainage could be necessary for water logging prevention.

Three hydrodynamic zones with low natural drainability occupy around 60 % of existing and prospective irrigated lands. Drainage is necessary or would be necessary in the future to prevent land salinization, sodification and water logging.

Large irrigation massifs could be characterized by presence of several hydrodynamic zones. But the oasises with homogenous drainability can happen as well.

Under significant thickness of the top low permeable layer (more than 10-15 m) underlain by highly permeable deposits natural drainability of this layer should be assessed separately. It depends on layer permeability, highly permeable strata water conductivity and relationship between levels in two strata. This relationship can be changed with time correspondingly to increasing or decreasing drainability of top strata that should be taken into account while preparing forecast.

Regions of over-moistened soils requiring drainage are located only within the zones of low drainability. Most important indicator of natural drainability in humid zone is ground water table depth with regards for its seasonal, annual and multi-year changes.

Ground water depth, salinity, regime and balance.

Ground water table and salinity characteristics under different climatic conditions and land drainability arepresented in table A.2.1. Depending on combination of climatic and hydrodynamic conditions ground water differ in salinity from fresh to very strongly saline (200-300 g/c). Ground water level changed within wide diapason. Ground water table as well as its salinity are subjected to seasonal, annual and multi-year fluctuations which subordinates to certain peculiarities of regime.

Ground water regime and balance on irrigated and dried lands are formed as a result of interactions of natural and economic factors.

General hydrogeochemical conditions

Within each climatic and hydrodinamic zone there are one several local factors complicating natural hydrogeochemical situation. These factors are as follow:

- modern and ancient sea salinization of soil and ground water;
- bedrocks salt bearing, denudation and accumulation processes;
- ground water recharge by saline artesian water;
- ground water alcalinity increase cansing soil sodification;
- mud volcano and salt-dome tectonics.

Geochemical situation comhlexity is reflected in increases of salt stock in ground water, bearinbg thickness and unsaturated zone that makes land reclamation more difficult.

Under hydrogeological conditions considered saline ground water or water with high alkalinity may be formed in any climatic zone, though highest salt accumulation has place under combination of complex geochemical conditions with absence of outflow and aridity.

Table A.2.1

Zones of natural drainability

zone	Zone characteristic					Geomorphological conditions
	ground water flow type	ground outflow mm/year	prevailing ground water salinity, g/l	prevailing ground water table, m	ground water role in soil formation processes	
1. Intensively drained	deep ground water flow moving with different speed	100-300 m in loams, 500-700 m in pebbles	ultrafresh in all climatic conditions	>50-10 (on irrigated canals)	do not participate, automorphous soils.	pre-mountain trains and upper parts of cones of withdrawal made of pebble-strongly corrugated pre-mountain planes and alluvial terraces, high river shelves made of loamy sediments
2. Drained	ground water flow moving with speed of >100-200 мм/day	300-500	the same	different on irrigated lands от 4-5; in humid zones more than 3	shallow table causing water lagging	alluvial terraces, ground water seepage zones, made of pebble with loamy soil
3. Slightly drained	slow ground water flow 25-100 mm/day.	150-300	fresh in humid climate brackish in arid climate	different on irrigated lands 0-3-4 m in humid regions 1,5-3 m.	shallow table causes water logging in arid climate slight salinization	middle and lower river terraces, central parts of cones of withdrawal made of sediments with loamy top soil, thickness 50-10 m. middle and lower river terraces
4. Very slightly drained	very slow flow - 5 - 25 мм/day	50-150	fresh in humid climate, saline in arid climate, salinity grows from steppe to desert	different on irrigated lands 0 до 2-3; in humid regions <1.0-1.5 m	shallow table caused water -logging in arid climate, soil salinization	broad river terraces, watershed, pre-mountain planes, river deltas, depessios between cones, lake and lake-glacial planes made of thick loamy sediments underlain by sandy or sand-clayey deposits.
5. Without outflow	ground water basin <5 мм/day	<50	then same	different on irrigated lands- 0 -1-3; in humid	then same	modern and ancient river deltas, pre-mountain-sea

zone	Zone characteristic					Geomorphological conditions
	ground water flow type	ground outflow mm/year	prevailing ground water salinity, g/l	prevailing ground water table, m	ground water role in soil formation processes	
				regions <0.5-1 m		depressions, sub-aeral deltas, plain planes, lake-glacial planes made of clayey sediments underlain by sands, sand clayey deposits or bedrock