COMBINED DRAINAGE WITH PRESSURE RELIEF WELLS IN THE FERGANA VALLEY

BAHADIR BOZ[1], PULATKHON UMAROV[2]

Abstract

Irrigated agriculture is the backbone of the Uzbek economy, accounting for 35% of GDP, 60% of foreign exchange receipts, and 45% of employment. However, about 75% of irrigated land has poor natural drainage; therefore, irrigation there involves rising of the water table, increase of salinity, and soil salinization. In parallel to the measures to be financed by the national budget, Government of Uzbekistan started implementing donor funded projects for solution of the above mentioned problems. The Fergana Valley Water Resources Management Project Phase-I (FWRMP), which is World Bank funded, has been devised to address constraints on agricultural productivity in parts of the Uzbekistan territory lying within the Fergana Valley (FV). In addition, it seeks to tackle chronic problems of waterlogging which are affecting infrastructure and buildings within this part of the FV. Combined drainage is a system of horizontal drainage enforced by pressure relief wells located along the drain placed in the impermeable cover silts and connected to vertical flowing wells with their water intake portion in a well-permeable underlying layer. Advantages of the combined drainage include: low construction costs, no power consumption, low operational costs, simplicity in operation, and shorter desalination period. As a result of a water balance conducted, the total amount of excess water to be removed from the project area has been calculated to be 190 million m^3/yr. It had been estimated that 1411 pressure relief wells which would give a yield in the order of 2 l/s, to be drilled would provide almost half of this volume. At the time being, almost one third of these wells have been constructed almost all of them giving minimum twice the expected yield. Results obtained show that combined drainage system has proven to be a sustainable solution which can be upscaled to very large areas.

Introduction

Irrigated agriculture is the backbone of the Uzbek economy, accounting for 35% of GDP, 60% of foreign exchange receipts, and 45% of employment. In the rural areas, agriculture and processing of agricultural products is by far the main source of employment and income for the population. The most important crop is cotton which accounts for about 50% of national export earnings. The irrigated area, which extends over about 4 million ha, is served principally by the Amu Darya and Syr Darya together with their tributaries.

However, about 75% of irrigated land has poor natural drainage; therefore, irrigation there involves rising of the water table, increase of salinity, and soil salinization. Improvement of land reclamation requires construction of advanced types of

[1] Team Leader, Fergana Valley Water Resources Management Project, Navoi Street 44, Room 512, Tashkent, Uzbekistan, bboz@temelsu.com.tr, +998 90 188 29 19
[2] Technical Expert, UNDP, pulatkhon.umarov@gmail.com

drainage (mainly subsurface horizontal and vertical drains) as well as proper operation and maintenance of irrigation and drainage systems.

Despite the reforms in agricultural sector undertaken in the first years after independence such as developing farming enterprises, uniting them into Water Users' Associations, and setting up production and market infrastructure did not universally lead to increased productivity and income generation of rural population. A major constraint for increased productivity and income of rural population was land degradation caused by water-imbalance of a significant portion of irrigated land. The first root cause of this degradation was lack of a comprehensive, systematic perspective during planning of the land reclamation facilities; secondly, their financing sources were not indicated specifically; thirdly, a weak performance of newly formed WUAs, and the last reason was that overall level of land reclamation has dropped. All these factors eventually brought to shallower water table, higher salinity of ground water, and land degradation caused by water-imbalance of irrigated land.

In order to rectify this situation, Presidential Decree # UP-3932 "*On measures for radical improvement of the reclamation land development system*" was issued on October 29, 2007, and Presidential Resolution #33-718 "*On Setting Up the Irrigated Land Reclamation Fund under the Ministry of Finance of the Republic of Uzbekistan*", on October 31, 2007. These statutes established the Irrigated Land Reclamation Fund incorporating Management Department. Its legal basis was also set forth by Presidential Resolution # PP-817 dated March 19, 2008, "*On the Government Program for Irrigated Land Reclamation for 2008–2012*"and CM's Resolution # 261 as of November 28, 2008, "*On Improvement of Planning and Implementation of Land Reclamation Programs*".

Taking into account that drainage is a primary method of irrigated land reclamation, the first Government program had following key objectives: (i) construction and renovation of land reclamation facilitiess; (ii) repair in irrigated land reclamation facilitiess; and (iii) supply of equipment and materials to the specialist construction and operating organizations involved in building and maintaining land reclamation facilities.

Fergana Valley Water Resources Management Project

In parallel to the above given measures, Government of Uzbekistan started implementing donor funded projects for solution of the above mentioned problems. The Fergana Valley Water Resources Management Project Phase-I (FWRMP), which is World Bank funded, has been devised to address constraints on agricultural productivity in parts of the Uzbekistan territory lying within the Fergana Valley (FV). In addition, it seeks to tackle chronic problems of waterlogging which are affecting infrastructure and buildings within this part of the FV.

The FV comprises parts of three Central Asian States: Uzbekistan, Tajikistan and the Kyrgyz Republic (**Figure 1**). The total area is approximately 2.6 million ha, and there is a total population of 14 million, of which 66% live in the rural areas. Compared to the other parts of these countries, population density in the Valley is high, and the amount of land available per person is small. Poverty is widespread.

The main water-sources for the FV are the Naryn River, the Kara Darya, and the Syr Darya, which is formed by the confluence of the Naryn and Kara Darya. Numerous small rivers flow in from the north, east and south, including the Sokh and Isfara. The FV has appreciable groundwater that has developed over geological time. The subterranean waters associated with the rivers noted above, especially the Sokh and Isfara, form a main source of potable water supply for the population in the Valley.

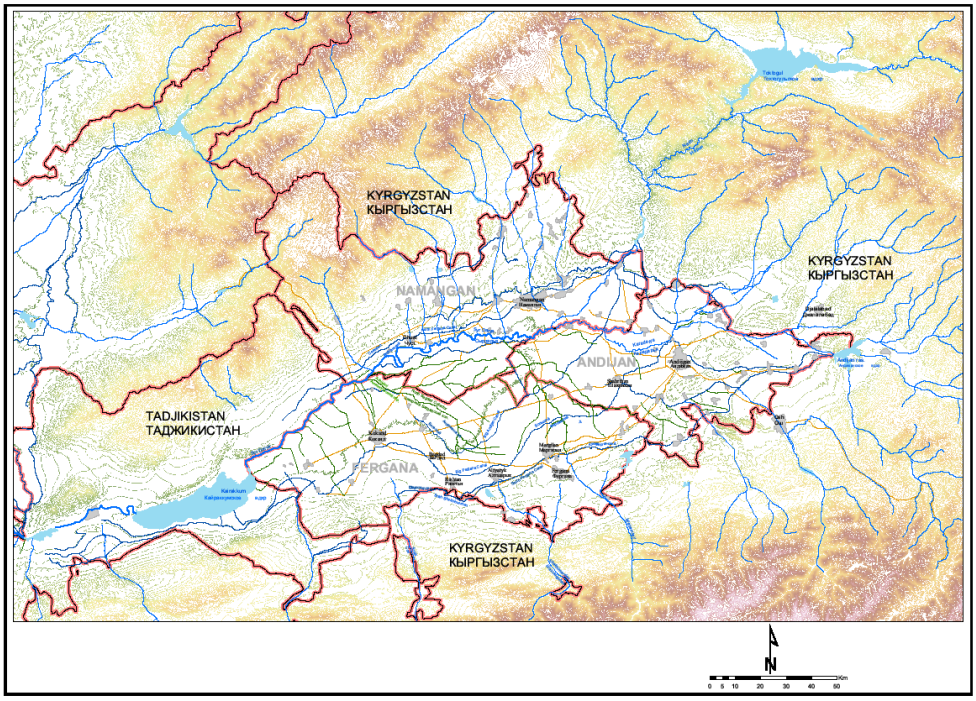

Figure 1 Fergana Valley Water Resources Management Project Area

A major problem in the FV is the high water table, especially in the lower and central parts of the FV. This widespread problem is particularly associated with the irrigated areas. It is generally believed that the high water table is due to the absence of an adequate drainage system; or a drainage system that is no longer properly functioning, because the necessary rehabilitation and maintenance has not been carried out during the past two decades; and because of poor water management practices. As a result, the area is suffering from substantial water logging and soil and water salinization. The high water table has mobilized salt in the soil which, with waterlogging, has resulted in destruction of buildings and residential houses located near the collector drains. For crops, it has resulted in lower yields and therefore lower incomes for the people living in the area.

The main objectives of the FWRMP are to: (i) Promote sustainable irrigated agriculture production, increase employment and generate farm incomes in the Uzbek part of the FV by improving drainage and irrigation systems and overall water resources management; (ii) Reduce damage to private and public infrastructure, and improve environmental and public health conditions by controlling water logging; (iii) Introduce participatory irrigation management through water users' associations and improved agricultural and irrigation practices, and income generating activities to enhance value of the products from the project area; and (iv) Strengthen water management, and irrigation and drainage institutions.

Vertical Drainage in the Fergana Valley

The large-scale development of irrigation in the whole of the FV has resulted in groundwater levels rising to near ground surface, with levels maintained by the artificial drainage system. Under such circumstances, groundwater movement is largely controlled by land gradients and aquifer properties. The flow system is complicated and of a 3D nature both due to land form (convergence of groundwater flow towards the central low lying part of the study area) and due to the nature of the aquifer system, which changes from basically one layered in the south to multi-layered in the north, while also aquifer transmissivity reduces from south to north.

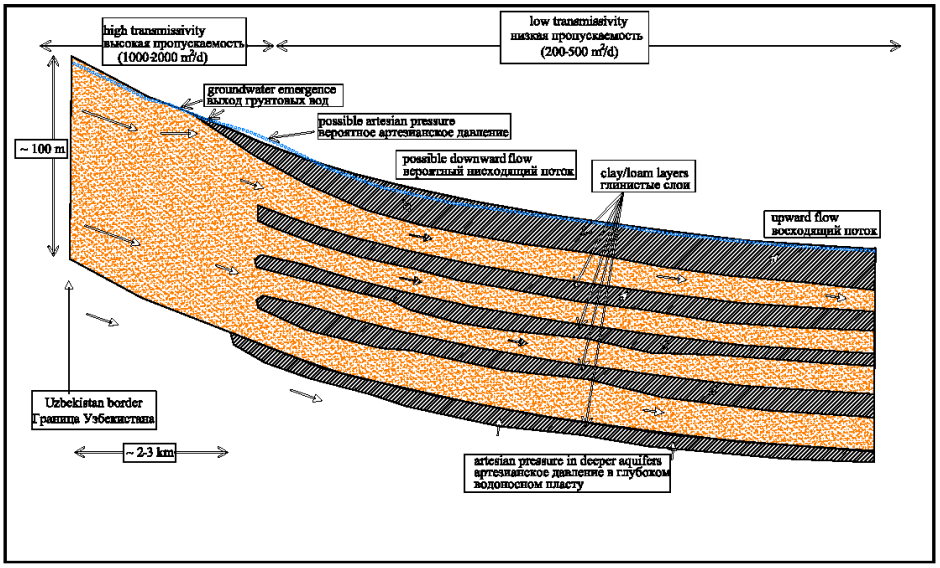

Figure 2 Typical Hydro-geological Cross-section in the Project Area

Local circulation of groundwater is largely controlled by changes in land surface gradient and also by the open drainage network. Although the groundwater table is close to ground surface, soil salinity problems tend to only occur in areas where there is a net upward flux from the deeper groundwater. It is possible and likely that the area of upward flux is closely associated with the areas where high soil salinity is observed. In the eastern part of the Project Area, there appear to be limited soil salinity problems, which may be indicative of a net downward flux contributing to groundwater flow towards the lower lying areas to the north and northwest.

Within the project districts, more than 400 vertical drainage wells have been constructed. Only around 170 are still operational and these suffer from power cuts, shortages of spare parts and poor maintenance regimes. The suitability of such drainage has been assessed with regard to the hydrogeological characteristics of the area.

Permeability values given for the low permeability layers are such that there is significant potential for vertical groundwater movement between aquifer layers. From the permeability values, one can derive that flows of the order of 5 to 25 mm/d would result from a head differential of 1 m. Such flows are generally well in excess of normal drainage requirements and thus indicate the good potential of the aquifer system for vertical drainage.

The majority of the Project Area currently has a depth to groundwater in the range of 1.5 to 2.0 m. At this depth, there is likely to be some risk of soil salinization through capillary rise but little direct impact on crop yields through waterlogging. Indeed, with these water depths in the spring (winter wheat) and summer (cotton) growing periods, the crops would draw water to meet evapotranspiration needs and hence be more robust in the face of intermittent irrigation water supplies.

For agricultural purposes optimum GWL is below 2 metres, to ensure that there is sufficient aerated rooting depth. Even making allowance for the fact that the GW maps are based on average data for the entire districts, it is clear that there has a decreasing trend in the land with GWLs below 2 metres over the last 10 years

Combined Drainage as an Alternative in the Fergana Valley

Combined drainage is a system of horizontal drainage enforced by pressure relief wells located along the drain placed in the impermeable cover silts and connected to vertical flowing wells with their water intake portion in a well-permeable underlying layer.

On salt-affected soils, deep drainage is more preferable than shallow as it allows: (i) maintaining the deeper water table and, consequently, achieving greater desalinization effect by leaching; (ii) making the secondary salinization process less rapid; and (iii) spacing out the drains for more efficient use of the cropland. Therefore, most common depth of drains in old-irrigated lands of the region is 2.0~2.5 m for drains, 2.5~3.0 m for collectors, and 3.0~4.0 m plus for main drainage systems.

Open drainage systems, despite their simplicity and relatively low installation cost are considered of limited functionality as they have some significant drawbacks, including: (i) rapid siltation and overgrowth of weeds and susceptibility to landslides and wall collapse requiring costly systematic cleaning and deepening; (ii) difficulty of providing timely periodical cleaning and deepening of drains and collectors to maintain their required working depth that determines their draining effectiveness; (iii) open drains and collectors occupying a large area inflict loss of irrigated land, prevent agricultural mechanization and vehicle traffic; and (iv) with a large amount of pressured ground water, open drainage systems do not provide sufficient desalinization and require a lot of irrigation water to achieve required reclamation efficiency.

The vertical drainage systems are effective for predominantly heterogeneous soil structures with a thick (15-45 m) silt cover, underlain by well permeable sand and gravel layers over 5 m thick and water transmissive capacity of more than 100 m^2/day. They can be effective in case of a lower water transmissive capacity if permeability of the silt cover is low (less than 0.1 m/day) or the groundwater in the aquifer is under pressure. The limitation regarding the cover silt thickness is important because whenthe capacity of subsoil is less than 15 m, vertical drainage creates spatial heterogenity of a number of factors: the water table depths, their drawdown rates, and the rates of soils desalinization. In formations with capacities of more than 45 m the resistivity of the cover silt sharply increases, and hydraulic connection between groundwater of the silt cover and groundwater of underlying layers is lost.

Under such conditions, the pressure occurring during watering and followed by the rise of water table is transferred to a lower well-permeable layer and forms an inflow to the vertical wells and then into a network of horizontal drainage. Thus, flowing wells placed along the drains increase its efficiency and, respectively, can significantly extend the drain spacing. To improve the water procuring capacity, combined drainage wells (max depth of 30 m) have a diameter of 346 mm and are cased with smooth plastic pipes with a diameter of 140 mm perforated in the bottom end placed in a well-permeable underlying layer. Sand-gravel mixture of specially selected composition used as filter protection is placed in the annulus between the casing and the well wall. The distance between the wells along drains depends on the hydrogeological conditions and can be 50~100 m. The pressure relief wells can be connected to both open or pipe-type horizontal drains or manholes.

Depending on the natural and economic conditions, the combined drainage systems may have two layouts: (i) Areal, when in addition to open collectors, pipe drains connected to pressure relief wells are built with a space ofno more than half the inter-drain distance; (ii) Linear, on which the pressure relief wells are installed along open collectors spaced usually at not more than 800~1000 m.

According to this classification, the horizontal drainage systems are effective for predominantly homogeneous soil structures with permeability of 0.01 to 1m/d and more, given a close (up to 5 m) occurrence of a water seal. It is also effective in a

heterogeneous soil structures with thin (3-4 m) covers of fine earth, when there is a good opportunity to uncover the underlying permeable (sand, gravel, etc.) layers to lay horizontal drains there.

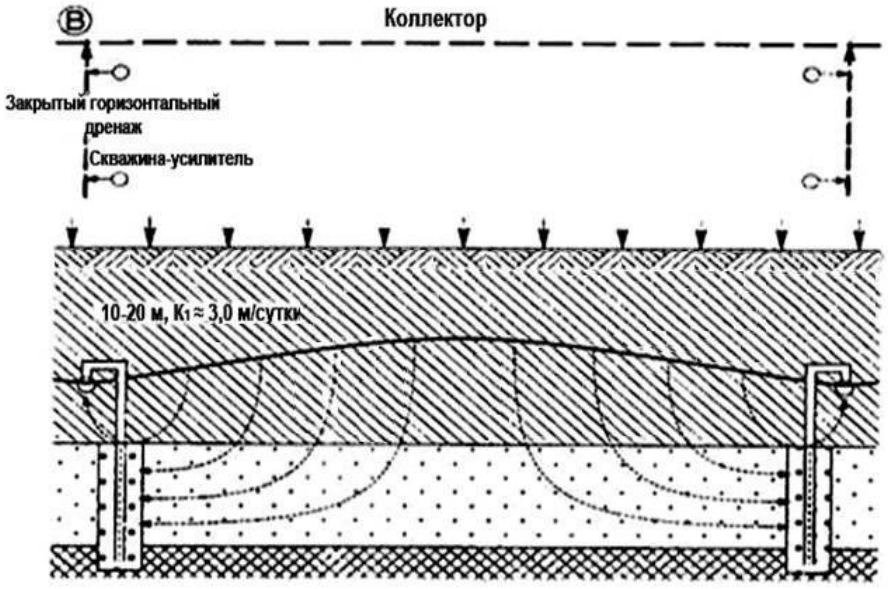

Figure 3 Typical Plan and Cross-section of Combined Drainage

The combined drainage systems are effective in case of heterogeneous structure of the soil and subsoil, with the poorly permeable (0.01-0.5 m/day) silty cover whose capacity ranges from 5 to 15 m and well permeable (over 10 m/day) underlying layers, with pressurized or not pressurized groundwater. The combined drainage systems is inapplicabile in case of a thin capacity of the silt cover because the horizontal elements (to a depth of 3-4 m) laid directly into the underlying permeable layers eliminate the need of the vertical elements (wells). When the silt cover reaches 15 m or more, its geofiltrational resistivity and hydraulic losses increase. In conditions of low permeability of the silt cover (less than 0.1 m/day) when the drainage capacity of horizontal systems can be neglected, drainage can be done with the use of non-perforated, “blind" water pipes only for transportation of drain water flowing from the combined drainage wells.

The key conditions for application of these systems are: non uniform soil structure with low permeability of upper and high permeability of lower soil levels. Drain is located in the upper soil level while well is drilled till the lower soil level. Due to such a design a pressure formed through irrigation and water table elevation transfers from the upper section with low permeability to the lower soil section with higher permeability. Thus an outflow to a vertical drain and well spring to the horizontal drain system is enforced. Wells located along the drains are reinforcing draining effect thus decreasing the density of the horizontal drainage network.

Advantages of the combined drainage include: low construction costs (the construction of combined drainage system is twice cheaper than those of closed horizontal drainage systems), savings in materials (the design of the pressure relief wells allows substitution of scarce materials with plastic materials), reduced electricity consumption (an operation of vertical drainage system requires 700-800 kW/hr/hectare of energy a year, whereas the combined drainage systems have no such costs involved), low operational costs (2-3 times less than for operation of vertical and 1.3-1.5 times of horizontal systems), simplicity in operation (the combined system, in comparison to vertical type, does not require a complicated

power equipment, and in comparison to horizontal type, is less exposed to siltation), shorter desalination period (optimized reclamation regimes allows desalination process to take place 1.2-1.3 times faster than that of closed horizontal and vertical drainage systems).

The systems proved to be extremely sustainable due to simplicity of design and ability to work in autonomy mode through the fluctuations of the ground water levels. For instance, combined drainage constructed in Karshi Steppe (south of Uzbekistan) in 1980 is still functioning without any maintenance effort and related costs. Therefore, combined drainage could be a low cost solution to improve land conditions where appropriate and subsequently increase water and land productivity.

Proposed Solutions in the Fergana Valley

From the analyses undertaken it has been concluded that the underlying causes for the problems in the Project Area show some differences both spatially and temporally. Combination of these analyses with the zoning developed has allowed specific solutions to be developed for different parts of the Project Area.

The interventions that are required are conventional. Tried and tested technology and application in standard configurations is proposed. However, to achieve the desired improvement in water table management, different approaches are required in different areas to suit the prevailing conditions, including the mechanisms believed to be responsible for the problems that currently exist.

A particular problem in the Project Area is the reduced drainage function because of intermittent power supplies. However, addressing this requires high-level attention. It is clearly undesirable, and potentially a wasteful application of funding, for the proposed drainage works to rely on power supplies which may not be provided by the state organization responsible. In the first instance strategic decisions are needed to prioritize power supplies to drainage installations serving crucial infrastructure. Longer term, but in the near future, the strategy for committing to supply other drainage infrastructure is required, with an appropriate level of government support. To reduce the project's immediate exposure to power shortages the drainage system has been designed to minimize the use of VDWs, the current 20% VDW usage factor assumed, and PRWs deployed where possible.

Detailed analyses show that irrigation return flow is not the only source for drainage water. Surface runoff, seepage losses, groundwater coming from Burgandin massive in Kyrgyzstan and piedmont lands, water pumped out by VDWs and IWs are other significant sources. Unlike the irrigation related problems, drainage induced problems are not homogenous throughout the project area. Therefore different solutions will be proposed for the different zones identified.

The changes in groundwater table over time vary across the study area. For the purpose of conceptualizing the dominant mechanisms, the following are considered as separate zones (**Figure 4**). Note that these have been delineated to follow physical and administrative boundaries for ease of presentation; in reality the driving mechanisms described in the conceptualization have far more fuzzy boundaries.

SHD pipes have been proposed for the north of the Project Area. The loamy soils allow a typical drain spacing of 90 m whereas the loam underlain by a clay layer indicates a 120 m typical spacing might be appropriate. For the zones subject to the influence of outside sources (Zones 3, 7, 8 and 10) construction of new interceptor drains has been proposed. These drains will discharge into the existing CDN. For the zones within the artesian zone (Zones 6 and 7) construction of artesian wells has been proposed. The zone and yield for these AWs have been determined based on the study made by the State Committee of Geology and Mineral Resources Institute of Hydrogeology and Engineering Geology. For the zones within the VDW belt

(mainly Zones 2, 6, 7 and 9, partially Zones 1, 4 and 8) rehabilitation of VDWs (based on the deficiency list provided by the local authorities) and construction of PRWs have been proposed.

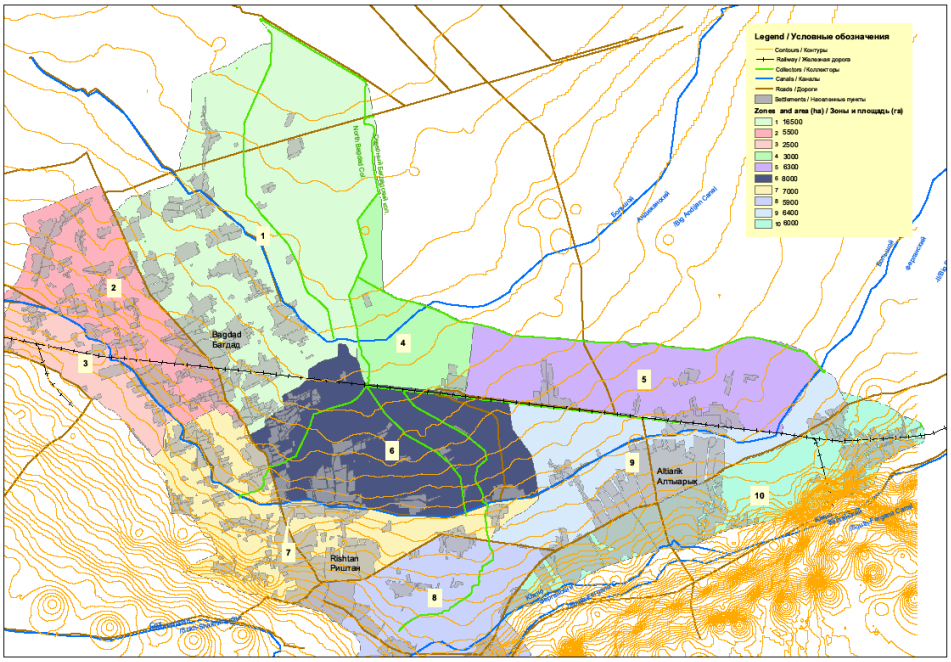

Figure 4 Conceptual Zones in the Project Area

As a result of a water balance conducted, the total amount of excess water to be removed from the project area has been calculated to be 190 million m^3/yr. It had been estimated that 1411 pressure relief wells which would give a yield in the order of 2 l/s, to be drilled would provide almost half of this volume.

Many of the proposed measures are designed to intercept or extract the excess water. However to remove this excess water out of the project area, the collector drainage network has to be in a sufficiently good operating condition. Therefore, in order to achieve this condition, the necessary cleaning / deepening works and repair / construction of structures for the inter-district, inter-farm and on-farm drains have been determined and are given below. Institutional and capacity-building needs to support physical interventions below.

Table 1 Proposed Interventions for the FWRMP

Intervention	Application and features
Drainage system	
Provision of subsurface horizontal drain system may include only interceptor pipes (perforated) which discharge directly to the drainage ditches, or interceptor pipes flowing into collector pipes (solid) which discharge into open collectors	Required as part of the intervention to reclaim saline soils. Field drainage in areas of heavier soils. Minimal loss of land to drainage system. Land take can be reduced further if buried collectors are used. SHD can also be used as interceptor drains to intercept (for example) inflows from the piedmont area or canal seepage.

Intervention	Application and features
Rehabilitation of subsurface horizontal drains	Flushing and relaying SHD; rehabilitation of SHD outfalls and inspection chambers
Provision of interceptor drains	Similar to deep open drains but specifically sited to intercept horizontal groundwater flows.
Rehabilitation of vertical drainage wells	Test and seek to overcome clogging of screens and parent rock matrix. Refurbish or replace pump motors and impellers, electrical equipment and other well head equipment.
Provision of pressure relief wells	Equivalent to VDW, but only suitable where piezometric head is high (close to, or above, ground level) such as in a confined or semi-confined aquifer situation. Typically PRW are between 30 and 50 m deep.
Provision of artesian wells	Equivalent to VDW, but only suitable where piezometric head is above ground level (such as in a confined or semi-confined situation). They differ from PRW in that they will have a depth of 100 to 150 m.
Rehabilitation of drainage network structures	Removing capacity constraints or addressing structural distress (including wear and tear deterioration), such as rehabilitation of culverts and siphons.
Rehabilitation of drainage channels	Cleaning and desiliting, reforming channel section and restoring suitable longitudinal design water level profile.
Install piezometers	For groundwater monitoring network.
Irrigation system	
Rehabilitation and upgrading of irrigation water control structures	Restoring functionality of water control equipment. Provision of measuring facilities. Construction of new outlets.
Rehabilitation of other irrigation structures	Removing capacity constraints or addressing structural distress (including wear and tear deterioration), such as rehabilitation of culverts and aqueducts.
Rehabilitation of irrigation channels	Cleaning and desilting, reforming channel section and repair of lining (concrete over impermeable sheeting).
On-field	
Deep ripping	Removal of plough pans and other relatively shallow semi-permeable or impermeable layers to improve field drainage so as to reduce incidence of water logging. Required as part of the intervention to reclaim saline soils.

Anticipated Outcome

With the realization of the proposed interventions, it is expected that the groundwater table will drop to the desired levels. This will allow proper leaching of soils, reduction of CDW reuse and consequently a decrease in soil salinity and groundwater mineralization. However, leaching and irrigation norms should be carefully reviewed, taking into account future circumstances.

Table 2 Additional Discharges Among Different Types of Drainage

Unit	Drainage discharge			Distribution of additional discharge among different types drainage			
	Design total	Existing	Additional	Interceptor drains	Vertical drainage wells	Pressure relief wells	Artesian wells
Km / nr				25	242	1 411	10
m^3/ha	14 683	11 184	3 499	944	855	1 663	130
'000 m^3	786 490	596 857	189 633	51 472	46 311	89 822	1 968

Early in the project design, the concept of developing a network of privately operated drainage wells was postulated. The idea behind this is that if the groundwater is of a good quality then farmers would be interested in operating such wells as they would get twin benefits: (i) An "on-demand" source of good quality irrigation water; and (ii) Control of their drainage needs. Drainage, being a common good, would not in itself be sufficiently attractive for farmers to invest time and money in drainage well O&M. In the Project Area surface water irrigation supplies are currently provided at a low cost; farmers are obligated to pay irrigation service fees to the WUAs, and under current arrangements would have to pay this regardless of where they sourced their water.

It should of course be recalled, that reuse of drainage water is commonplace in the Project Area and, furthermore, that drainage water discharged into the Syr Darya is available for irrigation or environmental needs further downstream. Use of water from the drains serving the Project Area will have some negative impact on crop production but, as in many locations the drainage water is of relatively low mineralization, overall the impact is expected to be modest.

While the drainage and collector systems create the conditions for sustainable agricultural development thus fulfilling economic and social functions, they also have an important role from the environmental perspective. By maintaining an optimal salt and water and nutritive regimes in soils that preclude salinity and degradation of soils and water resources, they prevent negative environmental impact.

Conclusion

At the time being, almost one third of these wells have been constructed almost all of them giving minimum twice the expected yield. Besides generic advantages, results obtained in the Fergana Valley Water Resources Management Project show that combined drainage system has proven to be a sustainable solution which can be upscaled to very large areas.