Waterlogged Soils:

Waterlogged means saturated or nearly saturated with water. Hence, waterlogged soils may be defined as soils that are saturated with water due to a high water table for a sufficiently long time annually which is detrimental to most of the field crops. Both soils temporarily saturated with water and soils having ground water tables permanently near the soil surface are called waterlogged soils. Therefore, all forms of excess water in the root zone of soil or on the soil surface cause waterlogging. Only a few crops can survive under such conditions. Waterlogging may be natural or induced by humans. This condition imposes salinity and oxygen stress on plants under arid climates.

Pakistan has the largest irrigation system spreading over an area of 17×10^6 ha. Nearly 90 % of its agricultural output comes from irrigated lands. Irrigation in this area is very old. However, the construction of the present system was started a century ago. Before the introduction of weir controlled irrigation system, lands adjacent to rivers were irrigated through inundation canals. Ground water tables were fairly deep with exceptions;

1. Near the confluences of rivers
2. Under narrow marginal plains along the river courses those were flooded each year during monsoon season.

The seepage of water from rivers, percolation of rainfall and irrigation water applied within a particular area were in equilibrium with the discharge of ground water through Evapotranspiration and by the movement out of the area towards the sea. As soon as perennial canal system was introduced, the dynamic equilibrium between the ground water recharge and discharge was disturbed. The percolation of water from canals and irrigated lands remained greater than the rate at which water can be discharged from the aquifer. As a result, water table rose in many parts of the canal irrigated area.

Categories of waterlogged soils:

There is no single internationally accepted categorization of waterlogged soils. In general, a water table depth within 1.5 m of the soil surface is considered as a criterion for the identification of waterlogged soils in Pakistan. Some scientists have classified waterlogged soils in association with soil salinity. In this way, two categories developed which are as under:

1. Saline waterlogged soils
2. Non saline waterlogged soils

For both the categories, a uniform water table depth within 1.5 m of the soil surface has been taken as a standard for the identification of waterlogged soils.

Extent of waterlogged area:

The extent of waterlogged soils in Pakistan given by various sources like Directorate of Land Reclamation, WAPDA and Soil Survey of Pakistan shows lot of variation so that of salt-affected soils. Many agencies consider a land as waterlogged if water table occurs within a 3 m depth of the surface. Many soil surveys have found that almost no crop suffers from excessive moisture as long as the water saturation zone remains below 1.5 m depth except sandy soils. Crops on sandy soils can benefit rather to suffer from a rise in water table within this depth if ground water is of useable quality. Most of the waterlogged soils have patchy/surface salinity. Estimates of a seasonal survey show a greater than two fold increase in the extent of waterlogged soils during post monsoon period.

Extent of waterlogged area (water table within 1.5 m) in Pakistan (000 ha):

Water table depth (m)	Province				Total
	Punjab	Sindh	NWFP	Baluchistan	
	Non saline soils (part with patchy/surface salinity)				
1.0-1.5	239.2	39.4	39.7	-	318.3
0.5-1.0	78.6	189.2	20.7	4.3	292.8
< 0.5	368.0	280.0	30.3	137.8	816.1
	Saline soils (porous, dense and gypsiferous)				
< 1.5	10.0	116.0	1.1	-	127.1
Total	695.8	624.6	91.8	142.1	1554.3

Sources/Causes of Waterlogging:

The main sources of waterlogging are recharge from:

1. Irrigation system including main canals, branches and distributaries link canals
2. Water courses and irrigated fields
3. Rainfall
4. Rivers
5. Subsurface flow from higher to lower areas.

Construction of irrigation networks, roads, rain links, factories and housing colonies in the path of natural drains has interrupted surface runoff at many places, resulting in the accumulation of water during the monsoon season, a part of which contributed to waterlogging through seepage.

Control Measures/Management/Remedies of Waterlogged Soils:

Important control measures are as under:

1. Seepage interceptor drains constructed to intercept seepage water from the source are called seepage interceptor drains. They are constructed parallel to the source of seepage water, their dimensions and length depending on the size and length of seepage source. Such drains were constructed along both sides of Upper Chenab Canal.

2. Tree plantation along the spoil banks.
3. Surface drains proved relatively effective in carrying away canal seepage water and rainfall runoff.
4. Lining of canals may reduce seepage by about 75 %.
5. Pumping of ground water has always been effective in lowering a shallow ground water table. Pumping not only lowers the ground water but also provides additional water for irrigation where its quality is suitable.

Hence, construction of drains and pumping of ground water by tube wells have proved to be quite effective against waterlogging.

Future strategies about waterlogged soils:

A sustainable irrigated agriculture in the Indus Basin requires a strategy that should be based on:

1) Water conservation measures to increase availability of water at farm gate. Lining of at least of the conveyance channels and improved on farm water management.
2) Rehabilitation and extension of the surface drainage system.
3) Implementation of high cost sub-surface drainage where urgently required.
4) Improved management of the system, i.e. studies on salt movement, mining of ground water and salt build up in fresh ground water areas, disposal and utilization of poor quality drainage effluent, drainage studies in brackish ground water areas.
5) Environmental impact of the drainage projects to alleviate drainage and public health problems.
6) It is proposed that some staff of the agricultural extension department must be given intensive training in soil reclamation technology so that they can handle the problem with confidence as well as train & guide the farmers properly and accordingly.
7) There is strong need to initiate new projects on farmer's fields in some participatory programmes comprising of scientist-extension worker-farmer trio.
8) All soil reclamation facilities such as subsidies on canal reclamation supplies, gypsum purchase, bank loan for soil reclamation purpose, provision of relevant agricultural machinery at reduced rates etc. should be provided in kind through the trained reclamation extension workers. This is very necessary because soil salination and sodication have to persist under the arid and semi-arid climate in irrigated lands of Pakistan which invites strong infrastructure to combat the problems.

Introduction to SCARP programmes:

(Salinity Control and Reclamation Project)

Irrigation system of Pakistan consists of 3 reservoirs, 23 barrages, 45 main canals and one million water courses. Ground water in most of the areas was sufficiently deep (below 33 m) before the introduction of surface irrigation system. But with the operation of this system without adequate drainage, water table started to raise leading to waterlogging and salinity in many parts which were further aggravated due to flat topography, seepage from unlined irrigation channels, poor irrigation management and use of brackish water for irrigation. During late 1950s, this problem was so serious that it was considered as number one problem of the sustainability of irrigated agriculture in the country. The SCARPs were launched by WAPDA in early 1960s to control this problem. In about 4 decades, WAPDA has completed 57 SCARPs mostly in Punjab and Sindh. The SCARP mainly aims at installation of tube wells and construction of surface and tile drains.

Soon after its creation, WAPDA developed a programme for construction of SCARPs. In last 35 years, WAPDA has completed 57 SCARPs at a total cost of Rs. 26.48 billion covering a gross area of 7.81 m ha. Even with these gigantic efforts, waterlogging and salinity are still a serious problem in Pakistan where 12 % of gross irrigated area has water table at less than 1.5 m and 14 % area is affected by moderate to high salinity. Under SCARPs, about 20000 large capacity tube wells have been installed, tile drainage system has been provided in 14000 ha and more than 10.845 km of surface drains have been constructed. As a result of these drainage efforts, farmers pumped more and more ground water. Consequently, waterlogging in Punjab has been alleviated but has decreased in Sindh by the year 2002.

Effectiveness of SCARPs:

Effectiveness of SCARPs can be visualized by the following explanation.

1. **Waterlogging:** A network of 5000 observation points was established in irrigated areas of Pakistan to monitor the water table. These points consist of open wells, observation wells, tube wells, dug wells and automatic water table recorders. Effects of drainage measures on water table show that waterlogging generally decreased. This decrease has been favoured by the installation of tube wells in private sector to meet water requirement of crops since the canal flow has gone down considerably in response to drought for the last several years.

2. **Cropping intensity:** Data show that as a result of additional supplies made available by SCARP tube wells and associated drainage, the cropping intensities have considerably increased ranging from 31 to 73 % in different SCARPs.

3. **Crop yield:** Before the start of SCARPs, crop yields in the agricultural areas were decreased and became very low, rather uneconomical, in many areas for several years. After the implementation of projects, yields have been increased tremendously.

4. **Soil salinity:** The improvement in surface and profile salinity of some projects is evident due to various efforts. However, during last few years, an increase in salt-affected area has been reported because of the installation of tube wells in private sector pumping poor quality water. About 70-80 % of the pumped water is hazardous; as a result significant salts from deeper depths are being brought to the soil surface.

5. **Socio-economic impacts:** The socio-economic status of the farming communities has been improved due to remedial measures for waterlogging and salinity. Farmers are getting more return from their lands because of better and favourable effects of SCARPs on soil environments.

6. **Performance of public & private tube wells:** A comparative review of public and private sector tube well performance show that SCARP tube wells have provided important benefits in terms of alleviating waterlogging and salinity, increasing agricultural production and helping to spur the growth of private tube wells. However, performance of SCARP tube wells suffered due to:

i. Under achievement of ambitious targets.

ii. Inefficient centralized management resulting in technical, operational and maintenance problems.

iii A significant and unsustainable financial burden on scarce public resources.

iv. Questionable economic performance for tube wells located in useable ground water areas.

v. Pumping of saline sodic water by deep tube wells of 3-5 cusecs capacity.

vi. Inappropriate mixing ratio of saline/sodic tube well water with canal water.

On the other hand, performance of private tube wells has exceeded expectations due to:

a. Efficient management, particularly to help meet peak crop water requirements.

b. Insignificant burden on public resources.

c. Produced returns that were economically justified. Private tube wells have also provided the bulk of ground water irrigation supplies as well as drainage where their density was adequate, resulting in significant increase in production and financial return to farmers.

d. Pumping of shallow ground water, which is generally less saline/sodic than deeper ground water, with tube wells of smaller size.

Future Strategies regarding Research Related to Water Sector:

Following research issues related to water sector are planned to be addressed:

1. Minimization of drainable surplus.
2. Appropriate choice of irrigation and drainage technologies.
3. Effective operation and maintenance of irrigation canals to help them attain regime condition.
4. Improvement of drainage facilities and drainage effluent disposal.
5. On farm water management (OFWM), economical methods of lining and observing losses under different soil conditions.
6. Maximization of economic productivity of water resources.
7. Minimization of environmental hazards in irrigation and drainage.
8. Sediment control in the watershed of reservoirs.
9. Use of brackish drainage effluent for agriculture and forestry.
10. Institutional framework to improve sustainability of irrigated agriculture.
11. Utilization of international research in irrigation and drainage and participatory management.

- Choice of irrigati.
- Maintenance of irrigation Canals
- OFWM