Chapter 6
Groundwater Governance in Pakistan: An Emerging Challenge

Ghulam Zakir-Hassan, Catherine Allan, Jehangir F. Punthakey, Lee Baumgartner, and Mahmood Ahmad

Abstract Water is an essential ingredient for life on this planet; major human civilizations settled along waterways. Control of water has remained central to all rulers. Water was under the jurisdiction of the national/federal government until the 18th amendment in the constitution of Pakistan in 2010. Groundwater has also become vitally important as demand for it has increased over the years in order to fill water supply-demand gaps and to safeguard against climate changes. Currently, surface water can irrigate only 27% of Pakistan's land, while the remaining 73% is irrigated directly or indirectly with groundwater. Punjab uses around 90% of the country's total extracted groundwater and is thus its food basket. Groundwater has become a source of drought mitigation and has thus helped in bringing a green revolution in the IRB. Uneven spatial and seasonal availability of surface water coupled with unplanned, unregulated, and poorly governed use of groundwater has resulted in multifarious and complicated water issues in the country, such as the over-mining of aquifers in freshwater areas, waterlogging and salinity, deterioration of quality, increasing energy use and overall extraction costs and interprovincial disputes. Climatic changes have aggravated the situation. After the 18th amendment, water policy was subject to the provinces and they have started to promulgate relevant

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policies and regulatory framework. Punjab has taken the lead in this area. This chapter encapsulates the recent policy paradigm shifts by the Punjab government to combat the challenges of water scarcity. Current initiatives by the Punjab government, including the Punjab Water Policy 2018, Punjab Water Act 2019, Punjab Local Govt Act 2019, The Punjab Khal Panchayat Act 2019, Punjab Local Govt Ordinance 2021, Punjab Water Resources Commission 2021, Punjab Water Services Regularity Authority 2021, have been discussed and evaluated as to how they can be helpful in mitigating the water crisis.

Keywords Groundwater extraction · Tail-end farmers · Open access regime · Water policy in Pakistan

6.1 Introduction

The use of groundwater in Pakistan—as in many other parts of the world—has risen rapidly over the past half century, bringing some prosperity but also new and now pressing problems of management and governance. In this chapter we consider the current situation with regards to groundwater governance by first situating Pakistan's groundwater use in the broader contexts of global water use and the country's total water use. The surface and groundwater challenges are then presented, with the contention that management and governance in Pakistan require an integrative approach. With these challenges in view, the policy, economic, and environmental perspectives of managing groundwater in Pakistan are considered, with Integrated Water Resource Management (IWRM) presented to integrate these issues in the context of rapidly changing policies.

6.2 Groundwater in the Global Context

Groundwater is a significant component of the hydrological cycle and is the largest source of fresh accessible water on the earth (Gleeson et al., 2020; Reinecke et al., 2020). Groundwater is the most important share of the water resources in many countries (Gorelick & Zheng, 2015). For example, in Tunisia 95% of water used is from groundwater sources, while in, Belgium it is 83%, and in the Netherlands, Germany and Morocco it is 75% (Gleeson et al., 2020). While groundwater is used in industrial and domestic sectors (Chesnaux, 2012), most of the 750–800 billion m^3/year of global groundwater withdrawals are used for agriculture (van Engelenburg et al., 2017; Shah, 2007). Groundwater is particularly important for countries with arid and semiarid climates, including southern and western areas of the United States of America, parts of Africa, Spain, Greece, Iran, India, and Pakistan (Shah et al., 2007; UNESCO, 2012). The unsustainable use of groundwater is a big threat for humanity (FAO, 2016), with overextraction essentially mining aquifers (Kahsay et al., 2018; Shrestha et al., 2020).

Groundwater pumping in the South Asian regions accounts for about one-third of global extraction (WB, 2020). The introduction of small pumps and drilling rigs in the 1970s brought a revolution in groundwater irrigation which the then-existing water administrations were unfamiliar with (Shah et al., 2006). For example, until the 1960s, India had been a minor user of groundwater, but the number of private tubewells increased from 150,000 in 1950 to 19 million in 2000; and by 2008 India was extracting 220–230 billion cubic meters per year (BCM/year) (Shah, 2009). This enabled India's groundwater-irrigated area to increase 178% between 1970 and 1999**.** Another example is Bangladesh, where groundwater contributes to 18.6% of GDP, and 80% of its population rely on groundwater for drinking and irrigation (Bhattacharjee et al., 2019).

Pakistan has been blessed with a large groundwater aquifer under a surface area of 16 million ha in the Indus Basin (Khan et al., 2017; LEAD, 2016). Groundwater in Pakistan has become source of livelihood and a safeguard against climate change, although it remains a poorly understood resource (Lytton et al., 2021; Mekonnen et al., 2016). Because of its ever-increasing use—indeed, mining—of aquifers, Pakistan has become the fourth largest user of groundwater after India, the United States, and China (Qureshi & Perry, 2021), with groundwater contributing about 45% of crop water requirements. It has thus attained a significant role in the national economy and in rural livelihoods (Hassan et al., 2019).

6.3 Groundwater in the IRB

Shah et al. (2007) points out that for millennia shallow wells and muscle-driven lifting devices have commonly been used in many parts of the world. In British India (which included current-day India, Pakistan, and Bangladesh), groundwater was used for over 30% of irrigated land even in 1903, when only 14% of the total cropped area was irrigated. During the 1970s, the introduction of pumping and drilling machinery, along with other factors (Fig. 6.1), gradually increased the amount of groundwater being pumped in the Indus Basin to the present alarming levels. Groundwater provides some resilience against climatic changes and their impacts like droughts and floods. It has helped in increasing the cropping intensity in the country from about 63% in 1947 to more than 120% in 2018 (Hassan et al., 2019; Qureshi & Ashraf, 2019). Groundwater is now being pumped by about 1.2 million (M) tubewells (Fig. 6.2) to meet 60% of irrigation water demand, over 90% of drinking water and almost 100% industrial water requirements (Qureshi & Ashraf, 2019).

While groundwater use can be beneficial, excessive extraction of groundwater impacts negatively on the social and economic development of the nation. These impacts include deterioration of groundwater dependent ecosystems and depletion of surface water resources. This depletion leads to increasing depth of wells, higher pumping costs, hence more energy consumption, higher costs of production and greenhouse gas release. The quality of groundwater is also impacted, including

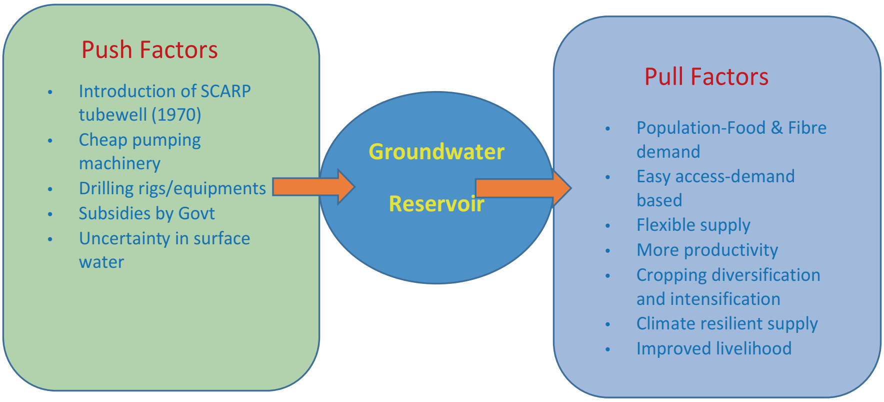

Fig. 6.1 Factors in the increasing use of groundwater in Pakistan. Source: modified from Shah et al. (2007)

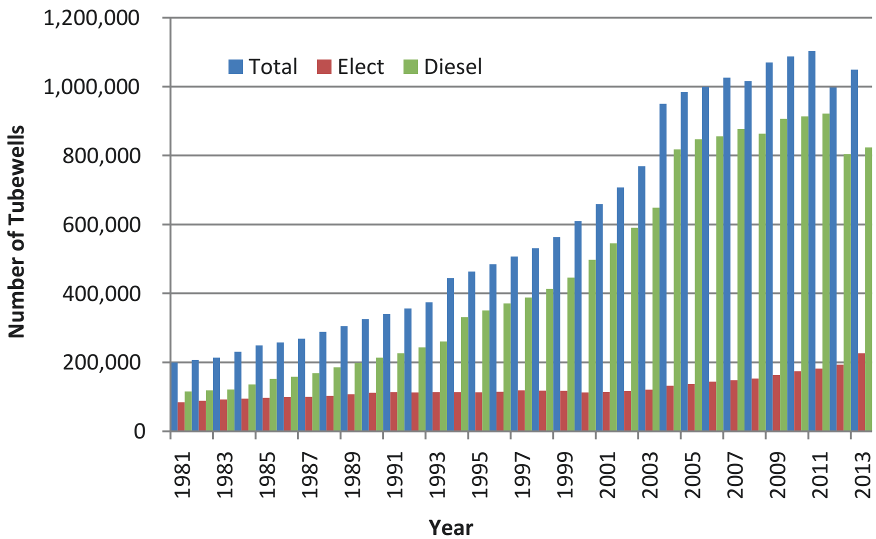

Fig. 6.2 Growth of private tubewells in Pakistan. (IRI, 2019b)

through saline intrusion from brackish groundwater areas, and sea water intrusion in coastal aquifers. Salinization and land subsidence reduces farm incomes. Additionally, competition among users and consumers results in social and political stresses and conflicts (Qureshi, 2018; Shah et al., 2007).

6.4 Poor Management of Infrastructure

Agriculture meets the growing demands for food and fiber for humans. The basic pre-requisites for successful agriculture include land, water, seeds, fertilizer, sunlight, and the labor or machinery. Irrigation is delivering water to where it is needed to support plant growth in agricultural fields. From an overall perspective, delivering water for irrigation entails the following components: (a) storage (dams/reservoirs); (b) diversion of water (barrages); (c) conveyance of water (canals); (c) distribution and application of water (water courses) to fields; and (d) drainage or removal of excess water from fields (drains) (PID_MIP, 2016). Successful irrigation systems require a network of infrastructure from the large, e.g., dams and barrages, right down to farm-scale watercourses, via canals and distributaries, minors, subminors, water courses, drains, escapes, flood-bunds (levees), small dams, and wetlands of various size. In Pakistan the infrastructure is centuries old and needs periodic maintenance. Although irrigators pay for their access to water, generally the fees coming into the system are much less than what is needed to cover the maintenance and operation costs; that is the government subsidizing Pakistan's surface irrigation system.

Groundwater infrastructure generally consists of different types of wells and pumps. Speaking historically, these include step-wells, Persian wheels, hand pumps, open/dug wells, and tube-wells. The type of structure varies from site to site, depending on the when it was built, what the underground water levels were, how much demand there was for groundwater, the type of aquifer and the quality of the groundwater, along with other factors such as the social, cultural and financial circumstances of the communities in which they were built.

Current groundwater pumping technology in Pakistan includes centrifugal pumps, submersible pumps, and deep vertical turbines. Groundwater energy sources include diesel (either by tractor or diesel/petrol engine) and electricity, with solar energy becoming more because of diesel costs and interruptions to the electricity supply. In contrast with the centralized surface water system, ownership in much of the groundwater infrastructure is dispersed. The number of tubewells is increasing, with current estimates suggesting that Punjab alone has 1.2 million private tubewells, mostly installed by farmers (Fig. 6.2**).** These extract about 50–62 BCM of groundwater annually.

Another, relatively new practice in the groundwater system is the monitoring of the network for levels and quality. Both WAPDA and the provincial irrigation departments are involved in this monitoring.

6.5 Public Perception and Cultural Aspects of Groundwater

While groundwater can be considered a public good, its hidden nature often leads it to be treated as private property. Countries approach ownership of groundwater through their own legal frameworks, with the result that it is often the case that the owner of the land has the right to extract it. In Islamic law groundwater is considered a public good, but the ownership of a well entails ownership of a certain amount of adjacent land called *harim,* or the forbidden area (Caponera & Alheritiere, 1978). As per Easement Act 1882 (Govt of India, 1882), groundwater under an aquifer belongs to the owner of land. It is not well understood that groundwater is a common pool resource (CPR) (Mbeyale et al., 2006). Because groundwater is mostly out of sight, the size of the resource and threats to it are often poorly understood—indeed to some it seems an infinite resource. This reduces the apparent urgency for action to manage groundwater better.

Many researchers like such as Agrawal (2001) and Ostrom (1990) have demonstrated that self-governance by communities—developing and enforcing their own rules and regulations for management of CPRs—can be more operative and effective on sustainable basis. They can decide as to who, when, where, and how a particular CPR can be used. (Meinzen-Dick et al., 2018) have described a pilot study in the Andhra Pradesh state of India in which groundwater was considered to as a CPR just like other natural resources, such as forests and fisheries.

6.6 Poor Economic Goals

The problems related to overuse of water, groundwater depletion, water logging and salinity highlighted in the above section are symptoms of much deeper problems embedded in policy and institutional failure both in the agriculture and water sectors (Ahmad et al., 2000). The "value" of groundwater currently reflects the cost of on-farm extraction, and this is complicated by the range of government subsidies and price distortions. For example, until 1991, Pakistan had metered electricity tariffs for irrigation tubewells, but in response to farmer complaints a flat tariff for the irrigation tubewells was introduced (Qureshi, 2018). Farmers in general supported this, since a flat tariff enabled higher pumping rates and longer hours. While this was to reduce pilfering and meter tampering, it also tends the water markets to seriously undervalue groundwater.

This policy failure is reflected in underpricing groundwater, as reflected in the investment and energy costs and the collection of only part of those costs (Kemper et al., 2004). Institutional failure is reflected in open access and a "race to the bottom" and market failure is embedded in rarely accounting for the external and opportunity costs.

Indian Punjab Guidelines for Groundwater Extraction and Conservation

The Punjab Water Regulation and Development Authority in Punjab India published the "Punjab Guidelines for Groundwater Extraction and Conservation" which shall apply to all commercial and industrial water users in the state of Punjab. Agriculture being the main user (95), the implementation mechanism is being proposed through any Water User or group or association of Water Users at their own level. Such Water Users shall earn appropriate Water Conservation Credits which shall effectively reduce their volumetric Groundwater Charges. The scheme incentivizes farmers through appropriate Water Conservation Schemes for water conservation in important sectors such as agriculture, groundwater recharge, urban rainwater harvesting, industrial wastewater treatment and reuse, and rural wastewater management. The tool proposed include conservation credits by water saving in existing crops; replacing paddy cultivation with other crops that consume less water.

A few examples are provided from the guidelines that identify feasible interventions (technologies or practices) that result in water saving, and thus cost-saving and also improve crop competiveness. For example, by delaying paddy transplanting to June 25th or later can result in water savings of 100–200 mm or 1000 to 2000 m^3 per hectare. Similarly, alternate wetting and drying, with a maximum water depth of 50 mm in the paddy field could result in saving 150–250 mm or 1500–2500 m^3 of water per hectare. Rice paddies can also be replaced with crops that consume less water in the *kharif* season. For example, planting maize could save a whopping 10,000 m^3 per hectare, while pulses pulses (moong bean) could save 11,000 m^3 per hectare.

For wheat and rice zones (also relevant with regards to Pakistan) the use of small irrigation plots (6–8 plots per acre) for wheat can save up to 35 mm or up to 350 m^3 of water per hectare. Sowing wheat directly in standing paddy stubble, using zero-till drills such as Happy Seeder or Super Seeder, have been documented to save up to 70 mm or up to 700 m^3 per hectare. And the most desirable intervention—furrow irrigation in bed-planted wheat—can be a major game changer by saving up to 75 mm or 750 m^3 of water per hectare.

This box also supports the case being made in Chap. 8 for a major paradigm shift in agriculture development—from traditional agricultural practices that waste water and degrade our soils to ones that look for nature-based or Regenerative Agriculture solutions. This can also, as discussed in Sect. 4.2, build on opportunities of the Punjab Local Govt Ordinance 2021 (GoPb_LG&CD, 2021).

Source: Adopted from Punjab Water Regulation and Development Authority 2020 "Punjab Guidelines for Groundwater Extraction and Conservation," Chandigarh.

6.6.1 Three Policy Responses to the Challenges with a Focus on Groundwater

Institutional reform requires a change in mindset; policy must move from business-as-usual to benefit-sharing mechanisms between provinces so that the needs and priorities of all provinces are met by the new water management legislative and institutional frameworks.

Policy is implemented partly through rules and regulations The existing regulatory framework in Pakistan deals mainly with the operation of the surface water/canal irrigation network. **We list** the policies and regulatory frameworks for water sector in Pakistan elsewhere in this chapter.

Prior to 2018, there was no comprehensive regulatory and policy framework to facilitate integration. However, current instruments such as the National Water Policy 2018 (GoP, 2018) and Punjab Water Policy 2018 (GoPb_PID, 2018) cover the development, exploitation and protection of groundwater resources thoroughly.

Punjab's government has enacted Punjab Water Act 2019, which deals with surface and groundwater in integrated mode under IWRM framework. This act envisiges the registration, licensing, permits, and pricing for groundwater.

Effective responses to the multiple challenges presented above require multiple and integrated approaches. Policy reform should seek to enable:

(i) improved coordination of surface and groundwater planning and management
(ii) better understanding of groundwater resources, including recharge management
(iii) increased awareness of groundwater issues in the general population
(iv) improved economic levers
(v) improved on-farm water use efficiency
(vi) integrated action (IWRM)

Major Water Laws and Policies in Pakistan

Federal/National Level

- The Easements Act of 1882
- Land Improvement Loans Act (1883)
- The Constitution of Pakistan 1973
- The Pakistan Water and Power Development Authority Act (1958)
- Indus Water Treaty (1960)
- Water Apportionment Accord (1991)
- Indus River System Authority (IRSA) Act (1992)
- Pakistan Environmental Protection Act (1997)
- Pakistan Water Vision 2025 (2001)
- Pakistan Water Resource Sector Strategy (2002)
- National Environment Policy (2005)

(continued)

National Sanitation Policy (2006)
National Drinking Water Policy (2009)
18th Amendment in the Constitution of Islamic Republic of Pakistan
Pakistan Water Vision/Framework for action 2025 (2010)
National Climate Change Policy (2012)
Pakistan Climate Change Act (2017)
National Water Policy (2018)
Provincial Level
The Canal & Drainage Act (1873)
Punjab Minor Canals Act (1905)
Soil Reclamation Act (1952)
On Form Water Management Ordinance (1981)
Punjab Water-User Association Ordinances (1981)
Water Apportionment Accord (1991)
The Punjab Irrigation and Drainage Authority Act (1997)
Punjab Government Rules of Business (2011)
Punjab Water Policy (2018)
Punjab Water Act (2019)
Local Level
Punjab Development of Cities Act 1976
Punjab Local Government Act (2019)
The Punjab Village Panchayats and Neighborhood Councils Act (2019)
The Punjab Local Govt Ordinance 2021
Punjab Khal Panchayat Act (2019)

While the new policies demonstrate a desire for more holistic and integrated management, implementation is still a work in progress. The actions taken by Punjab's government, discussed in Sect. 3.1, test ways to best implement new national and provincial policies.

6.7 Punjab Government – Some Recent Responses

6.7.1 Improving Coordination of Surface and Groundwater Planning and Management

Different steps have been and are being taken by the Punjab government to manage groundwater in conjunction with surface water, taking into account best practices around the world. A water resources zone has been created within the PID to monitor and help in regulating groundwater. The following steps have been taken:

(i) Monitoring of groundwater (level and quality) biannually and mapping throughout the Punjab province
(ii) Establishment of Punjab Water Resources Commission
(iii) Establishment of Punjab Water Services Regularity Authority
(iv) Establishment of Water Resources Zone in PID

6.7.2 A Better Understanding of Groundwater Resources and Recharge Management

6.7.2.1 Resource Assessment

To properly manage groundwater, it is imperative to properly assess the nature of the aquifer and its potential. The Punjab government is taking steps to monitor, manage, and regulate groundwater resources to use it sustainably. In Punjab about 3000 piezometers were installed in 2006 and onward to monitor groundwater levels in canal command areas, which is about 50% of the area of the province (IRI, 2019b; Zakir-Hassan et al., 2020). These steps include:

(i) Monitoring/ mapping/modelling
(ii) Geo-referencing of all tubewells in the Punjab
(iii) Strengthening of groundwater monitoring network (addition of 2000 observation points to cover the reaming areas and fill the gaps in existing network)
(iv) Introduction ICTs in monitoring loggers, sensors, and transmitters to improve the quality and frequency monitoring system in the province
(v) Demarcation of basin/subbasins (Fig. 6.3)
(vi) Development of hydrogeological zones

6.7.2.2 Resource Protection and Conservation

To sustainably use groundwater, it is of the utmost importance that it is assessed, protected, and regulated. In this respect, PID has executed some important research studies through thee Irrigation Research Institute (IRI). A few are mentioned in Table 6.1.

6.7.3 Increased Awareness of Groundwater Issues in General Population

Another step in raising awareness for stakeholders was a series of national seminars and six field workshops on groundwater governance and management that were held throughout Punjab. A few examples are given in Table 6.2.

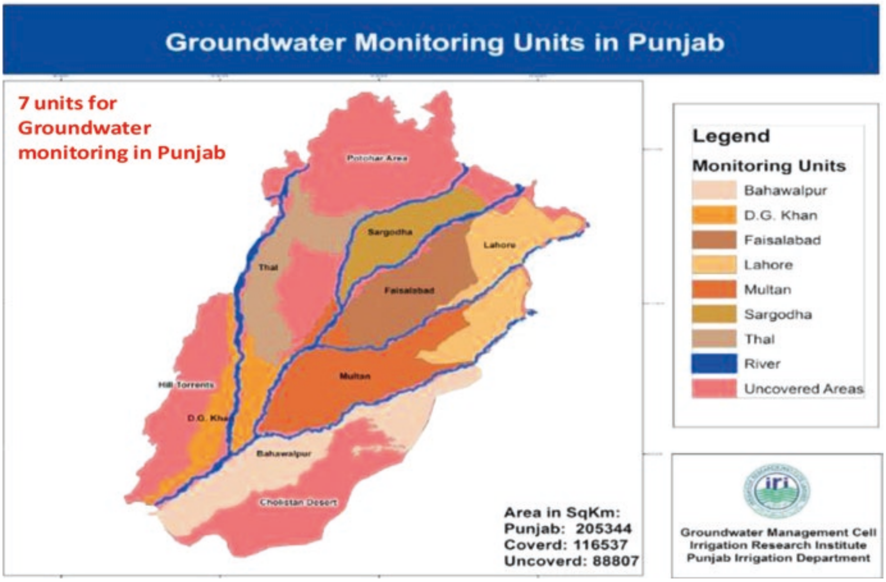

Fig. 6.3 Hydrological Zones in Punjab for groundwater management. (IRI, 2015)

6.7.4 Integration

The Punjab Water Act 2019 has been formulated and promulgated within an IWRM framework (GoPb-PID, 2019). All water resources are treated as one source and all demands/consumers have been assigned a priority for water, allocated according to the Punjab Water Policy (GoPb_PID, 2018). Dealing with each water resource (canals, rainfall, groundwater, rainfall, wastewater) in isolation leads to the uneven and unequitable distribution of water resources over time and space. The government is taking action to integrate functions: for example, management, regulation, and governance have all been entrusted to the department responsible for surface water resources. This means that all concerned stakeholders are working together under one umbrella—a body comprising of 22 departments headed by the Chief Executive of the Province i.e., the Punjab Water Resources Commission. This is the first time in Pakistan's history that a high-level body has been established in the province, which is evidence of ownership by the government and makes water a priority on its agenda.

6.8 Improved Economic Levers

Water discourse can be redefined in terms of unbundling land and water rights. Pricing policies could be developed to enable farmers to meet their crops' water needs while also restricting unnecessary exploitation of groundwater.

Table 6.1 Research studies from Irrigation Research Institute (IRI)

Sr#	Title of research study/report	References
i.	Improving groundwater management to enhance agriculture and farming livelihoods in Pakistan:	Punthakey et al. (2021b)
ii.	Improving groundwater management to enhance agriculture and farming livelihoods: Integrating web and mobile based applications for groundwater management:	Khan et al. (2021)
iii.	Improving groundwater management to enhance agriculture and farming livelihoods: Groundwater model for the lower Bari Doab Canal, Punjab, Pakistan.	Anjum et al. (2021)
iv.	Recharge of aquifer for groundwater management in Punjab (old Mailsi Canal project)	IRI (2020b)
v.	Feasibility of rainfall harvesting for artificial recharge of groundwater	IRI (2019a)
vi.	Artificial aquifer recharge by rainwater harvesting at experimental Research Station Thokar Niaz Beg Lahore	IRI (2020a)
vii.	Historical sustainability of groundwater in Indus Basin of Pakistan:	Hassan et al. (2019)
viii.	Sustainable use of groundwater for irrigated agriculture: A case study of Punjab, Pakistan	Hassan and Hassan (2017)
ix.	Impact of drainage effluents on groundwater quality—a case study from Lahore Pakistan	Zakir-Hassan et al. (2017)
x.	Plastic pollution, canal irrigation and groundwater contamination in Punjab, Pakistan	Zakir-Hassan et al. (2021)
xi.	Environmental issues and concerns of groundwater in Lahore	Zakir-Hassan et al. (2016)
xii.	Research studies on artificial recharges of aquifer in Punjab.	IRI (2013)
xiii.	Groundwater investigations for water supply to FDA-city housing scheme Faisalabad	IRI (2012)
xiv.	Research studies on artificial recharge of aquifer in Punjab; preliminary activities for identification of potential sites for recharging of aquifer in Punjab	IRI (2009)
xv.	Seepage measurement and soil investigation from channels proposed for lining under PPSGDP: Punjab private sector groundwater development project (PPSGWDP	IRI (1998)
xvi.	Lining of distributaries and minors in Punjab; canal seepage and groundwater investigations: JICA-funded study	IRI (1996)
xvii.	Groundwater behaviour in Rechna Doab-Punjab- Pakistan	IRI (2015)
xviii.	Impacts of flood on groundwater – Example shown in Fig. 6.4	IRI (2016) and Zakir-Hassan et al. (2021)
xix.	Awareness raising and capacity building of FOs/farmers regarding “groundwater governance and management in Punjab”	IRI (2017)

Table 6.2 Workshops given to raise awareness among stakeholders

Seminars/Workshops	Location	Date
Seminar on the use of geosynthetics as canal lining material	IRI Lahore Auditorium	28-05-2013
Seminar on groundwater issues and way forward	IRI Lahore Auditorium	10-06-2013
Seminar on groundwater governance and Management in Punjab	IRI Lahore Auditorium	25-10-2017
Three Nos workshop on groundwater issues and Management in Punjab	Kamalia, District Toba Tak Singh	28-11-2015
	Pir Mahal, District Toba Tak Singh	20-02-2016
	Pabbarwala Disty, District Faisalabad	23-04-2016
Three Nos workshop on groundwater issues and Management in Punjab	Nai wala Bangla, District Sahiwal	25-11-2017
	Farooqabad, District Sheikhupura	9-12-2017
	Ada Musafir Khana, District Bahawalpur	21-12-2017

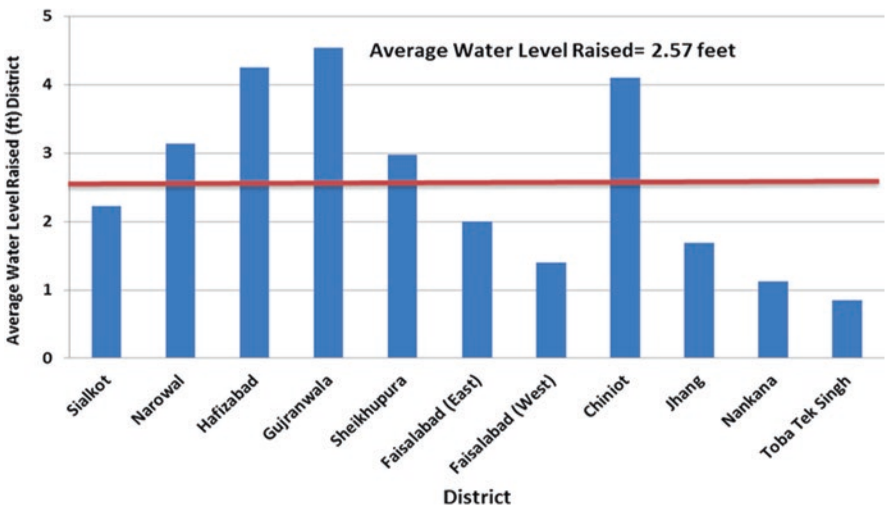

Fig. 6.4 Impact of flood 2014 in Rechna Doab area in Punjab, Pakistan

There is some movement towards clearer pricing signals. The flat tariff policy for tubewells was discontinued in 1999 and a flat-cum-metered tariff was introduced in 2000. The new incentive policy was designed to set a different tariff schedule, with fixed-cum-variable pricing—in addition to a cost per unit, consumers were charged a flat rate of approximately Rs. 400, Rs.700, or Rs.1050 per month for 5-, 7- and 10-horsepower motors, respectively. So the government is moving to a more rational pricing policy to cover not only the financial cost (fixed cost) but also the economic cost (the variable part), thus minimizing the risk of water overuse. The case study of Oman illustrates how it is moving towards monitoring,

Case Study: Smart Meters—The Case of Oman

In 1992, the government of Oman took an important step towards groundwater monitoring that included (1) performing a national inventory of installed tubewells, with GPS locations for each (2) considering the possibility of groundwater monitoring through individual quotas. The law or regulatory decree (MD 264/2000) stipulates that "The Ministry shall determine the quantity of water to be taken from each well," thus moving a step forward in their ability to monitor the wells and regulate how much water is extracted. The idea is that farmers use sanctioned water to grow more high value crops and use groundwater storage as a hedge against drought.

The feasibility of the above-mentioned policy was evaluated using the MODFLOW groundwater simulation model. The results revealed that the Net Present Value of measuring and monitoring groundwater extraction using climate smart water meters was $790 million (41,332/ha/year) with an internal rate of return of 93%—a very good return on the investment. Further, the research shows that the sustainable use of aquifers results in a 20% reduction in groundwater extractions, with a change in cropping pattern and 42% of the least efficient farmers exit farming when they have the option to convert the land for other uses. (Zekria et al., 2017).

Pricing irrigation groundwater is not politically feasible, nor is increasing electricity prices. A number of researchers argue that the best solution is to allocate groundwater shares to each farmer according to farm size and historical cropped area. Oman's case, in which 40 farms have benefitted from the installation of intelligent energy and water meters. The objectives are to reduce the cost of monitoring, to allow weekly/monthly observation of groundwater abstraction and send early alerts to those farmers who are in danger of exceeding their allocated water quota. India is a success story and an example for other regions/countries that are facing groundwater depletion. The successful farmer-managed groundwater systems initiative, Andhra Pradesh Farmer Managed Groundwater Systems (APFMGS), offers useful lessons on participatory groundwater management.[1] Collective action has resulted in sustainable ground water management, reductions in cost, and more growing of high value crops. While we in Pakistan continue to promote rice and sugarcane, we cannot justify growing either of them in conditions of water scarcity, unless we ration water use in agriculture, and more specifically for these two thirsty crops.

[1] Participatory Ground Water Management in AP; Draft Outline of the legal framework emerging following discussions with the Principal Secretary, RD, Govt of AP on 10th August.

It is often suggested that creating water rights and a water market would alleviate the problems of water allocation, availability, and accessibility, but the question is whether it would lead to water saving. This is true especially where water rights are not well defined or enacted. Pakistan provides an interesting case: while water markets are illegal, more than 70% of farmers trade water on the watercourses to meet scarcity and improve supply (World Bank, 1994). In Pakistan, given its social setup, the paramount concern is that legalizing water trading would add to the existing inequity between upstream and downstream users and so from that perspective, putting a value on water rights is not desirable. It is hard to stop illegal water markets for urban supply since there is much more willingness to pay in urban areas than in agriculture. Even if a regulatory structure was set up to manage the sale of water, underground markets will still exist. One must weigh these negative externalities against the expected benefits from this policy shift, keeping in view the facts on the ground. We should focus more on whether water rights should be tied to the land or whether they can be traded separately.

In summary, the energy pricing and load shedding policies have shown to play an important role in controlling overexploitation of groundwater; in addition, farmers who purchased water from tubewells with diesel pumps found them to be more reliable than tubewells powered by electricity. The introduction of water metering, though costly (though the cost is coming down) is a prudent policy option in order to ration water use in agriculture. In order to implement water metering, agencies must have the authority to enforce compliance on tubewell owners and formulate incentives to enforce metered tariffs.

6.9 Improved on Farm Water Use Efficiency

Inefficient use of water in agriculture is a big challenge for Punjab, since agriculture consumes more than 90% of total water resources while contributing only 22% to GDP.

Steps to Improve the Water Use Efficiency at Farm Level

(i) Groundwater Management to enhance agricultural farming community participation in water management
(ii) Reliability in water supplies
(iii) Water recycling/reuse at least in agriculture sector
(iv) Precision irrigation and precision agriculture
(v) Improved crop varieties and cropping pattern- climate smart agriculture
(vi) Improved cultural practices – shift from lower to higher value crops
(vii) Highly efficient irrigation techniques- shift from flood method
(viii) Rationalization of surface water allowances- in conjunction with groundwater

6.10 Integrated Water Resources Management (IWRM) Framework

6.10.1 Integrated Water Resource Management (IWRM) Policy Framework

Integrated Water Resources Management (IWRM) is "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (UN_Water, 2007). In its broadest sense, IWRM is a framework which mainstreams water for all needs of the society, involves stakeholders in decision making, integrates demand and supply management, invokes gender issues, accounts for the all water sources—waste, sewage, groundwater, rainfall, surface-water—faces the challenges of climate change that lead to floods and droughts, and to adaptive management. IWRM is understood to be crucial for water stressed areas to enable water management to integrate with the broader contexts of economic and social development and of environmental sensitivity (Chéné, 2009). Critics of IWRM have noted that it is vague in conceptualisation and difficult to find in practice. For example, (Biswas, 2008) attempts at IWRM in South Africa, (Colvin et al., 2008) in Nepal (Birendra et al., 2021), and Ghana (Frimpong et al., 2021) partly bely these claims, but also reveal just how difficult integration is. These and other works show that while specific tools are necessary, IWRM also requires an emphasis on governance (Katusiime & Schütt, 2020; Lankford & Hepworth, 2010). Food security and IWRM are strongly linked as IWRM can contribute significantly to meeting the increasing demands of food security. IWRM can allocate water for agro-ecosystems as well as for non-agricultural ecosystems (Boelee, 2011).

The Integrated Water Resource Management (IWRM) approach requires defining hydrological basins and sub-basins which are clearly represented/demarcated with boundaries and empowered basin/sub basin authorities, with sustainable financial resources and an IWRM framework. The challenge of implementing the IWRM approach is to bring about institutional and legal processes, decision-making, transparency, and a participatory approach to decision making as opposed to the traditional departmental hierarchical decision making process. Main components of IWRM framework are shown in Fig. 6.5.

6.11 Groundwater Governance Might Work Within an IWRM Framework: A Case Study in Punjab

6.11.1 Punjab Groundwater Management

With a large groundwater aquifer, Punjab is the most blessed province of Pakistan. Only 1.23 billion cubic meter (BCM) of groundwater was pumped in 1965, using the old Persian wheels. This has increased to 55 BCM at present, through 1.2

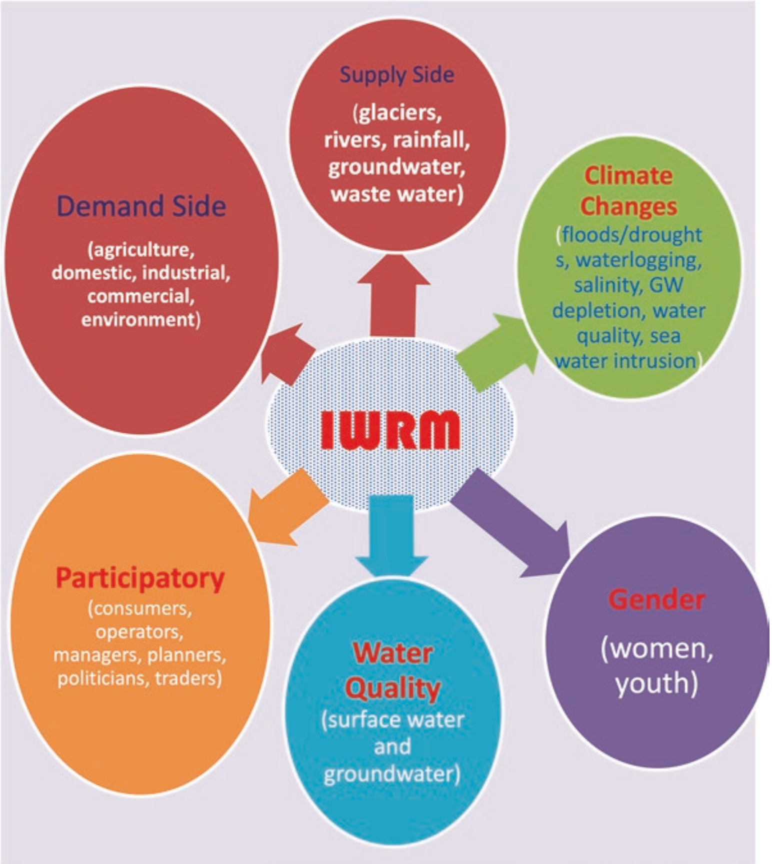

Fig. 6.5 Components of complex IWRM framework

million private sector tubewells (GoPb_PID, 2018). After the introduction of SCARP tubewells in the public sector during the 1960s, there were rapid advances in private groundwater development in Punjab (PID_MIP, 2017). To monitor rising groundwater tables, some 14 lines of open water table observation wells (called provincial well-lines) were installed across the doabs of Punjab by WAPDA. Some records of groundwater levels are available from 1882, but systematic observations started in 1886 (Bhutta & Smedema, 2007).

In 2006, the Punjab Irrigation Department also installed about 3000 observation wells (OWs) and started monitoring the depth to water table twice in a year: pre and post monsoon season. Locations of these observation wells are shown in Fig. 6.6.

Observation wells have been installed only in Punjab's canal command areas leaving large geographical areas of the province unmonitored, as shown in Fig. 6.7. These observation wells have also deteriorated over time. Some points have become dry because of falling water levels and presently only 50% of the wells are active. Because of this, human error, and the low frequency of sampling, the data from this monitoring is unlikely to represent the true impact on aquifers by recharge and discharge components.

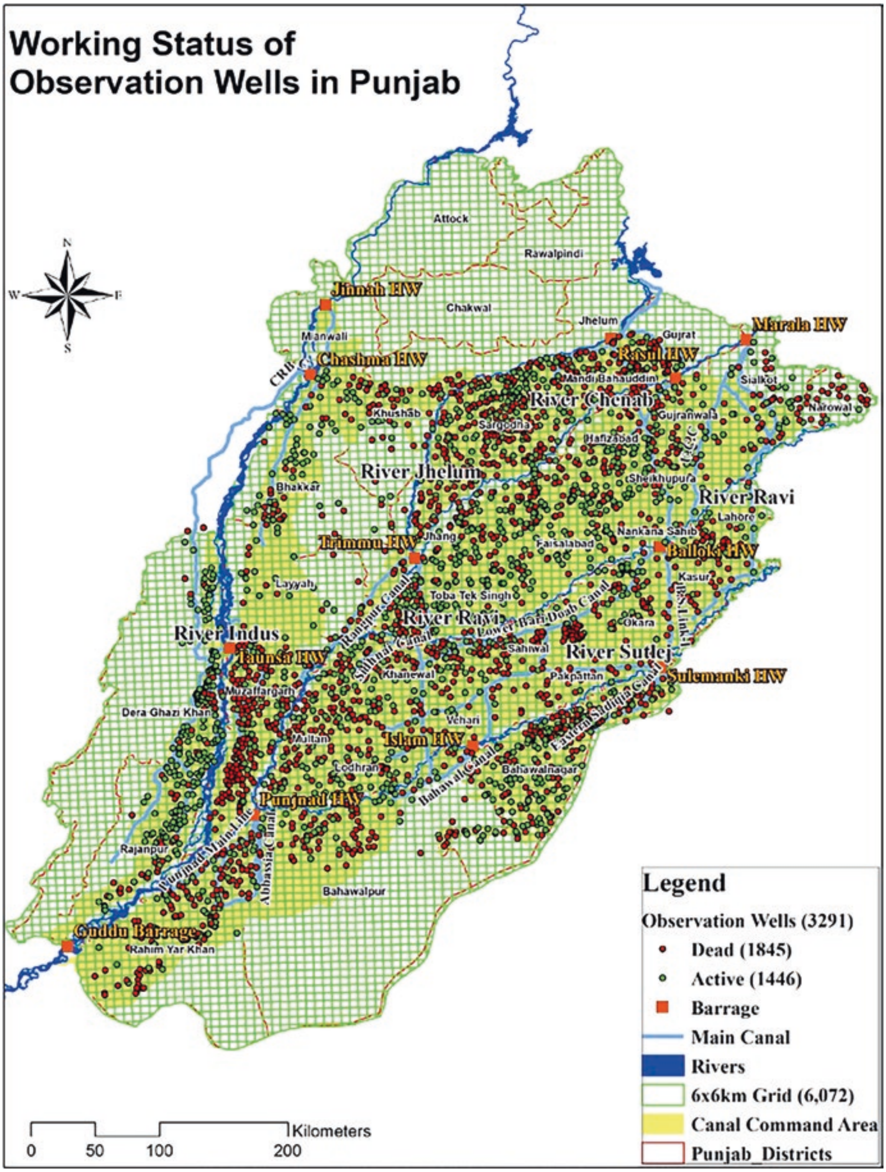

Fig. 6.6 Locations of observation wells in Punjab (Source: Punjab Irrigation Department)

Recently, with guidance from two projects—one funded by the World Bank, the other by ACIAR (Punthakey et al., 2021a, b), about 12 loggers have been installed to monitor the continuous fluctuations of groundwater table and transmit them directly to the main server at the Lahore head office.

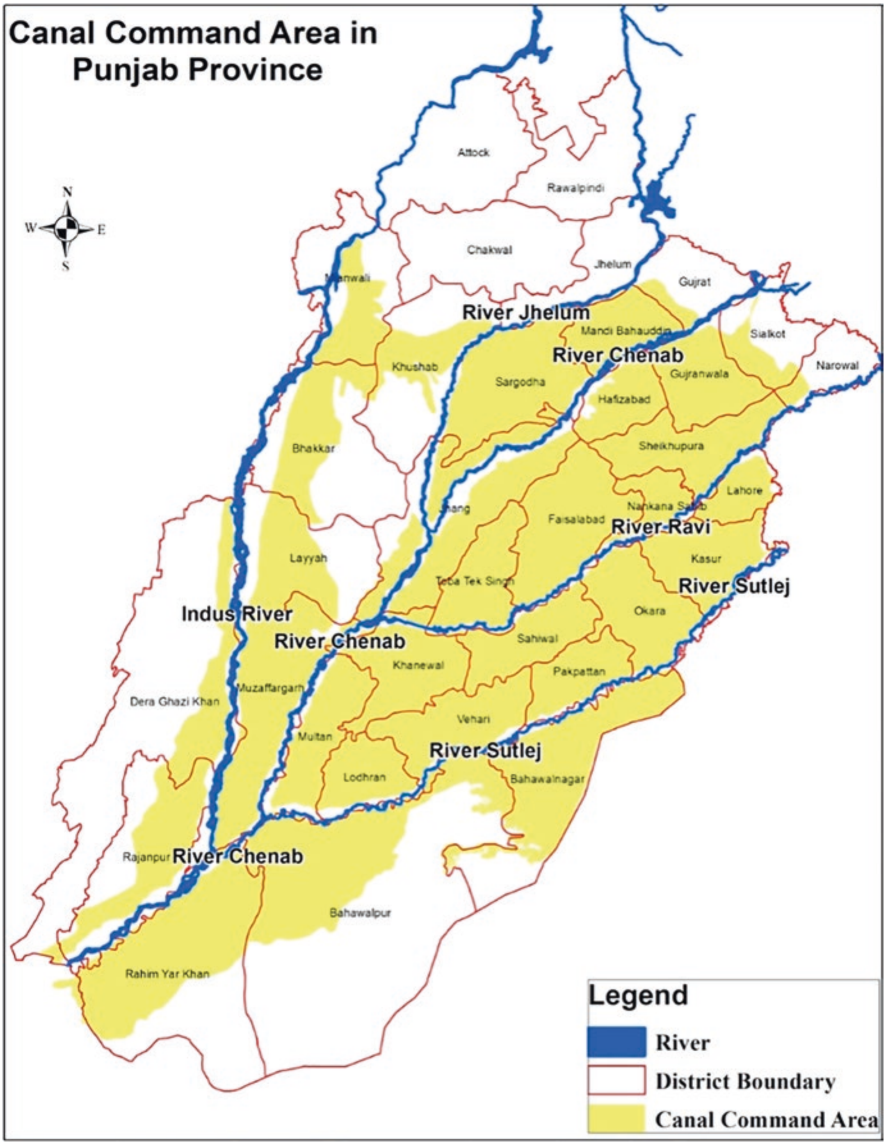

Fig. 6.7 Canal command areas in Punjab. (Punjab Irrigation Department)

In addition to depth, the quality of the water table quality is also being monitored for about more than 2500 farmers' tubewells in the canal command of the Punjab. Groundwater quality is mostly monitored and tested in labs for irrigation purposes. Groundwater quality status in Punjab for the year 2020 is shown in Fig. 6.8.

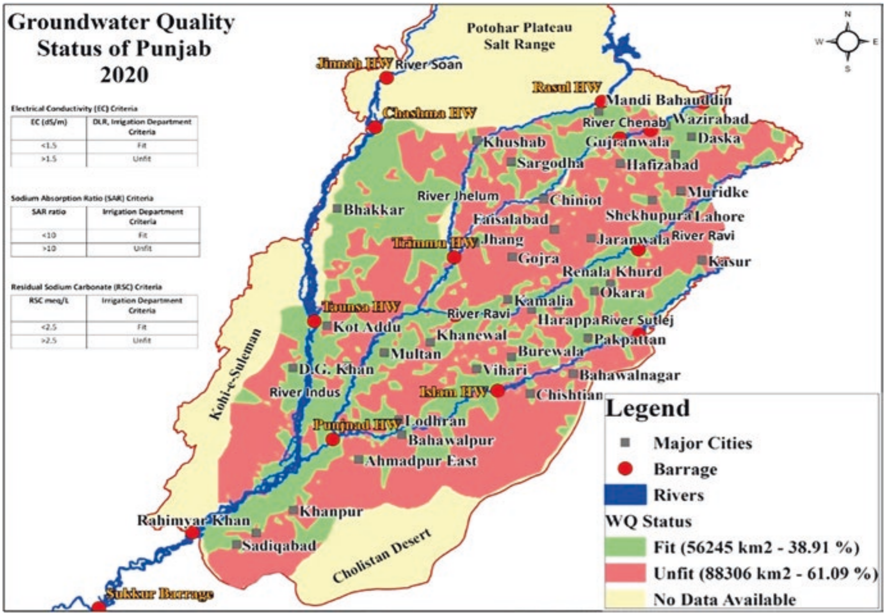

Fig. 6.8 Groundwater quality status of Punjab in 2020. (Punjab Irrigation Department)

Maps detailing depth to water table and groundwater quality are being prepared and placed on the website of the department. Different research studies and investigations are being carried out by Groundwater Management Cell established by PID in the Irrigation Research Institute (IRI). The Punjab province has been divided into different hydrogeological basins (doabs) for groundwater investigations and modelling studies. At present groundwater is contributing about 35–45% of Punjab's irrigation requirements (IRI, 2013). Extensive and unplanned pumping of groundwater has put the groundwater budget in the danger zone. The depth to water table map for the year 2020 is shown in Fig. 6.9, which indicates that southeastern areas of the province are badly depleted. The recharge to the aquifer has decreased while the pumping rate has increased. Punjab, as the largest food producer of Pakistan, is more stressed with respect to falling water levels—after Baluchistan—and deterioration of groundwater quality. At present, no comprehensive law or monitoring framework is in place for proper assessment of this natural resource, but the Punjab government is taking concrete steps to improve the system.

The quality of groundwater in the province is also deteriorating due to the intermixing of fresh and brackish ground waters which are further aggravated by the leaching contamination from domestic, industrial, and agricultural effluents (Zakir-Hassan et al., 2017). Groundwater quality in Punjab is shown in Fig. 6.10, which indicates that groundwater quality in many areas is not fit for irrigation purposes based on three criterions indicated in the figure.

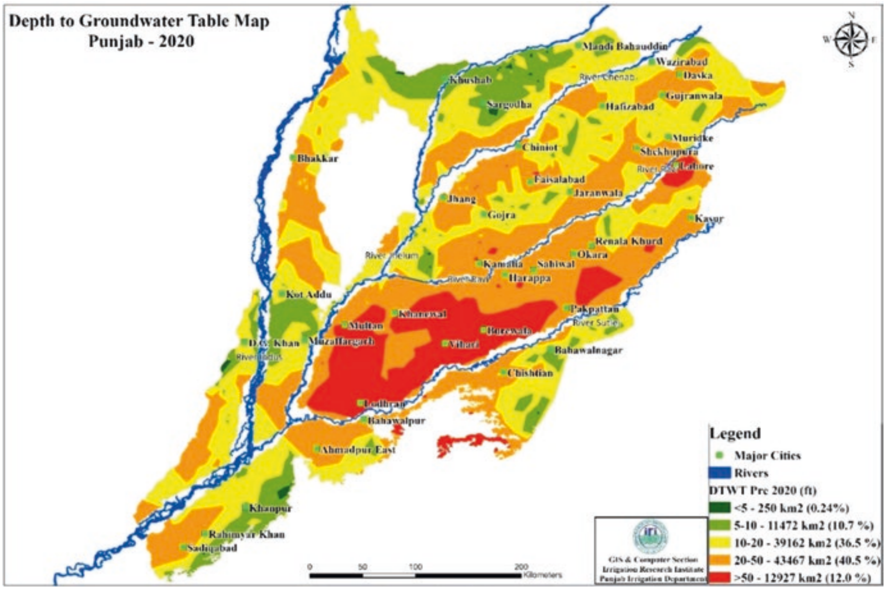

Fig. 6.9 Depth to groundwater table map (Punjab Irrigation Department)

Over time, many piezometers have become dead and dry and at present less than two thousand are functional as per 2018 records.

Keeping in view the importance of groundwater management and groundwater recharge under the National Climate Change Policy (GoP_MoCC, 2012) and National Water Policy (GoP, 2018), the Government of the Punjab under Punjab Water Policy (GoPb_PID, 2018) has clearly given the future line-of-action for beneficial use of floodwater. The policy outlines the guiding principles for implementation:

(i) Construction of flood channels to divert flood waters to desert areas like Cholistan, Thal and other similar areas.
(ii) Allow flood waters to spread overland through pre-planned breaches
(iii) Harness flood waters in Hill Torrent areas like DG Khan through construction of storage and delay action dams, dispersion, and diversion structures
(iv) Augment artificial recharge of aquifer from flood water

Globally, a lot of work is being done on managed aquifer recharge (MAR) using flood water (Rawluk et al., 2013).

As is the case anywhere, the use of groundwater in Punjab is a complex issue beset by numerous governance challenges. Governing and managing groundwater is difficult in conjunction with the planning and management of surface water, since the institutions that govern both are different (Fullagar et al., 2009).

Challenges for Groundwater Governance

- Groundwater use much beyond the sustainable limits
- Multiple groundwater uses.
- Complexities in defining groundwater entitlements and enforcement.
- General lack of awareness and capacity among the stakeholders.
- Slow implementation of regulatory framework
- Deterioration of groundwater quality
- Increasing cost of groundwater pumping with decline in water table.
- Poor and inadequate resource monitoring

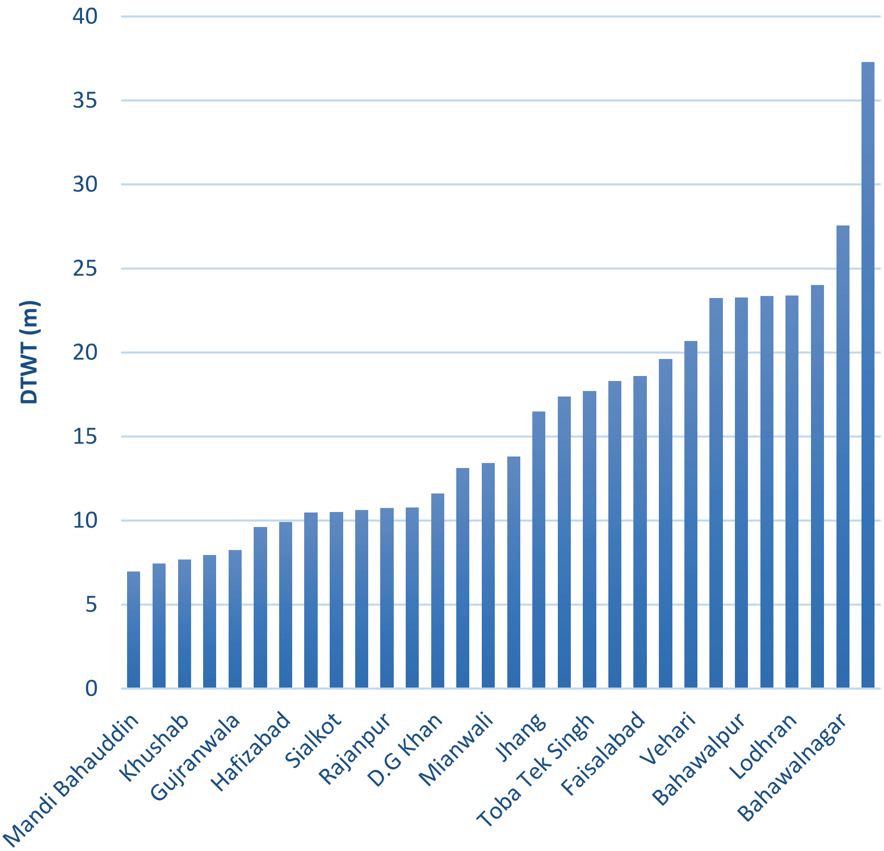

Fig. 6.10 Depth to water table below land surface in different district of Punjab (2016) (Punjab Irrigation Department)

6.11.2 *Potential Integrated Approach for Groundwater*

Groundwater is extracted mostly (90%) by farming communities for agricultural use. Participatory management of groundwater, through consultation, "bottom-up" planning and collaboration is most likely to result in positive on-farm groundwater management. One potential way to achieve this is to build on opportunities of the Punjab Local Govt Ordinance 2021 (GoPb_LG&CD, 2021). Village-scale Aquifer User Associations, (or Water User Associations, or Village Development Societies, or Village Councils) could be established and supported, initially by PID. The aim would be to strengthen and empower them to manage groundwater better through information sharing, training, and incentives. Resources for these associations may include extension services providers, agricultural machinery, community tubewells, village ponds, market access, surface water availability, rainfall harvesting infrastructure, soil and water testing facilities, high efficiency irrigation systems, updated information about subsidies from the government, flood and weather alerts. Other services which can be integrated at the grassroots level include measuring soil moisture and crop water needs, access to fertilizers and pesticides, value addition to agricultural products, storage facilities, guidance about latest tools and models such as tunnel farming, zero-tillage, hydroponics, land care services, protection of water quality, solid waste management, disposal of village effluents, cottage industry and handicrafts development centre, groundwater recharge facilities, on-farm storage options, smooth implementation of the *warabandi* system, mechanized farming, precision agriculture, use of ICTs, introduction of bio-fertilizers and pesticides, climate smart, energy auditing, taping the potential of solar energy, livestock and dairy development, aquaculture service, media and training centre. The village should be a strong institution that provides access to resources, information, and infrastructure, and focus on both sharing and maintenance (Fig. 6.11).

6.11.2.1 Vertical and Horizontal Linkages

Policies have been developed at the national, provincial, and local (grass root) levels to streamline water governance. This setup can support the groundwater governance if `implementation is carried out in both letter and spirit (Fig. 6.12).

The Punjab Khal Panchayat act 2019
– Establishment of Khal Panchayat.

(1) There shall be a Khal Panchayat for each water course.
(2) Every farmer entitled to obtain water for irrigation purposes under the Act shall be a member of the Khal Panchayat of a water course.
(3) Every Khal Panchayat shall have a President and a General Secretary to be elected through votes of all eligible members or the shareholders of a water course.

(continued)

(4) The term of President and General Secretary shall be 3 years.
(5) The elections of a Khal Panchayat shall be conducted by a person nominated by the Authority.
(6) No person, who is in arrears of payment of abiana, shall be eligible either to vote or contest for the election of President or General Secretary.

4) Functions and duties of Khal Panchayat.

(1) Every Khal Panchayat shall submit a warabandi to the Sub Divisional Canal Officer on the prescribed form.
(2) The Sub Divisional Canal Officer shall approve the warabandi after such modifications and changes as he deems necessary.
(3) Where a Warabandi is not submitted to the Sub Divisional Canal Officer by Khal Panchayat within 60 days, the Sub Divisional Canal Officer shall formulate a Warabandi and provide a copy of such warabandi to the Khal Panchayat for its implementation.
(4) A Khal Panchayat may lodge complaint to the Sub Divisional Canal Officer or the Deputy Collector Irrigation that a warabandi is being violated or water theft is being committed.
(5) Every such complaint shall be duly inquired into as soon as practicable, and the outcome thereof shall be communicated to the Khal Panchayat.
(6) The Sub Divisional Canal Officer shall inform the Khal Panchayat about rotational running of channels and the Khal Panchayat shall inform all members of the Khal Panchayat of such rotational running of channels.
(7) A Khal Panchayat shall mediate in disputes between farmers for equitable distribution of water.
(8) A Khal Panchayat shall check cattle trespassing on canal or drainage channels, right of way and report to the concerned Canal Officer for appropriate action.
(9) A Khal Panchayat shall help in preparation and distribution of abiana bill when so requested by the Sub Divisional Canal Officer.

Punjab Local Government Ordinance 2021
– Functions and powers of Neighborhood Council and Village Council.–

1. The functions and powers of Neighborhood Council and the Village Council shall be to:

   a) approve its budget;
   b) approve the levy of tax and fee etc.
   c) collect approved taxes, fees, rates, rents, tolls, charges, fines and penalties;

(continued)

d) enforce this Ordinance, rules and bye-laws regulating its functioning;
e) nominate members of the Community Councils in its respective urban area and monitor their performance;
f) nominate members of the Panchayats within its respective rural area and monitor their performance;
g) mobilize the community:
    i. for maintenance of public ways, public streets, streetlights, culverts, bridges, public buildings and local drains;
    ii. for plantation of trees, landscaping and beautification of public places;
    iii. for prevention and removal of encroachments on public ways, streets and places;
h) provide and maintain public sources of drinking water, such as wells, water pumps, tanks and ponds, and open drains;
i) coordinate with the community organizations for proper maintenance of water supply schemes and sewerage in the prescribed manner;
j) manage and maintain grazing areas, common meeting places and other common property
k) hold local fairs and recreational activities;
l) registration of births, deaths, marriages and divorces; (m) promote local, school and traditional sports;
m) promote local, school and traditional sports;
n) take other measures likely to promote the welfare, health, safety, comfort or convenience of the inhabitants of its local area;
o) identify deficiencies in delivery of services and make recommendations for improvement of services;
p) execute small scale development works relating to its functions;
q) report illegal excavation of earth, sand, stones or other material to the relevant authorities;
r) celebration of public festivals;
s) assist the relevant authorities in disaster management and relief activities;
t) manage properties, assets and funds vested in it; and
u) maintain such statistics and data as may be prescribed and disseminate information on matters of public interest; and

2. A Neighborhood Council and the Village Council may perform any other function entrusted to it by the Government or its respective upper level local government, in whose local area the Neighborhood Council or as the case may be the Village Council is situated.

Fig. 6.11 The village council as a central hub

6.12 Conclusions and Recommendations

6.12.1 Conclusions

To share a scarce resource while limiting environmental damage, it is imperative to limit future water use. Important ways to grow enough food with limited water are to increase the productivity of water in irrigated and rainfed areas, in animal husbandry and in aquaculture; improve water management in low-yielding rainfed areas; change food consumption patterns; and (possibly) by enabling trade between water rich and water scarce countries and areas. Increasing the water use efficiency of crop, livestock, and aquatic production, while preserving the functioning of water bodies in a context of increased demand for food and energy, is a real challenge. Consideration of the various ecosystem functions in irrigated and rainfed

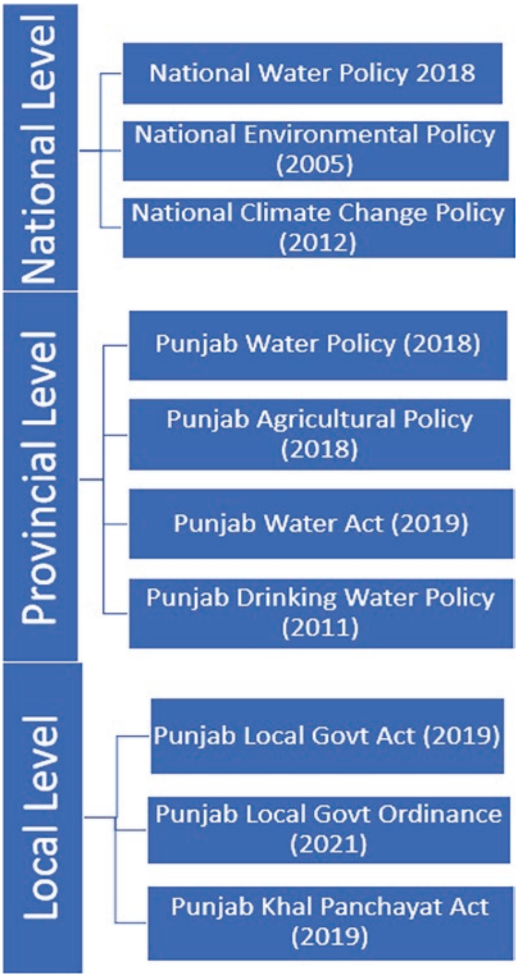

Fig. 6.12 Water sector policy and regulatory paradigm shift and linkages in Punjab

agroecosystems is crucial, as is effective water governance at different and appropriate scales to help ensure sustainable use of water resources. Water storage options along the continuum, from soil and groundwater to natural wetlands and dams, can make water more accessible at different spatial and temporal scales. This is especially important in rainfed agriculture, where other water management options and appropriate farming practices can help increase agricultural and water productivity through various water management options. Support should be given to systems and approaches that ensure high water productivity as well as gender and social equity and contribute to closing the water cycle to the benefit of many ecosystem functions. Sustainable livestock production systems should be encouraged in order to respond to changing diets and the increased demand for animal products while maintaining environmental flows and ecosystem services. The resulting improved livestock water productivity would allow more animal products and food to be produced without increasing the volume of water depleted. For aquaculture, various practical approaches and policies to enhance water use have been developed in different geographical settings all of which have potential to be useful elsewhere. Greater awareness of these amongst producers and policy-makers.

could encourage more cost effective water management strategies that would concomitantly reduce animal, environmental, and public health risks. Mass media campaigns are needed to raise awareness among the general public.

6.12.2 Recommendations

As mentioned earlier in the chapter, we need to manage groundwater on both sides i.e., demand (manage the people) and supply side (mange the resource/aquifer). Some recommendations for sustainable groundwater governance and management are tabulated in Table 6.3.

The monitoring of groundwater is a prerequisite for its proper management, governance, development and utilization. "*If we cannot monitor, we cannot manage*" (Zakir-Hassan et al., 2020). At present the state-of-the-art in monitoring groundwater is still not up to the mark. About 50% area of the province, including the Pothohar region (districts Chakwal, Jhelum, Rawalpindi, Attock), the Thal area, and the Cholistan area do not have monitoring network coverage. About half of the existing piezometers have become dead and dry and need replacement. Safety of observation points is another challenge in the field. Monitoring equipment needs to be upgraded and the capacities of human resources also need to be enhanced. For more frequent, consistent, reliable and more accurate data acquisition, some automatic loggers

Table 6.3 Options for the management of water resources

Supply side	Demand side
Improved O & M Regulatory framework-policy/law Resource development Monitoring GW—Aquifers mapping Protection of GW quality Rainwater harvesting Groundwater recharge—Natural and managed Watershed management Water education/professional capacity building Storage capacity increase Storage of flood water in aquifers Construction of storage dams	Reduced pumping Efficient use of available surface water resources Improved land and water productivity—More crop per drop Enhancing capacity and awareness Reliability in water supplies-supply based Precision irrigation/high efficiency systems Institutional strengthening Water & climate smart crop Irrigation scheduling (how much, when, and how to irrigate) Reallocation of water-higher values crops Cropping patterns/agro ecological zones Water recycling/waste water use for agriculture Conjunctive use/water quality management Awareness and capacity building Skimming well technology On-farm storages (supply based to demand based)

equipped with sensors and transmitters are required to be installed at some safe points. A framework for the monitoring grid for the Punjab province would look like this:

Proposed Framework for Installation of Groundwater Monitoring Network

- Division of the province into monitoring zones/basins and sub-basins.
- Coverage of non-canal commanded areas- whole geographical area.
- Monitoring may vary for basin to basin or sub-basin.
- Demarcation of critical zones.
- Intensive monitoring grid for critical areas/locations like steep slopes/hydraulic gradients; high depletion rates, extensive extraction like industries, water supply schemes; fresh-saline interface, potential sites for MAR and rainfall harvesting.
- Monitoring points may be installed away from water bodies to avoid misleading observations.
- Water quality shall also be part of monitoring framework.
- Different grids for rural and urban areas.
- Priority to be given to the restoration of dead points-data continuity.
- Build on existing network, instead of complete net network.
- Transboundary location (international, provincial, regional sub-basins).
- Overlapping with other agencies (SMO/WAPDA, PCRWR, and others) shall be checked.

Demarcation of basins and sub-basins is another important and complex challenge for the proper management, governance, and monitoring of groundwater resource. The nature of groundwater is more complex, since it is a hidden and invisible resource, and does not follow geographical or administrative boundaries. Therefore, its division into basins and sub-basins is very complex, and hydrogeological boundary conditions are imperative, which can help in studying the aquifer system and its modeling for future decision making. A proposed framework for demarcation of groundwater basins and sub-basins in Punjab is given in Sect. 6.12.2.1.

6.12.2.1 Proposed Parameters for Demarcation of Groundwater Basins and Sub-Basins in Punjab

- The size of the area- whole province
- Geological conditions/Hydrogeological boundaries
- Topography/Physiography
- Aquifer parameters with a relatively high permeability (aquifers), zones with limited permeability (aquitards) and zones with virtually no permeability (aquicludes)
- Sizes of the aquifer/depth
- Land use of the area (cropped, built up, rural, urban, desert, hilly, plain)
- Lithology, (lithological and geophysical)
- Groundwater system (groundwater levels, quality, critical zones, depleting areas),
- Surface water systems (canals, rivers, lakes, drains)

- Climatic parameters (rainfall, temperature, rainfall, evapotranspiration, droughts, floods)
- Cropping patterns, cropping zone, crop calendars
- Physiography, i.e., desert, hills, plains
- Aquifer recharge sources
- Climatic Conditions of the Area (rainfall, temperate, drought)
- Existing monitoring systems.
- Population of the area
- Aquifer hydraulic gradient
- Agro-ecological zones
- Current and future use of groundwater

6.12.2.2 Gaps Identification

Although many policies have been approved and implemented to tackle the looming water crisis in the country, to achieve the objective of bottom-up governance of groundwater, gaps have been identified for further improvement:

(i) As far as the institutional setup is concerned, there are very few human resources to manage groundwater as compared to surface water. Therefore, more dedicated staff with the appropriate capacity are needed.
(ii) Management of groundwater at the provincial level may entail transboundary issues among the provinces, which may require another look at the Water Apportionment Accord of 1991 (GoP-IRSA, 1991), as in its current iteration, does not take groundwater into account.
(iii) Interlinkages between different national and provincial policies and regulations are required to develop a sustainable management plan for groundwater use;
(iv) At the grassroots level, the Khal Panchayat Act, Punjab Local Government Ordinance 2021, Punjab Water Act 2019, and other relevant regulations and policy frameworks may be read together to strengthen the integrated groundwater governance model at the grassroots/village level;
(v) The Punjab Water Act may be a good initial step, but with the passage of time, it may not be able to cover the full governance and regulatory challenges of managing groundwater, since it is much more different and complex as compared with surface water management.
(vi) v) Implementation frameworks for the existing regulatory framework are not very clear, leading to very slow on-the-ground implementation.
(vii) Consultation with the community/stakeholders on developing IWRM frameworks is still lacking.
(viii) Proper monitoring and feedback mechanisms need to be embedded in the regulatory framework.

(ix) To implement policies, cooperative governance through top-bottom collaboration is imperative. Failure to recognize the role of local bodies/councils would be a departure from the stated objectives.
(x) Historically, the capacity of local councils at the grassroots level to handle water management issues has hindered groundwater governance. This aspect will need to be taken up in integrated mode. Providing training and institutional support at local level is a prerequisite to this.
(xi) The use of solar power in the private sector to pump groundwater is rapidly taking root in rural areas; proper policy and regulation in this regard is required. If there is a failure to do so, or if it delayed too long, we will repeat the history of using up groundwater (as we did in Balochistan) because of electricity subsidies given to pump groundwater (Khair et al., 2015).
(xii) All water sector challenges must be linked logically with relevant policy intervention.
(xiii) Generally, policies can not be successful due week and ambiguous, and non-practicable regulatory framework. Therefore, and well thought regulatory framework coupled with IWRM framework will warranty the success of policies.
(xiv) All policies and regulations must be published widely in local languages, so that these can get public acceptability.
(xv) Role of women and youth needs to be highlighted at policy and implementation level.

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