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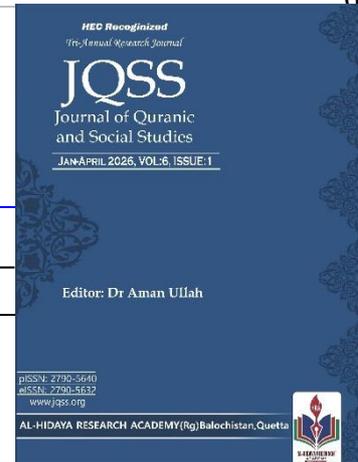
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Water Scarcity in Quetta City: A Critical Analysis and Pathways to Sustainability

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Abstract and



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Abstract

Water shortages in Quetta affect public health, environmental sustainability, and economic stability. Despite an expanding body of hydrological and policy studies, substantial empirical and conceptual gaps remain in understanding water scarcity in Quetta. This study examines the groundwater depletion in Quetta city. A mixed-methods approach analyses groundwater levels, stakeholder perceptions, and water service station operations and roles. The research employs structured questionnaires to gather quantitative data and investigates water service stations regarding their activities, water sources, and the influence on groundwater. A sample of N=153 households is chosen to achieve statistical significance. The sample includes residences from various socioeconomic strata to represent a range of water consumption behaviours, challenges and awareness levels. Four Local government officials, WASA representatives, stakeholders, and community leaders were interviewed using a semi-structured interview design. Quantitative data analysis and thematic analysis to analyse qualitative interview data. The study concludes that awareness is nearly universal, with 88% agreeing that they are aware of groundwater depletion in Quetta. The study showed no association between race, culture, or residence and water saving. Current research indicates that Quetta's regulations and stakeholder activities are failing due to a fragmented operational chain, characterised by the absence of universal licensing, limited metering, infrequent inspections and minimal penalties. A transformation from normative to operational governance is necessary. Important steps include declaring the Quetta Valley a Critical Aquifer Management Zone in accordance with IWRM, instituting well suspensions, and designating priority recharge areas.

Keywords: Water scarcity, groundwater depletion, water consumption behaviours, hydrological policies, Critical Aquifer Management Zone.

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I. Introduction

Quetta, the provincial capital of Balochistan, Pakistan, is in one of the country's most arid regions with severe water scarcity (Barech & Ainuddin, 2019). Rapid urban growth and infrastructural deficiencies exacerbate the city's water shortages, which are caused by its geography and climate (Aslam Khan, 2023). Quetta's natural water resources cannot meet its growing population due to low rainfall and high evaporation (Barrech et al., 2018). Human consumption of water is largely determined by the quality of the surrounding environment (Jafari et al., 2008).

Groundwater is among the most prized water resources on the planet, with approximately 50% of the world's population dependent on it. Groundwater is extensively used in numerous parts of Pakistan, as well as in Balochistan, for drinking, household, agricultural and industrial reasons. Due to the various filtration mechanisms occurring in the soil, groundwater is believed to be the cleanest kind of water in comparison to other water sources (Mohammad & Rind, 2020).

Water shortages in Quetta affect public health, environmental sustainability, and economic stability (Barech & Ainuddin, 2019). Groundwater over-extraction, low rainfall, and poor water management caused this problem (Kakar et al., 2020). Service stations and other sectors are extracting too much groundwater, Quetta's main water source (Aftab et al., 2018). The irresponsible extraction by Service stations worsens the city's water shortages and affects municipal water management and distribution. Outdated infrastructure cannot support a rapidly urbanising population (Naz et al., 2020). Water shortages, inconsistent availability, and increased rivalry for little water influence many aspects of Quetta life. The city's water supply needs a thorough groundwater depletion, management, and targeted initiatives review. The study analyses these issues to help develop sustainable water management strategies to meet Quetta's urgent needs and tries to answer following questions:

- i. How do households in Quetta District use water, to what extent are they aware of groundwater depletion, and how do they perceive the current severity and future risks of water scarcity?
- ii. What challenges do stakeholders face in regulating groundwater use in Quetta, particularly regarding household consumption, service stations, and public awareness of over-extraction?
- iii. How effective are current policies and stakeholder strategies in addressing water scarcity in Quetta, and what further measures can enhance sustainable water management?

2. Literature Review

In large agricultural and urban areas, rapid population growth degrades groundwater quality and quantity, making groundwater vulnerability a major issue (Foster & Chilton, 2003). Rapid urbanisation in Quetta has depleted the water table, disrupting water supply (Qureshi et al., 2022). More tube wells and borehole connections have been installed locally, increasing water usage and making drinking water access difficult in many areas (Kakar et al., 2018). Thus, households use water tankers, which costs more

(Durrani et al., 2018). Groundwater decline in Quetta began in 1989 at 0.25 meters per year. The groundwater monitoring system, which was expanded in 1987, is currently maintained by the Water and Sanitation Authority (WASA), which oversees 10 automatic level recorders and several dozen monitoring wells (ibid).

McDonald et al. (2011) predicted a 3-billion-person urban population boom by 2050. Despite struggling to supply water to new citizens, cities will undergo enormous hydrologic shifts due to global climate change. Mekonnen and Hoekstra (2016) remark that many believe freshwater scarcity poses a global systemic risk. Due to their failure to account for seasonal variations in water availability and consumption, previous global water scarcity assessments that measure water scarcity annually have understated actual water scarcity.

Pahl-Wostl (2007) highlighted that water management is confronted with significant challenges due to rapidly shifting socio-economic boundary conditions and growing uncertainties brought on by climate change and globalisation. This suggests that the approach to water management is changing from prediction and control to management as learning. Rijsberman (2006) argues that determining whether water is actually physically scarce on a global scale (a supply problem) or if it is available but needs to be used more efficiently (a demand problem) is surprisingly challenging.

The extensive installation of tube wells, electricity subsidy programs, and government inaction in anticipating the short- and long-term effects have all contributed to the decline in groundwater levels in Balochistan (Khair, Shahbaz, & Reardon-Smith, 2015). Financial operations such as selling water in return for a crop share also affect groundwater (Razzaq et al., 2022). Water markets are a buffer against the increasing water deficit in upland Balochistan by reducing risk to high-value horticultural crops (Khair, Mushtaq, & Culas, 2011).

Furthermore, satellite images from 1975 to 2009, which span almost three decades, show increased agricultural lands in the city's central region (Khan, Khan, & Kakar, 2013). In addition, Quetta's economy, trees, agriculture, and public health have all suffered from the lack of water. A water shortage has forced many people to relocate (Barrech, Ainuddin, & Najeebullah, 2018).

Additionally, there was continuous groundwater loss due to the tube wells' systematic collapse and emptying of the old Karez irrigation system (Kakar, Shah, & Khan, 2018). The construction of tube wells caused water scarcity in the study area, extended use, and a drop in the water table (Kakar & Ahmad, 2016). Groundwater development plans, the continuation of the subsidised electric tariff policy, the rise in tube wells, the expansion of the area irrigated by tube wells, and decreased annual average rainfall are all blamed for this decline. More than 72% of rural Balochistan's drink water from tube wells and streams (Syed, Richard, & Muhammad, 2010).

Despite an expanding body of hydrological and policy studies, substantial empirical and conceptual gaps remain in understanding water scarcity in Quetta District. Most existing literature focuses on hydrogeological decline, aquifer mapping, or land subsidence, while fewer studies capture household users lived realities or stakeholders'

institutional experiences. One critical gap is the lack of longitudinal household-level data. Most recent research has examined Baluchistan's water deficit causes and effects. Quetta's water deficit and its potential negative implications have received little attention in the literature. 2.5 million people live in Quetta, which has a severe water scarcity. Due of Quetta's rapidly dropping groundwater level, this study is important.

3. Methodology

This study examines Quetta groundwater depletion and water resource management using quantitative and qualitative methodologies. A mixed-methods approach can analyse groundwater levels, stakeholder perceptions, and water service station operations and roles.

3.1 Global definitions of Water Scarcity and Sustainability

Rijsberman's classic review disentangles "water scarcity" into physical (hydrological limits) and economic (infrastructural/institutional) scarcity, arguing that many regions face water stress less because there is absolutely no water and more. After all, societies lack the capacity, institutions, or incentives to capture, store, treat, and equitably allocate it (e.g., inadequate storage, leaky networks, under-pricing) (Rijsberman, 2006). This framing is important for Quetta: aquifer depletion can coexist with tanker markets and intermittency that reflect institutional failures as much as biophysical shortfall.

3.2 Sustainable Water Management Frameworks

Two frameworks prevail in sustainability discourse. Rockström et al. (2009) situate freshwater utilisation within the framework of "planetary boundaries," advocating for a worldwide 'safe operating space' to prevent the destabilisation of Earth-system processes. While global, the boundary logic scales to basins: environmental flow needs and aquifer renewal rates act as local "guardrails" for planning. The boundary frame complements scarcity metrics by embedding them in risk-avoidance rather than pure efficiency (ibid).

3.3 Data Collection

3.3.1 Primary Data Collection

The research employs structured questionnaires to collect quantitative data regarding water usage patterns, awareness of groundwater depletion, and adaptive strategies from households and municipal service stations that excessively utilise water. Furthermore, it investigates with water service stations regarding their activities, water sources, and the influence on groundwater. Sample of N=153 households is chosen to achieve statistical significance. The sample includes residences from various socioeconomic strata to represent a range of water consumption behaviours, challenges and awareness level.

3.3.2 Semi-Structured Interviews

Local government officials, WASA representatives, stakeholders, and community leaders were interviewed semi-structured designed. These interviews include groundwater management issues, policy efficacy, and water service station functions in the water supply system. Semi-structured research lets researchers explore deeper into

discussion concerns. Interview of the 4 important stakeholders were carried out. Given their experience and semi-structured interviews' qualitative depth, this group's modest sample size is suitable.

3.4 Data Analysis

SPSS evaluates quantitative survey, groundwater monitoring, and water service station data. Descriptive statistics summarises water use. Thematic analysis is employed to analyse qualitative interview data. Data is coded to find groundwater management challenges and strategies themes, patterns, and insights. Triangulation with quantitative findings provides a complete insight.

4. Study Area and Respondent's Profile

4.1 Profile of Quetta City

Quetta Valley is situated at an elevation of 1,676 meters above sea level, with surrounding hills rising up to 3,000 meters (Aftab et al., 2018). Quetta District is mostly mountainous, with elevations between 1,254 and 3,500 meters. Regionally important mountain ranges include Mashlakh, Chiltan, Murdar, and Zarghoon. Gaps in the Murdar, Chiltan, Takatu, and Zarghoon mountains allow transportation through Quetta. Key indicators, factors and their sources are tabulated below:

Table 1: Quetta City Water Profile: Key Indicators and Sources (2025)

Factor	Indicators	Source
Demand and supply gap	~25–37 MGD shortfall	Khan and Malik (2023)
Groundwater decline	~3–4 ft/yr	Qureshi et al., (2022).
Quality flags: Elevated Fluoride levels /microbial risks	PCRWR/PHE testing presence by Water Resources Research Centre (WRRC), Quetta	Vide Notification Issued by Public Health Engineering Department, Government of Balochistan dated 07-February-2025
Climate	~270–310 mm annual precipitation (low/variable)	Wikipedia

4.2 Participants' Profile

The survey participants from Quetta city and interviewees from stakeholders were chosen purposively and their demographic information are appended below. The researcher provided contextual information regarding the participants to enhance comprehension in this section.

4.2.1 Profile of Interviewed officials

A total of four participants were interviewed in detail to probe the challenges and awareness about groundwater use, assessing the effectiveness of existing policies and strategies, and suggestion to reform existing water management. The participant A is a 56-year-old male who has lived in the urban area of Quetta since birth. His position as a stakeholder is multi-level, encompassing roles such as resident, family member, manager, researcher, and organiser. Participant B is a 35-year-old male who has been living in the

semi-urban area of Quetta for Twenty Years. His position as a stakeholder is Senior Hydro-geologist in the Public Health Engineering (PHE) Department, Balochistan. Participant C is a 30-year-old male who has been living in the urban area of Quetta for thirty years. His position as a stakeholder is senior Hydro-geologist at Quetta Water and Sanitation Authority (WASA). The participant D is a 64-year-old male who has lived in the urban area of Quetta since birth. His position as a stakeholder is multi-level, encompassing roles such as a resident and a retired government servant.

4.2.2 Profile of Surveyed Participants

A total of N=153 people including men and women participated in an online survey regarding their opinion about household water usage patterns, awareness of water scarcity, and adaptive strategies to save water. Section A of the survey questionnaire explored the background information of the participants including gender and age group tabulated below in the table 2. The maximum number of participants 52.3 % are from the age group of 26-35 years old. Plus, utmost efforts were made by researcher to explore the views of women but due to certain societal circumstances only 15 % participants are women in the study. The high academic background of the participants tabulated below in Table 2 illustrates the richness of the data collected for this study. The participants belong to almost every academic field and provided their valuable feedback for the study.

Table 2: Demographic Profile of Surveyed Participants

Variables		Frequency (N)	Percent
Gender	Female	23	15
	Male	130	85
	Total	153	100.0
Age Group	Below 25	25	16.3
	26-35	80	52.3
	36-45	33	21.6
	46 and above	15	9.8
Educational Information	Intermediate / FSc	7	4.6
	Bachelors	44	28.8
	Masters	56	36.6
	MSc	2	1.3
	MPhil	17	11.1
	Bachelors (Engineering)	8	5.2
	Masters (Engineering)	2	1.3
	MBA	2	1.3

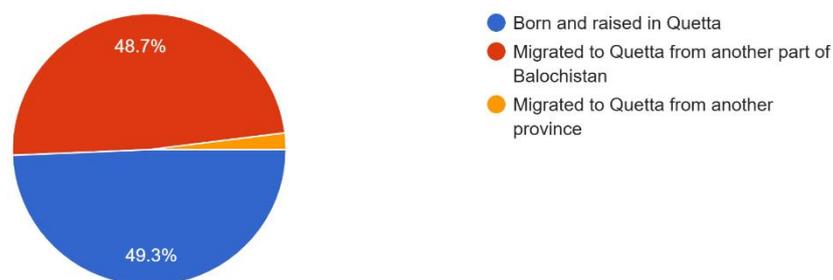
	MS/M. E	3	2
	PhD	3	2
	MBBS	2	1.3
	Masters (Public Health/FCPS)	2	1.3
	M.E Civil Engineering	1	0.7
	Masters (Computer Science)	1	0.7
	Masters (LLB)	1	0.7
	Masters (Political Science)	1	0.7
	Postgraduate	1	0.7
	Total	153	100

Moreover, the issue of water scarcity in the Quetta city is concern of every citizen despite the academic background and role in the community that's why researcher tried to get the survey data from the participants of every notable profession in the region. The participants belong to teacher community, medical professionals, media persons, bankers, engineers, business persons, civil servant and employees of different government organizations, researcher, publisher, social worker, lawyers and many others.

The scarcity of water is an alarming for every resident of Quetta city despite of their duration of stay in the city and other circumstances. The participants stay in the city is shown in figure 1.

Figure 1: The participants' residential status in the city

How would you best describe yourself?
 152 responses



The size of the family of participants helped to determine the pattern of household usage.

The average family members of the survey participants are 4-6 that are 36.6% of the

total participants. Plus, 7-9 and 10-12 family members are also reported by each 22.2 % participants. Table 3 presents the family members data in details.

Table 3: Family Members Data

Family Size Group	Frequency (N)	Percent	Valid Percent	Cumulative Percent
1-3	9	5.9	5.9	5.9
4-6	56	36.6	36.6	42.5
7-9	34	22.2	22.2	64.7
10-12	34	22.2	22.2	86.9
13-15	9	5.9	5.9	92.8
16-19	7	4.6	4.6	97.4
20-29	2	1.3	1.3	98.7
30+	2	1.3	1.3	100
Total	153	100	100	

5. Household Water Use, Awareness, and Adaptive Responses to Water Scarcity

5.1 Water Usage Patterns in Households

The section B of the survey explored the water usage pattern of household in the Quetta city. The 76.5% participants relied on groundwater for their household needs. Substantively, this supports a citywide dependence on groundwater and aligns with known supply deficits. The issue of private tanker mafia, demand-supply gaps and declining groundwater availability is examined.

Table 4: Water usage patterns (%) in the surveyed Households

	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
I rely primarily on groundwater for household needs.	56.2	20.3	6.5	5.9	11.1
Water is used generously in activities like gardening and washing.	38.6	26.1	17	8.5	9.8
We frequently experience water shortages.	64.7	15.7	9.8	5.9	3.9

Water is available in our home for most hours of the day.	21.6	21.6	19.6	19	18.3
During shortages, we purchase water from private tankers.	77.1	14.4	2.6	3.3	2.6
Our water system (pipes, tanks, etc.) is well-maintained.	22.9	22.2	15.7	17.6	21.6
I have noticed a decline in water availability over the years.	64.7	17.6	8.5	3.9	5.2
Total Responses (<i>N</i>)	153				

This result indicated tanker purchase is the standard coping mechanism when shortages occur. This confirms a marketed safety net households bridge supply gaps by buying tanker water. Perceptions of maintenance quality are divided, indicating varied household conditions. Notwithstanding recurrent shortages and significant dependence on tankers, a modest plurality continues to regard their systems as well-maintained. The survey participants also worry about water supplies declining over time.

5.2 Awareness of Groundwater Depletion

Section C of the survey raised Quetta's water scarcity awareness. Awareness is near-universal and the majority of inhabitants recognise that aquifers are depleting. This response illustrates that individual's link daily scarcity to a systemic groundwater issue.

Table 5: Awareness of Respondents' Groundwater Depletion (%)

	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
I am aware of groundwater depletion in Quetta.	63.4	24.8	6.5	1.3	3.9
I believe agriculture contributes significantly to groundwater depletion.	28.8	34	19	10.5	7.8
Industrial and service stations over-extract groundwater.	43.8	31.4	13.7	9.2	2
If current trends continue, future generations will face extreme water shortages.	79.7	10.5	3.9	2.6	3.3
Water scarcity is a serious problem in my area and will worsen in the next 5–10 years.	66.7	26.8	2	0.7	3.9
I am worried about access to clean water in the future.	75.8	16.3	3.3	1.3	3.3

Awareness campaigns on water conservation are effective.	56.9	15.7	9.8	5.9	11.8
Government efforts to address water depletion are visible.	14.4	9.8	17.6	20.9	37.3
Total Responses (<i>N</i>)	153				

According to survey respondents, industrial and service stations over-extract groundwater. They concerned that current patterns will cause severe water shortages for future generations and will worsen in the next 5–10 years. The response explicitly shows that public support likely exists for quality assurance measures. Most residents think awareness campaigns work but nearly 1 in 5 remain unconvinced. Perceptions about Government efforts to address water depletion are decisively negative showing that most respondents do not see visible government action on groundwater depletion.

5.3 Adaptive Practices and Household-Level Conservation Responses

The section D of the survey focused on the adaptive strategies to save water. The answer of the water conservation strategies respondents is implementing at their homes shows a tilt toward self-reported conservation, but with a very large uncertain middle. Agreement reaches 75.1% showing that three out of four households report actively discouraging wasteful water use in vehicle washing—a typically high-consumption, discretionary activity. The leaking taps and water pipes are the main reason for waste of water.

Table 6: Adaptive Practices and Household-Level Conservation Responses

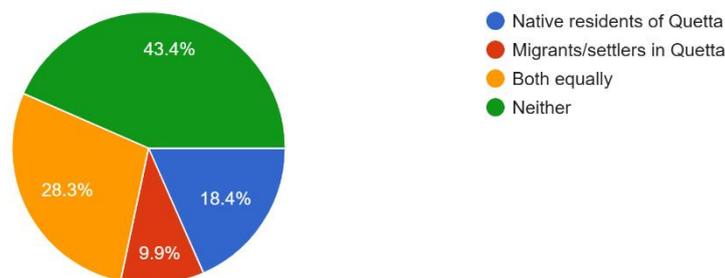
	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
My household has adopted measures to conserve water.	25.5	28.8	26.1	12.4	7.2
We discourage excessive water use when washing a bike or car at home.	39.2	35.9	12.4	5.9	6.5
We promptly repair any leaking taps or water pipes.	52.9	30.1	8.5	5.2	3.3
We clean our water tanks regularly to avoid water contamination.	37.3	26.8	19	11.8	5.2
We collect and store rainwater for use.	14.4	5.9	9.8	19	51
We educate family members and children about the importance of saving water.	39.2	32.7	13.7	5.2	9.2

I am willing to participate in community-level conservation programs.	54.9	24.8	11.8	6.5	2
Effective public policies are essential for long-term water sustainability.	65.4	19	10.5	2.6	2.6
Total Responses (<i>N</i>)	153				

Answers about water tank cleaning to prevent contamination suggest agreement is 64.1%, indicating that two-thirds of families clean their tanks regularly. Another 17.0% disagree meaning that one in six homes does not maintain tanks systematically. Responses about the understanding of family members and children of the importance of water conservation demonstrate exceptional intra-household consciousness. The predominant portion, 43.4%, choose 'Neither', indicating that more than half perceive no group as aggressively conserving water.

Figure 2: Which group shows greater efforts in adopting water-saving practices

In your opinion, which group shows greater effort in adopting water-saving practices?
 152 responses



The response shows high willingness to participate in community water conservation projects. About four in five responders (79.7%) agree to join communal conservation efforts. People view conservation as a private responsibility and are open to neighbourhood-level programs with leadership and institutional support. The response was nearly unanimous on the significance of state action on good public policies for long-term water sustainability. The result therefore underlines a strong public mandate for coherent, long-term water governance in Quetta.

6. Challenges in Regulating Groundwater Use

6.1 Governance Context and Institutional Challenges

Quetta's groundwater crisis sits at the intersection of arid hydro-climate, rapid urbanization, and an implementation gap between policy and practice. The legal

scaffolding for groundwater governance in Balochistan and Quetta is not absent; indeed, the National Water Policy (2018) sets integrated principles for provincial action, the Balochistan Groundwater Rights Administration Ordinance (1978) created a Provincial Water Board with licensing powers, the Balochistan Environmental Protection Act (2012) gives the Environmental Protection Agency (EPA) a regulatory mandate over pollution and EIAs, and the Quetta Water and Sanitation Authority Act (2004/2010) establishes an urban service utility. Yet outcomes remain weak: abstraction overwhelms recharge, aquifer levels continue to decline, and service-sector and household practices are only weakly shaped by enforceable standards.

Participant A highlighted the governmental challenges related to water crises: “The biggest concerns are the unsustainable over-extraction of groundwater... Over the past decade, groundwater levels in Quetta have dropped drastically from around 180–200 feet to over 1,100 feet in some areas. The Annual depletion in surrounding Balochistan averages 2 to 5 meters”. Similarly participant B also noted that “The biggest challenge in managing groundwater in Quetta city is uncontrolled population growth which is causing over extraction of groundwater”. Overpopulation is also contributory factor for water crises in the city as highlighted by participant B and C. Participant C also noted some other factors “A combination of arid climate with low precipitation rates, increased population, rapid urbanization and mismanagement.

The legal “skeleton” exists, but city-level “muscle and nerves” are thin: few binding, specific, time-bound requirements on high-volume users; limited licensing and metering; and weak linkage between environmental approvals and day-to-day abstraction control. Effectiveness is limited not by the absence of policy documents but by the gap between strategy and enforceable mechanisms in Quetta. Enforcement requires inspectors, budgets, laboratories, digital systems (GIS, telemetry), and legal procedures. Participant A revealed that “Apparently government lacks specific regulations or enforced standards that limit their water consumption”. Enforcement capacity is diluted by overlapping roles: Q-WASA is built for urban service delivery, not citywide licensing/policing of private bores; PHED/Irrigation focuses on infrastructure and non-urban supply; the EPA primarily governs environmental compliance (EIA/IEE, pollution control) rather than day-to-day allocation/abstraction limits.

The current monitoring architecture means managers often know that the aquifer is falling, but not which users are driving it this month and by how much, making it difficult to ration, prioritize, or penalize effectively. Quetta’s enforcement gap is less about the absence of laws and more about absent instrumentation and diffuse accountability. Until the city operationalizes an urban groundwater unit with authority, tools, and a publish-or-penalize regimen for high-use categories, policy effectiveness will remain modest relative to the pace of aquifer decline.

6.2 Water Use and Awareness in Service Stations

Vehicle service stations are a small but high-visibility slice of urban commercial demand that matters disproportionately for regulatory effectiveness. International and sectoral guidance shows a wide range driven by wash type (manual vs.

automated), nuzzling/pressure, and whether reclamation/recycling is installed: The U.S. EPA's Water Sense (2023 update) reports average fresh-water use for conveyor washes around 30–34 gallons per vehicle (\approx 114–129 L) in studies spanning 2002–2018, with total on-site use higher when including recycled volumes; facilities that optimize flow/pressure and reclaim rinse water can drive fresh-water demand down further. Participant A noted that: "Service stations in Quetta do use a substantial amount of water which estimates 80 Liters per wash, where hardly any service station has recycling system".

Engineering syntheses suggest 30–60 gallons (\approx 114–227 L) per car, varying by vehicle size and process; a survey of 59 facilities reported very high aggregate annual volumes, underscoring the cumulative effect of small per-car figures across busy urban centres (Elgaali & Akram, 2021). Participant B revealed that "Service stations in Quetta city almost use 200-300 liters for each vehicle and In Balochistan / Quetta there's currently no publicly documented law or formal regulation specifically mandating recycling at service stations". Participant B also reported that "Service station owners in Quetta are partially aware of groundwater depletion (mainly from personal experience and rising costs), but lack technical understanding and often continue unsustainable practices due to weak regulation and economic priorities". According to Participant D "15 to 20 gallons per car yes they use more than required yes rules are available but not implemented".

The Participant C also noted "Definitely, they are using more than they should, no rules over viewed yet". First, per-wash benchmarks (e.g., " \leq 30–40-gal fresh water" with mandatory recycling) can be codified to provide clear compliance targets. Second, metering at the service-station boundary (and sub-metering for wash bays) is essential; absent meters, regulators cannot track monthly consumption or verify claimed recycling rates. In practice, most effective jurisdictions pair benchmarks, meters and logs (number of vehicles washed per day) to produce auditable Liters-per-vehicle metrics.

6.2.1 Regulation and Compliance among Service Stations

Participant B articulated that "There is no any such rule or policy regarding service stations of Quetta city". For Quetta/Balochistan, two observations matter: A working local precedent for recycling exists. In 2019, the UNDP–Byco pilot inaugurated Balochistan's first car-wash recycling plant in Quetta, demonstrating technical feasibility (UNDP described a cost-effective, indigenous prototype able to recycle \sim 5,000 L). While a pilot is not a citywide program, it proves that recycling is deployable in Quetta's operating environment. Details of the programme is available at official website of The United Nations Development Programme (UNDP, 2019).

Figure 3: Inauguration of the water recycling plant at Byco service station in Quetta



Participant A discussed it in brief:

“It seems that currently no specific provincial or municipal regulations exist nor there any standard of water usage being followed except the service station infrastructure... UNDP have done one project by ByCo but that is not considered to be a standard which the learnings were not replicate to other service stations which remains a voluntarily pilot project.”

Participant C also highlighted the need of using recycling water for service stations in the city “I guess there are no rules but a strong suggestion that there should be treated water which can be used for service stations”. Additionally, Participant D stressed on lack for week implementation of WASA act in the city “WASA act is there but implementation is weak.

Participant A draws a comparison between Quetta and Punjab in terms of regulating service stations.

“There is no documented evidence of government-imposed fines or shutdowns against service stations in Quetta or Balochistan specifically for overusing groundwater. No known enforcement actions have been reported in terms of water saving efforts. Whereas in Punjab the government has taken significant actions to regulate the water usage at car wash and service centres”.

Participant B also confirmed that “No any actions or fines have been taken or charged against service stations that overuse groundwater”. Similar opinion was expressed by Participant C “Not in my knowledge. But we hardly ever hear about such steps taken against them”.

6.2.3 Awareness and Technological Adaptation

Awareness alone does not predict adoption; regulatory certainty and payback maths do. Participant B discussed the groundwater over-extraction in details: “Boreholes in Quetta now need to reach 1,000 ft or more to get water. Despite this awareness, few adopt water recycling or efficient washing systems (e.g., pressure nozzles, recycling pits), since the cost is high and regulations are weak”. Participant A highlighted the consumerist nature of service station owners and lack of governance in treating the water issue in Quetta city.

“Service station owners are well aware of groundwater but their little incentive and clear business benefits remained prime for them. The absence of policies and its implementation coupled with lack of research, capacity building and demonstration projects or innovative technologies and lack of watch-dog system contributes to the problem rather solutions.”

Participant D noted the ignorance of service stations owners in dealing with water scarcity “Majority of them are ignorant some of them take care Water recycling can be adopted to save water”. Quetta’s arid climate, low recharge, and urban growth mean that service-station controls are necessary but not sufficient.

6.3 Key Challenges in Managing Groundwater Use

Groundwater regulation in Quetta operates under conditions that make effectiveness unusually hard to achieve: a rapidly depleting aquifer; incomplete city-level by-laws, fragmented mandates, thin monitoring infrastructure, and high social dependence on informal coping. The result is a persistent *de jure–de facto* gap—formal policies exist, but day-to-day controls remain underdeveloped or inconsistently applied. Balochistan’s IWRM Policy 2024 sets a credible strategic frame—recognizing over-extraction, climate risk, and institutional fragmentation—and calls for mapping, monitoring, and better coordination.

7. Effectiveness of Policies and Strategies for Sustainable Water Management

In Quetta's groundwater governance, policy abundance and operational weakness conflict. The gap between law and practice has been widened by technological inertia, political interference, and the absence of financial mechanisms—such as volumetric tariffs or licensing fees—that would internalize scarcity into user behaviour. Respondent A explained the existing policies on the subject issue in details:

“The government has Balochistan Groundwater Rights Administration Ordinance (1978) and the establishment of WASA with clear act, considering the problem the implementation of the ordinance and WASA appeared to be fail in achieving their goals. . .the policies of government are not working to combat the issue of water which we are facing.”

On paper, the key provincial and national frameworks empower provincial and municipal authorities to license wells, regulate abstraction, and promote integrated management but on ground implementation is not carried out. Participant B also

remarked about the policies and legal framework exists to address the water issues in Quetta city. He notes that:

“Balochistan Groundwater Rights Administration Ordinance (1978) ...explain how to register wells, issue permits, and enforce penalties. ... Q-WASA Act (2004) gives Q-WASA powers over urban water supply, connections, and enforcement; Q-WASA Water Supply Regulations (2020) codify service rules, connections, and penalties. Balochistan ... (IWRM) Policy (2006)—a province-level framework to manage water resources in a basin/integrated way. Pakistan National Water Policy (2018) Implementation Framework (2020)—sets national direction ... that provinces are meant to operationalize.”

Nationally, the NWP 2018 envisaged the creation of groundwater regulatory authorities and the adoption of IWRM-based basin management, yet Quetta’s implementation remains stalled at the policy-draft level. Moreover, institutional fragmentation among Q-WASA, the Public Health Engineering Department (PHED), the Irrigation Department, and the Environmental Protection Agency (EPA-Balochistan) leads to overlapping jurisdictions without a unified chain of command (WWF-Pakistan, 2024).

7.1 Barriers to Policy Implementation

Consistent with Participant D’s observations, these frameworks remain under-implemented due to limited fiscal capacity, bureaucratic inertia, and political disengagement “lack of political motivation and irrational selection of development program”. Participant C also delineates the existing policies “Water Policy designed by the Irrigation Department in 2024. Q-WASA Act, 2024, and there may be some others”. He also asserted that “Most of the policies are not truly implemented”.

Respondent A further added about the failure of these existing policies:

“Water management departments and policies exist but are appearing as constrained by weak enforcement, overlapping mandates, political interference, lack of data and research, funding shortages, low public cooperation and lack of vision with innovative technologies. These hurdles mean that even when policies exist, they fail to translate into real groundwater protection”.

The Balochistan Groundwater Rights Administration Ordinance (1978) once intended to control drilling and require permits has become largely obsolete in the face of rapid urbanization and the explosion of private tubewells. Similarly, the Quetta WASA Act (2004) authorizes urban supply management but does not give Q-WASA explicit jurisdiction to regulate private abstraction.

Participant D’s primary hurdles in water management are the absence of governmental motivation and irrational development priorities. Participant D’s mention of “irrational development selection” also aligns with findings that planning processes are reactive rather than evidence-driven. These are familiar to Pakistan’s urban water

governance and converge on three structural problems. Even good policy intentions fail without the tools: calibrated meters on commercial bores, inspection protocols, notice-and-sealing procedures, and penalty schedules. Other provinces demonstrate what an “operational package” looks like.

The use of technology in Quetta’s water management remains undeveloped and fragmented. Basic hydro-monitoring and small-dam construction exist, but real-time data systems, smart metering, and leak-detection tools are rare. Studies on urban water governance in Pakistan highlight that the lack of metering and monitoring prevents regulators from identifying high-volume users and enforcing limits (WWF-Pakistan, 2024). Although the Pakistan Council of Research in Water Resources (PCRWR) operates national monitoring wells, data dissemination to local managers is limited, leaving WASA and PHED to rely on manual reporting.

Technological under-adoption has two causes: first, financial constraints, as provincial departments face recurrent funding shortages; and second, project-dependency, where innovation is driven by short-term donor pilots rather than institutionalized programs. Participant A highlighted the role and need of technology in solving Quetta’s water crises, criticizing the government for not using it appropriately:

“The government in Quetta is using basic groundwater monitoring and small dams, but modern technology adoption is minimal. Most efforts are donor-driven pilots rather than large-scale, institutionalized systems. Without scaling up technology (like smart meters, leak detection, recycling), managing Quetta’s shrinking aquifers will remain extremely difficult”.

Another technological gap is recharge and reuse infrastructure. Participant B highlighted the negative role of technology that how “Low-cost pumping incentives: Solarization and subsidies reduce cost barriers, encouraging more extraction”. He also emphasized that “Lack of reliable data: No comprehensive well inventory or active metering makes monitoring and enforcement nearly impossible”. Absence of current well inventory or real-time abstraction monitoring shows insufficient technology integration, making enforcement practically impossible. Ultimately, Quetta’s technology deficit is a governance failure rather than an innovation failure. Tools exist smart meters, GIS dashboards, remote-sensing analytics but their adoption depends on budgets, trained personnel, and continuity of leadership. Without digital visibility, enforcement remains symbolic and depletion invisible.

Participant B’s responses also underscore the missed opportunity of renewable-energy incentives. The solarization of pumping systems, while economically appealing, has inadvertently lowered pumping costs and accelerated depletion. Similar findings from national policy studies show that unconditional solar subsidies for agriculture and urban bores increase extraction unless paired with metering and quota-based incentives (PCRWR, 2024).

The vacuum is partly filled by donor and NGO interventions, which Participant D acknowledges. Programs by the Asian Development Bank (ADB), UNDP, UNICEF, and local NGOs e.g., BRSP, SCSP, EWB have delivered check dams, community training, and pilot

recycling facilities. Although limited, donors and NGOs have helped. To enhance water quality, UNICEF, BRSP, SCSPEB, and WWF-Pakistan have promoted awareness, school outreach, and filtration units. They face funding cycles and lack coordination under a provincial data structure; thus, their efforts are modest and short-term (Accountability Lab Pakistan, 2025). Without integration into government systems, these projects cannot offset institutional inertia. Participant A explained the role of NGOs and donor partners in details in helping Quetta city water crises:

“Several donors and NGOs like World Bank, UNICEF, ADB, UNDP, SCSPEB, BRSP, etc. are helping Quetta through small dams, awareness, community schemes, and technical support, but their impact is fragmented and short-term, mostly project based, compared to the severity of Quetta’s groundwater depletion. A more coordinated, large-scale, and government-led approach is required”.

Participant B also acknowledged the role of NGOs and donor partners: “Yes, donors or NGOs are helping water problems in Quetta in somewhat extent while installing water filtration plants to improve Quality and conducting events, workshops and Trainings for stakeholders”. Participant A warned that “Quetta faces an alarming water crisis, with groundwater dropping 2–3 meters per year in some areas”. He suggested that “Sustainability requires immediate reforms across policy, technology, institutions, and public behaviour with mixed of regulation, enforcement, technology, incentives, and public awareness”.

Participant A warned that “Without these reforms, the city risks running out of usable groundwater”. The policy reforms proposed by Participant B provide a pragmatic blueprint consistent with best practices in other water-stressed regions: Participant D’s policy suggestions “switching over to surface water resources, ban on further tubewells, action against illegal consumers and tanker mafia, control on leakages” mirror the priorities of recent technical reviews.

Quetta's semi-arid climate, decreasing precipitation, and rising temperatures limit recharge. Climate-risk assessments in the IVRM policy cycle might prioritise controlled aquifer recharge, stormwater collection, and drought-response planning. Participant C argues that “laws and policies are there-implement them for all”. Participant C suggested: “Stopping rapid urbanization, stopping population settlement on piedmont recharge zones, ban on water extraction from weak zones and letting them for recharge to revive, effective modern water conservation strategies, etc”.

7.2 Pathways Toward Sustainable Water Management

A credible pathway to sustainability in Quetta must align policy, technology, and social behaviour. At the strategic level, government should pursue three complementary priorities: Integrated governance, Digital transformation and Public-private partnerships (PPP). Participant A suggested the steps for future water sustainability in Quetta city:

Strengthening legal and financial tools could make a big difference. Changes in Laws or Fines could help reduce water overuse which may include Groundwater Extraction Permits, Metering & Pricing for Commercial Users, Progressive Tariff System,

Ban on Wasteful Practices, Mandatory Water Recycling for Businesses, Recharge & Conservation Incentives, Institutional Strengthening & Enforcement, Research and Data Collection and Capacity Building dovetailed with strong monitoring framework and its implementation with due spirit. The PPP model may be an emerging factor to help in water crises management.

Participant B's suggestions point toward a multi-dimensional pathway combining regulation, infrastructure, and civic engagement. Furthermore "Any unregistered/illegal tubewell automatically subject to heavy penalties and immediate disconnection. Annual renewal of licenses tied to compliance (meter readings, quota adherence)".

The President of the Private Water Supply Union informed the members and openly admitted to providing information that 400 Private Operational Tube Wells are running under his Association, out of which 330 are illegally installed without seeking permission or obtaining a No Objection Certificate from the District Water Committee or Provincial Water Board. At the same time, the other 70 are legally registered. Additionally, he informed us that out of 400 tube wells, some 320 are located in hard rock (limestone) or piedmont (near limestone) formations. In comparison, the remaining 80 tube wells are installed and operational in the alluvial aquifer of Quetta district. He also added that approximately 30,000 tankers are sold daily to tanker owners for 500 PKR, who then supply them to consumers at their doorstep for a price ranging from 1,500 to 2,000 PKR.

Participant B also proposed "Volumetric water rights / quotas that Instead of "flat" well permits, tie rights to measurable volumes (e.g., cubic meters per year). Farmers, industries, and service stations get capped allocations based on recharge potential". Metering and reporting requirement is also suggested that "Mandatory installation of digital flow meters on all tubewells above a certain capacity and Tampering with meters classified as a criminal offence" (Participant B).

The industry /service sector fines are also suggested by Participant B "Car washes, service stations, and industries using groundwater without permits: closure orders plus fines. Incentivize them to adopt recycling/reuse technologies by offering fine waivers if they install treatment/recycling units". Participant A highlighted another important reason of over population: "Migration, hosting and climate change seems to be taken in consideration. This is something we have underlined in one of the other projects (intra-city bus service) that influx of Afghan refugees and intra-district migration". Governance integration, technical modernisation, and societal co-ownership could help Quetta shift from crisis management to adaptive, sustainable water governance.

8. Conclusion and Recommendations

The study concludes that awareness about water issues is near universal: 88% know about groundwater depletion in Quetta. More than 75% said industrial users and service stations withdraw too much, perhaps because to urban pumping and vehicle washing. The survey found 73% of citizen value awareness initiatives. The study concludes that Quetta households generally use basic, low-cost conservation strategies but are inconsistent in their care and cleanliness. People are eager to work together and expect

government regulations to ensure sustainability. Households work hard but face structural, infrastructural, and contextual barriers, the survey revealed. The present trend shows schools might increase community awareness and engagement. The study showed no association between race, culture, or residence and water saving.

Current research indicates that Quetta's regulations and stakeholder activities are failing due to a fragmented operational chain, characterised by the absence of universal licensing, limited metering, infrequent inspections, minimal penalties, and inadequate land-use management in essential recharge zones. Interviewees' concerns about political engagement, the unpredictable rule of law, and restricted innovation align with these structural issues. The best approach is to protect recharge zones and ban new boreholes in susceptible subsidence areas, regulate major consumers through metering, quotas, and recycling mandates, improve Managed Aquifer Recharge (MAR) where hydrogeological conditions allow, and publish monthly compliance and hydrology dashboards to institutionalise accountability.

A transformation from normative to operational governance is necessary. Important steps include declaring the Quetta Valley a Critical Aquifer Management Zone in accordance with IWRM, instituting well suspensions, and designating priority recharge areas. All commercial and institutional tubewells must be registered and metered digitally, with annual licence renewals based on compliance. These priorities will align governance with the water security and accountability goals of SDG 6.

Balochistan must appoint a single, autonomous city-level regulatory authority, improve real-time monitoring and public data transparency, align tariffs and energy subsidies with conservation initiatives, and implement recharge and reuse strategies, such as urban infiltration basins, grey-water systems in new developments, and service station recycling, to achieve sustainable water security. These approaches would transform Quetta's water governance from crisis management to one that is evidence-based, accountable, and participatory.

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