



FROM INVISIBLE RESOURCE TO MANAGED ASSET

Islamabad's Journey Towards
Sustainable Groundwater Management

FINAL REPORT

Alumni Engagement Innovation Fund (AEIF) Project 2025
titled 'Protecting Islamabad's Groundwater Aquifer'

Implemented by ScaleX Technologies Pvt. Ltd. with support from the
U.S. Mission to Pakistan in partnership with the Pakistan-U.S. Alumni Network (PUAN)

Authored by
ScaleX Technologies Pvt. Ltd.

TEAM MEMBERS INCLUDED
Adnan Faisal, Sayaf Arbab, Adeel Ahmad, Samita Khan



TABLE OF CONTENTS

Acknowledgements	01
Executive Summary	02
Chapter 1: Pakistan's Groundwater Challenge	03
1.1 A Growing Dependence on Groundwater	03
1.2 Why Cities Are Particularly Vulnerable	03
Chapter 2: Islamabad: A City at a Turning Point	05
2.1 Islamabad's Groundwater Challenge	05
2.2 The Recharge Opportunity	05
2.3 Islamabad's Recharge Efforts and the Monitoring Gap	05
Chapter 3: Project Overview: Protecting Islamabad's Groundwater Aquifer	06
Chapter 4: Understanding the Groundwater Landscape	07
4.1 Technical Insights	07
4.1.1 Baseline Groundwater Quality Assessment	07
4.1.2 Assessment of Existing Recharge Infrastructure	09
4.1.3 Key Insights	10
4.2 Community Perspectives and Adoption Insights	10
4.2.1 Community Survey Insights	10
4.2.2 Key Insights	23
4.3 Institutional Perspectives	23
4.3.1 National Perspectives	23
4.3.2 International Perspectives	26
4.3.3 Key Lessons	28
4.4 Conclusions	28
Chapter 5: Making Groundwater Recharge Measurable	29
5.1 The Monitoring System	29
5.2 The Digital Dashboard	30
5.3 What This Enables	31
Chapter 6: Practical Guidance for Residents: Moving Towards Adoption	32
6.1 Why Recharge?	32
6.2 Is Recharge Suitable for Your Property?	33
6.3 Before You Build	33
6.4 Operation and Maintenance: Protecting Your Investment	34
6.5 The Bigger Picture	34
Chapter 7: The Way Forward: From Pilot to Groundwater Management	35
7.1 A Five-Step Pathway for Islamabad	35
7.1.1. Protect and assess existing recharge assets	35
7.1.2. Build a citywide groundwater monitoring network	36
7.1.3. Map and model Islamabad's groundwater system	36
7.1.4. Target high-capacity recharge where it will have the greatest impact	37
7.1.5. Use the data to manage the groundwater balance	37
7.2 Taking the Approach Beyond Islamabad	38
7.3 What Government and Development Partners Should Support Next	39
7.4 Moving Towards PPPs and Groundwater Management Services	39
7.5 The Long-Term Goal: Managing the Groundwater Balance	40
Chapter 8: Project Sustainability: From a Two-Well Pilot to a Lasting Groundwater Venture	41
References	42

ACKNOWLEDGEMENTS

This report was developed as part of the Alumni Engagement Innovation Fund (AEIF) project 2025 titled '**Protecting Islamabad's Groundwater Aquifer**', implemented by **ScaleX Technologies Pvt. Ltd.** and supported by the **U.S. Mission to Pakistan** in partnership with the **Pakistan-U.S. Alumni Network** and **TiE Islamabad Chapter**. We gratefully acknowledge this support in enabling the initiative and the broader commitment to strengthening climate resilience and water security in Pakistan. We are especially thankful to the **Capital Development Authority's (CDA)** Water Management Wing, particularly **Director General Sardar Khan Zimri** and his team, whose cooperation and support were instrumental in making this project possible.

We also extend our sincere appreciation to **Pir Mehr Ali Shah Arid Agriculture University**, Rawalpindi, and particularly **Dr. Naveed Anjum**, for their technical support, guidance, and continued engagement throughout the project. We further recognize the government institutions, technical experts, researchers, community members, and other stakeholders who shared their time, knowledge, and perspectives. Their contributions helped ground this work in the realities of groundwater management in Pakistan.



EXECUTIVE SUMMARY

Islamabad faces a growing groundwater challenge. The city depends heavily on groundwater, while urban development limits natural recharge and large volumes of rainfall continue to leave the city as runoff. PCRWR estimates that Islamabad generates approximately **275 million cubic metres of surface runoff annually**, creating a significant opportunity to replenish the aquifer through managed recharge.

CDA has already taken important steps by developing approximately 100 recharge wells across the city. The next challenge is to move beyond simply constructing recharge infrastructure towards understanding **how well these systems perform, how they should be maintained, and how their contribution to the aquifer can be measured and managed over time**.

The Alumni Engagement Innovation Fund (AEIF) 2025 project titled '**Protecting Islamabad's Groundwater Aquifer**', implemented by ScaleX Technologies with support from the U.S. Mission to Pakistan in partnership with the Pakistan-U.S. Alumni Network (PUAN), was designed around this gap. The project combined technical assessment, community research and stakeholder engagement with the installation of smart monitoring systems at two existing CDA recharge wells.

The findings point to several clear lessons. The technical assessment showed that Islamabad already has a valuable recharge infrastructure base, but long-term performance depends on stronger **operation and maintenance, technical support, clear responsibility and protection of assets**. The community study, based on **128 respondents**, found high concern about groundwater decline but comparatively low exposure to recharge solutions; awareness, practical guidance and visible examples emerged as important factors for wider adoption. Stakeholder consultations reinforced that recharge must be adapted to local hydrogeology and water-quality risks, while international experience highlighted the importance of monitoring, aquifer-scale planning and sustained O&M.

To address the visibility gap directly, the project installed monitoring systems that track **rainfall, recharge volumes, groundwater levels and selected water-quality parameters**, supported by a digital dashboard. This creates a practical foundation for evaluating recharge performance over time and for making future investment decisions based on evidence rather than assumptions.

The report ultimately points towards a broader shift: Islamabad now has the opportunity to build on existing recharge infrastructure by expanding monitoring, improving O&M, mapping and modelling the aquifer, and directing future recharge towards the areas where it can have the greatest impact. The long-term goal is to move from individual recharge wells towards **measurable, coordinated and sustainable groundwater management**.

PAKISTAN'S GROUNDWATER CHALLENGE

Pakistan's water challenge is increasingly one of managing variability in water availability. Water may be abundant during floods and monsoon periods and severely constrained during dry periods, while population growth and rising demand continue to increase pressure on available supplies. The challenge is therefore not simply how much water Pakistan receives, but how effectively it can store, manage and use water across seasons.

1.1 A Growing Dependence on Groundwater

Pakistan's water resources are under growing pressure from population growth, climate variability and persistent weaknesses in water management. Per-capita water availability in the country has declined considerably, from approximately **5,650 m³ in 1951 to less than 1,000 m³ per person per year in recent years**, while limited storage and management capacity make it difficult to carry water from periods of abundance into periods of scarcity (PCRWR, 2019).

Against this uncertainty, **groundwater has become one of Pakistan's most important water-security buffers**. Aquifers provide water when rainfall, canals and other surface supplies are insufficient or unreliable, supplying approximately **70% of domestic water nationally and more than half of agricultural water** (Lytton et al., 2021). This dependence, however, has been accompanied by growing extraction through agricultural tube wells, municipal systems and private bores.

The resulting challenge is to maintain a sustainable balance between groundwater extraction and replenishment. When extraction consistently exceeds replenishment, groundwater levels decline, making water increasingly difficult and costly to access. Yet groundwater has historically received limited monitoring and management compared with surface water. Protecting this critical buffer therefore requires greater attention to how much groundwater is extracted, how it is replenished, and how the resource is managed over time.

1.2 Why Cities Are Particularly Vulnerable

Groundwater stress is **not distributed evenly across Pakistan**. It is often concentrated in pockets where extraction is particularly intensive, and rapidly growing urban areas are among the clearest examples. Cities concentrate large populations, institutions, businesses and industries within relatively small areas, creating high and continuous demand for water. Between 1998 and 2017 alone, the combined population of Pakistan's major cities increased from approximately **23.4 million to 40.9 million** (Lytton et al., 2021).

Where municipal systems cannot fully or reliably meet this demand, groundwater becomes an important supplementary source. Public utilities operate tube wells, while households, apartment buildings, commercial facilities and institutions increasingly rely on private boreholes to supplement, or in some cases replace, municipal supplies. This creates **concentrated extraction from the aquifer beneath densely populated areas**.

At the same time, the physical development of cities can reduce the aquifer's ability to replenish naturally. Buildings, roads, parking areas and other paved surfaces replace permeable land, preventing rainfall from infiltrating where it falls and instead directing much of it into drains. Cities can therefore create a double pressure: increasing groundwater extraction while simultaneously restricting natural recharge.

The consequences eventually reach residents through deeper drilling, higher pumping costs, unreliable wells and, where other supplies are insufficient, greater dependence on expensive alternatives such as tanker water. Yet the same concentration that increases groundwater stress also creates an important opportunity. **An effective intervention in an urban area can directly benefit a large number of people within a relatively small geographic area.** Better recharge, monitoring and groundwater management in these high-stress pockets can therefore generate substantial and visible impact. Islamabad provides a particularly relevant example of both the challenge and this opportunity.



Figure 1.1: Water tankers being filled at CDA's G-10 office for supply to water-scarce sectors of Islamabad. (Photo: Mohammad Asim/Dawn)

CHAPTER 2

ISLAMABAD: A CITY AT A TURNING POINT

Islamabad brings Pakistan's wider groundwater challenge into sharp focus. The city combines growing water demand and significant groundwater dependence with relatively high rainfall—creating both a concentrated water-security challenge and an opportunity to manage groundwater differently.

2.1 Islamabad's Groundwater Challenge

Groundwater has become an essential part of Islamabad's water supply, with public tube wells and private bores helping meet demand that cannot be fully served through surface-water systems. PCRWR estimates groundwater abstraction just from municipal CDA tube wells at approximately **47 million cubic metres (MCM) annually (12.4 Billion Gallons)** and identifies water-table depletion, shrinking natural recharge zones and a widening demand-supply gap among the city's major water challenges (Pakistan Council of Research in Water Resources [PCRWR], 2023a).

Urban development adds to this pressure. Roads, buildings and other impermeable surfaces reduce the land available for natural infiltration and instead channel rainfall into the city's drainage network. Islamabad therefore faces an important imbalance: **a city increasingly dependent on groundwater is also losing opportunities to replenish it naturally.**

2.2 The Recharge Opportunity

This challenge also creates an opportunity. PCRWR estimates that Islamabad generates approximately **275 MCM of surface-runoff potential annually**. Its assessment suggests that harvesting around **17% of this potential—approximately 47 MCM—through managed aquifer recharge could theoretically balance current abstraction from CDA tube wells** (PCRWR, 2023a).

Managed recharge provides a way to capture some of this excess rainfall, filter it and return it underground. In doing so, the aquifer can function as **natural underground storage**—retaining water for later use without requiring large surface reservoirs and with lower exposure to evaporation. This model provides a practical and economical way to make better use of water that would otherwise leave the city as runoff.

2.3 Islamabad's Recharge Efforts and the Monitoring Gap

Islamabad has already begun acting on this opportunity. CDA has developed approximately **100 groundwater recharge wells** across different parts of the city, demonstrating a significant institutional commitment to rainwater harvesting and aquifer replenishment. CDA has also introduced requirements for rooftop rainwater harvesting, indicating a broader move towards incorporating recharge into urban water management (PCRWR, 2023a; Capital Development Authority [CDA], 2026).

The next challenge is understanding **how well these interventions perform over time**. Without consistent monitoring, it is difficult for water managers to quantify how much water individual systems recharge, how groundwater responds, when performance begins to deteriorate, or which designs and locations provide the greatest return on investment. For residents and potential adopters, the benefits of recharge may be intuitive, but measurable evidence of performance can build confidence in whether an investment is actually delivering the expected results.

Effective adoption of this solution—by residents, private-sector users and government institutions alike—requires its performance to be visible, measurable and understandable. Addressing this gap became a central focus of this project.

CHAPTER 3

PROJECT OVERVIEW: PROTECTING ISLAMABAD'S GROUNDWATER AQUIFER

The need for stronger monitoring and evidence around groundwater recharge was identified by **ScaleX Technologies** in consultation with CDA and other technical stakeholders. With support from the U.S. Mission to Pakistan in partnership with the Pakistan-U.S. Alumni Network (PUAN), ScaleX launched **Protecting Islamabad's Groundwater Aquifer** to help strengthen groundwater management and support wider adoption of recharge solutions in Islamabad.

Project Goal: Increase the adoption of sustainable groundwater management practices in Islamabad and build the case for other cities.

To work towards this goal, the project focused on two core objectives:

1. Understand the Groundwater Landscape

Assess existing recharge infrastructure and technical conditions, while gathering perspectives from residents, government institutions, groundwater users and technical experts. This provided a clearer understanding of the technical, institutional and social factors influencing the performance, management and adoption of groundwater recharge.

2. Making Groundwater Recharge Measurable

Install smart monitoring systems at two existing CDA recharge wells—located at the **Nokia Networks office in H-8** and **Iqra University in H-9, Islamabad**—to track recharge activity, groundwater levels, rainfall and selected water-quality parameters, supported by a digital dashboard. The aim is to create measurable evidence on system performance and aquifer response over time, helping inform future management, investment and adoption.

The project therefore combined on-ground understanding with real-time monitoring to strengthen the evidence base for groundwater recharge in Islamabad.



Figure 3.1: In-situ conditions at the groundwater recharge sites, showing Nokia (left) and Iqra University (right).

CHAPTER 4

UNDERSTANDING THE GROUNDWATER LANDSCAPE

The first objective of the project was to better understand the existing groundwater landscape and the factors influencing the performance, management and adoption of recharge solutions. This was explored through a combination of technical assessments and engagement with relevant stakeholders involved in groundwater use and management.

4.1 Technical Insights

The technical assessment focused on establishing the existing conditions at the project sites before the monitoring systems were installed. This provided a baseline for understanding the aquifer and existing infrastructure against which future monitoring can be interpreted.

4.1.1 Baseline Groundwater Quality Assessment

To establish a baseline understanding of aquifer conditions before project implementation, a quality analysis was conducted for the groundwater in the area. The sample was taken from a house downstream of the chosen recharge wells. The assessment included physical, chemical, and microbiological parameters to evaluate the existing condition of groundwater and provide a reference for future monitoring. The complete laboratory results are presented in **Table 4.1**

Table 4.1. Baseline Groundwater Quality Assessment Before Project Implementation				
Parameter	Unit	Drinking Water Standard*	Observed Value	Interpretation
Color	–	Colorless	Colorless	Acceptable aesthetic quality
Electrical Conductivity (EC)	µS/cm	No guideline value	780	Indicates moderate dissolved mineral content; suitable as baseline for groundwater characterization
pH	–	6.5–8.5	7.27	Within the recommended drinking water range
Turbidity	NTU	< 5	1.61	Low turbidity; indicates relatively clear water
Alkalinity (as CaCO ₃)	mg/L	No guideline value	252	Indicates moderate buffering capacity of groundwater
Bicarbonates	mg/L	No guideline value	252	Reflects the natural carbonate chemistry of the aquifer
Calcium	mg/L	No guideline value	81	Typical groundwater mineral content
Carbonates	mg/L	No guideline value	BDL	Below detection limit

Chlorides	mg/L	< 250	60	Well within the recommended limit
Total Hardness	mg/L	< 500	322	Hard water; within the drinking-water limit
Magnesium	mg/L	No guideline value	29	Typical groundwater concentration
Potassium	mg/L	No guideline value	1.9	Low concentration; no concern identified
Sodium	mg/L	No guideline value	33	Typical groundwater concentration
Sulphate	mg/L	No guideline value	33	Low concentration; within acceptable range
Nitrate (as N)	mg/L	< 10	8.26	Within the drinking water standard, though approaching the upper limit
Total Dissolved Solids (TDS)	mg/L	< 1000	468	Within the drinking water standard; moderate dissolved solids
Dissolved Oxygen (DO)	mg/L	No guideline value	7.16	Indicates good oxygenation of the sampled water
Total Coliforms	CFU/100 mL	0	20	Presence of total coliform bacteria indicates possible microbial contamination and warrants further investigation
Fecal Coliforms	CFU/100 mL	0	Negative	No fecal coliforms detected
E. coli	CFU/100 mL	0	Negative	No evidence of fecal contamination by E. coli

Source: Pakistan Council of Research in Water Resources (PCRWR), National Water Quality Laboratory. Water sample analyzed under Report Serial No. AR-08566 (Sample Code: MCL-22909-25) for the project Bore Water (Sample for Recharge Well). Drinking water standards referenced from the Pakistan National Standards for Drinking Water Quality (NSDWQ, 2010).

The key findings from the above report are as follows:

- Most tested chemical parameters complied with the applicable Pakistan National Standards for Drinking Water Quality (NSDWQ, 2010).
- The groundwater exhibited moderate mineralization and low turbidity, indicating generally good physical and chemical quality.
- No fecal coliforms or E. coli were detected; however, the presence of total coliform bacteria indicates the need for continued monitoring and protection of recharge systems from potential contamination.
- The results provide a valuable baseline against which future changes in groundwater quality can be evaluated following implementation of the recharge system.

4.1.2 Assessment of Existing Recharge Infrastructure

As part of the technical assessment, the project team conducted a field survey of **approximately 100 existing CDA recharge wells across Islamabad** to understand their physical condition, surrounding catchments, maintenance needs and suitability for monitoring. CDA has established an important citywide network of recharge infrastructure, but managing a distributed network of this scale alongside its wider water-supply and management responsibilities requires **sustained operational capacity and continued technical support**.

The assessment highlighted the need for strengthening routine cleaning and maintenance, clear operational responsibility, dedicated budgets and trained personnel to sustain performance over time. It also identified practical risks associated with open or publicly accessible sites, including damage or theft of equipment. These findings do not diminish the value of the existing infrastructure; rather, they show that the next stage is to strengthen the **management systems around it** so that CDA can protect its investment and operate the network more effectively.

Sites located within managed premises generally performed better than those in open public locations. Where office or institutional staff were present to oversee the area, routine upkeep, site security and day-to-day attention were more consistent. This suggests that **partnership-based and privately managed models can play an important role in supporting public recharge infrastructure, particularly by strengthening maintenance, accountability and protection of assets.**



Figure 4.1: Selected recharge well sites documented during the survey of CDA's existing recharge well network in Islamabad.

Based on this survey, two suitable and operationally secure sites were selected for the project’s monitoring intervention, allowing the systems to be installed where they could be safely maintained while generating useful evidence on recharge performance and groundwater conditions.

4.1.3 Key Insights

The technical assessment shows that Islamabad already has a strong foundation for groundwater recharge, but sustained performance depends on more than just construction of the recharge systems. Continuous engagement is required for protecting groundwater quality, maintaining recharge pathways, and securing infrastructure. **Without regular maintenance, sediment and debris can clog recharge pathways, while monitoring is needed to identify and mitigate declining performance and potential water-quality risks.** Therefore, operational maintenance and oversight are both critical to ensuring that existing systems continue to deliver value over time instead of becoming contaminant pathways that end up causing harm instead.

4.2 Community Perspectives and Adoption Insights

Understanding groundwater management also requires understanding how people experience water stress, what they know about recharge, and what influences their willingness to adopt new solutions. This section brings together community-level evidence on water use, awareness, attitudes and adoption readiness.

4.2.1 Community Survey Insights

A survey of 128 Islamabad residents was conducted to better understand household water conditions, groundwater awareness, perceptions of recharge, and factors influencing adoption. The findings provide a quantitative picture of how residents currently experience and respond to groundwater-related challenges.

Respondent and household profile

The survey included 128 respondents. Men represented 62.5% of the sample and women 37.5%.

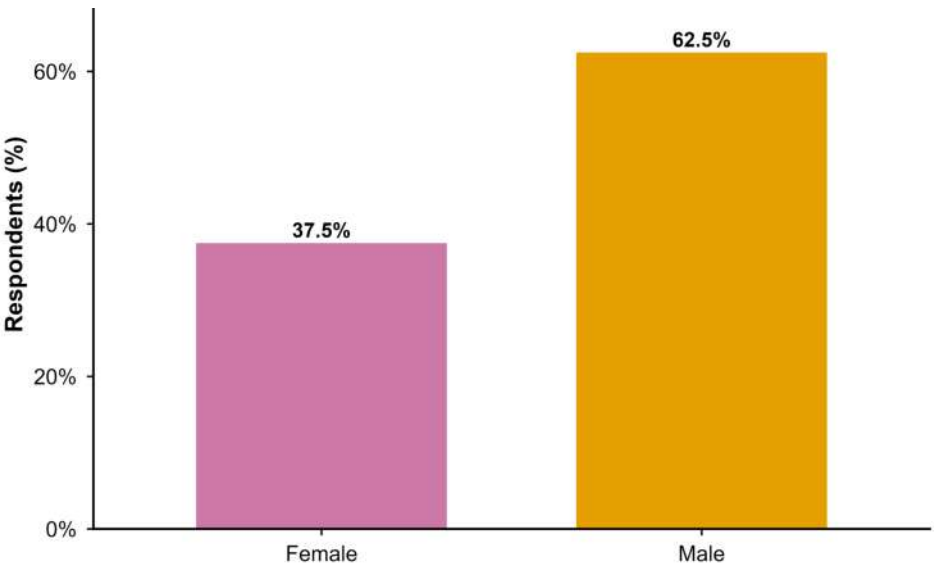


Figure 4.2: Gender composition of survey respondents.

The largest age group was 36–45 years (33.6%), followed by 26–35 years (28.9%) and 18–25 years (21.9%); respondents aged 46–60 and 60+ accounted for 10.9% and 4.7%, respectively. Job holders formed the largest occupational group (43.8%), followed by students (26.6%), businesspersons/entrepreneurs (15.6%), homemakers (8.6%), and retired respondents (5.5%). More than half of respondents lived in independent houses (56.2%), while 26.6% lived in apartments/flats and 17.2% in shared or rented portions. Income information was limited because 53.9% of respondents preferred not to report their household income. Geographically, the sample was distributed across multiple Islamabad sectors, with I-8 (10.2%), G-8 (8.6%), and I-10 (7.0%) being the most represented locations.

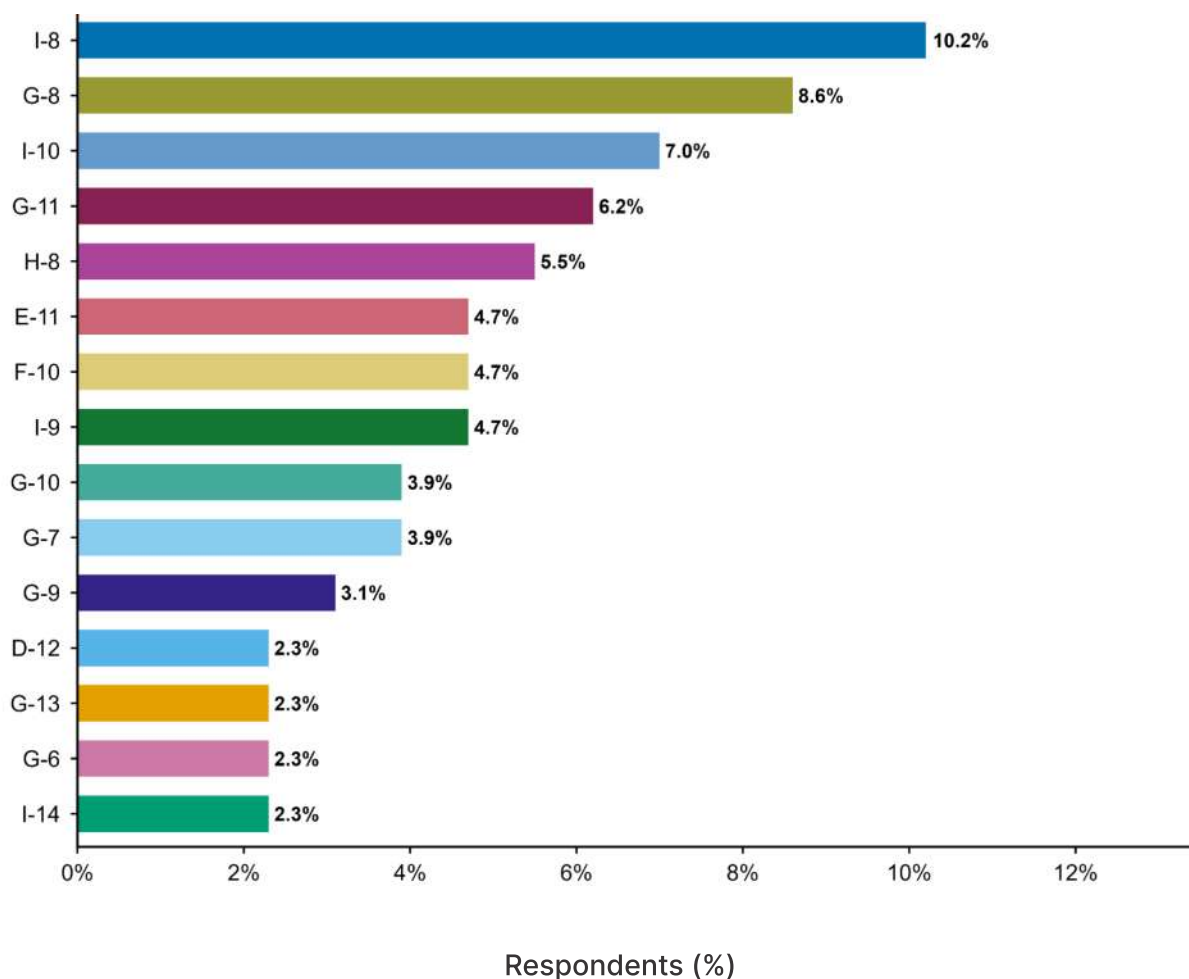


Figure 4.4: Top 15 sectoral locations represented among survey respondents.

Household water sources and supply reliability

Households relied on a mixed water-supply system. CDA piped supply was reported by 69.5% of respondents, while 56.2% used a borewell/tubewell and 7.8% used water tankers.

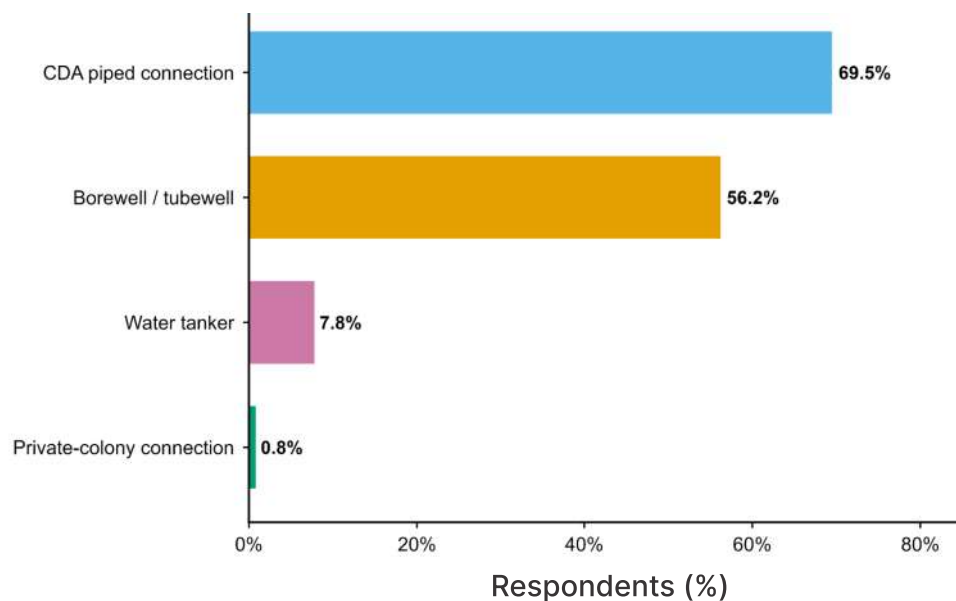


Figure 4.5: Household water sources reported by survey respondents (multiple selections allowed).

The source-combination results show that 37.5% relied on CDA alone, 29.7% combined CDA supply with a borewell, and 24.2% relied on a borewell alone.

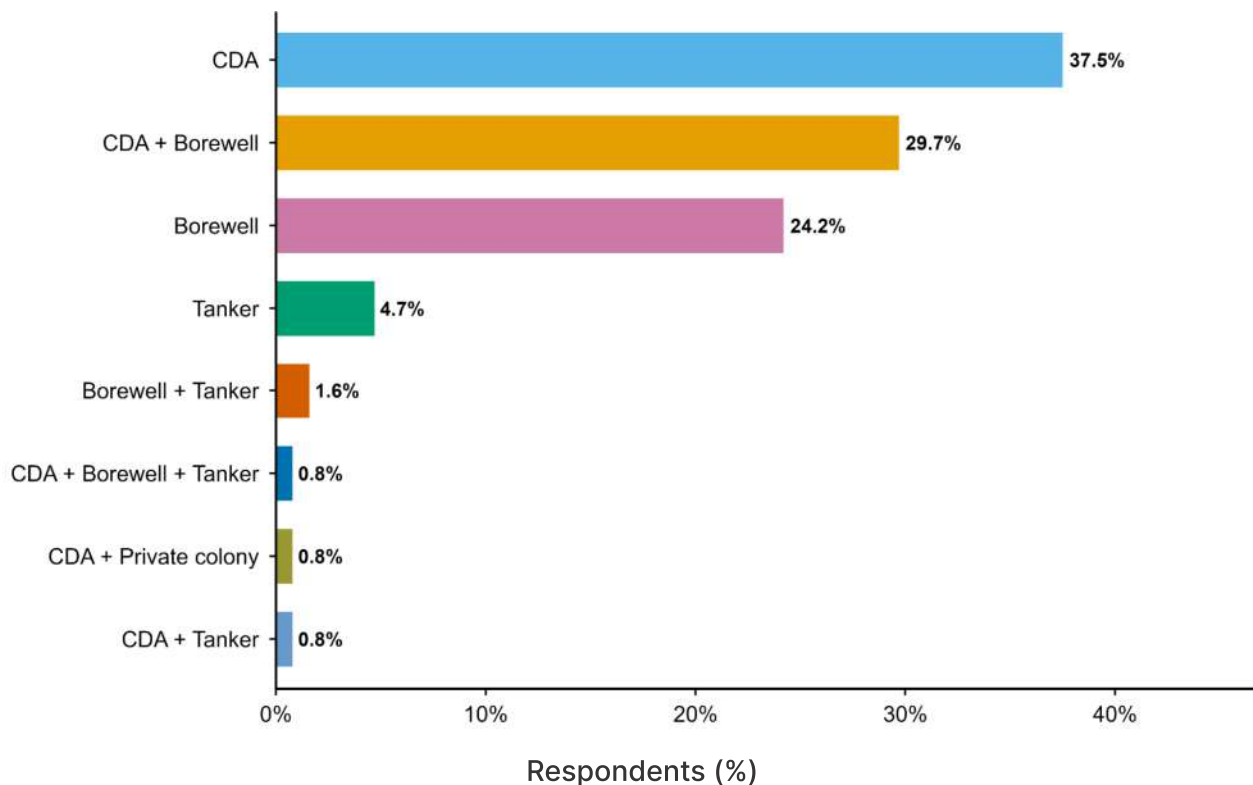


Figure 4.6: Most common combinations of household water sources.

Water shortages were nevertheless common: 47.7% reported monthly shortages and 16.4% weekly shortages, while 28.9% reported never experiencing shortages.

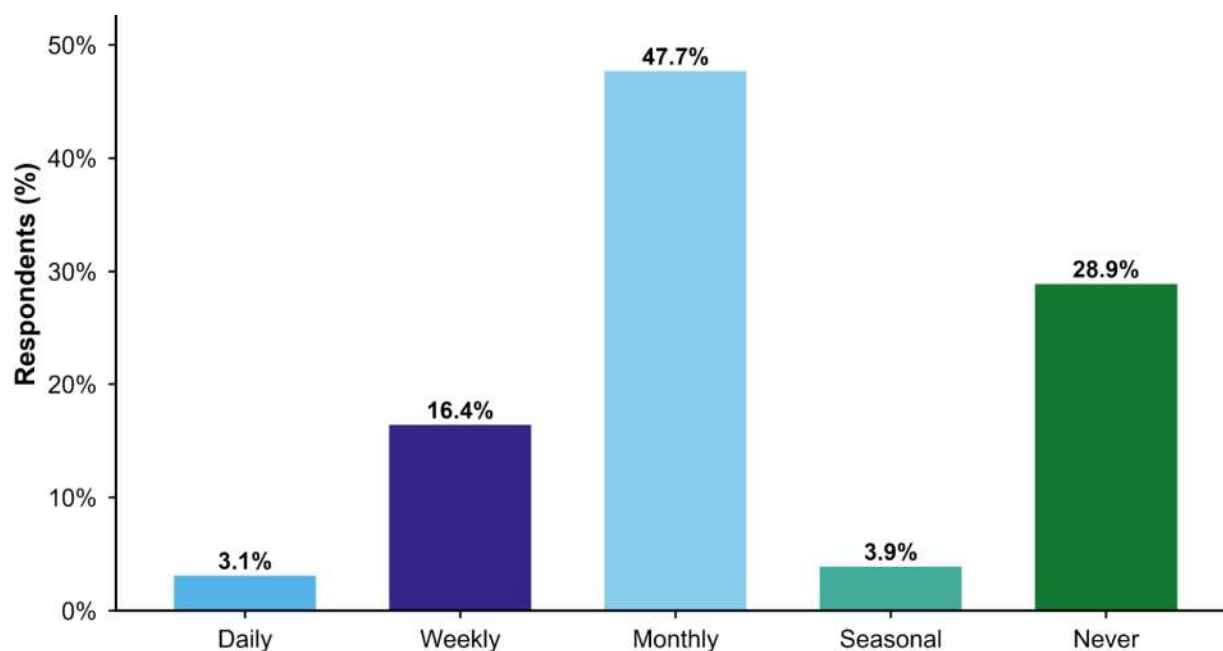


Figure 4.7: Frequency of household water shortages reported by survey respondents.

Among CDA-connected households with known supply duration (n = 81), 43.2% received less than two hours of supply per day, and 45.7% received 2–4 hours; only 11.1% reported more than four hours.

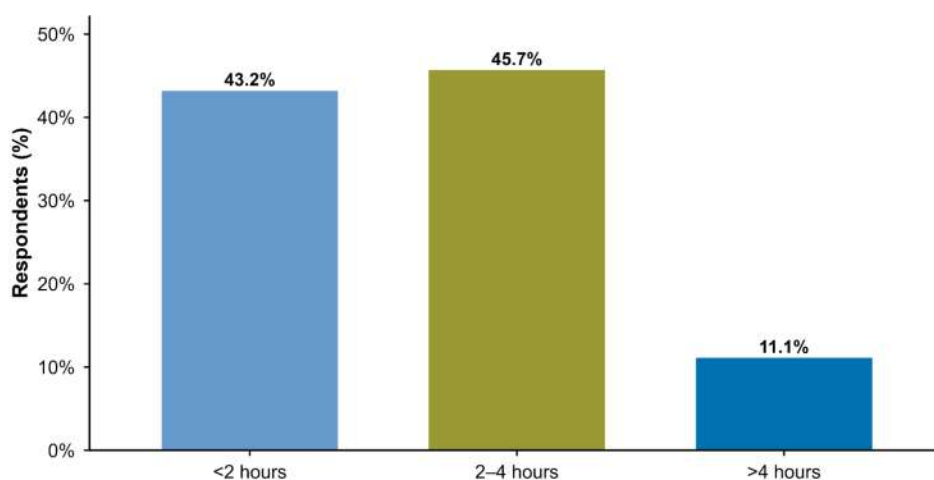


Figure 4.8: Daily duration of CDA water supply as reported by survey respondents (n = 81 respondents with access to CDA water supply).

Coping strategies and household water costs

Households used several strategies to manage water shortages. Purchasing or using a tanker was the most frequently reported response (34.4%), followed by reducing consumption (28.9%), storing water (23.4%), and using a borewell/tubewell (23.4%); borrowing or sharing water was less common (6.2%).

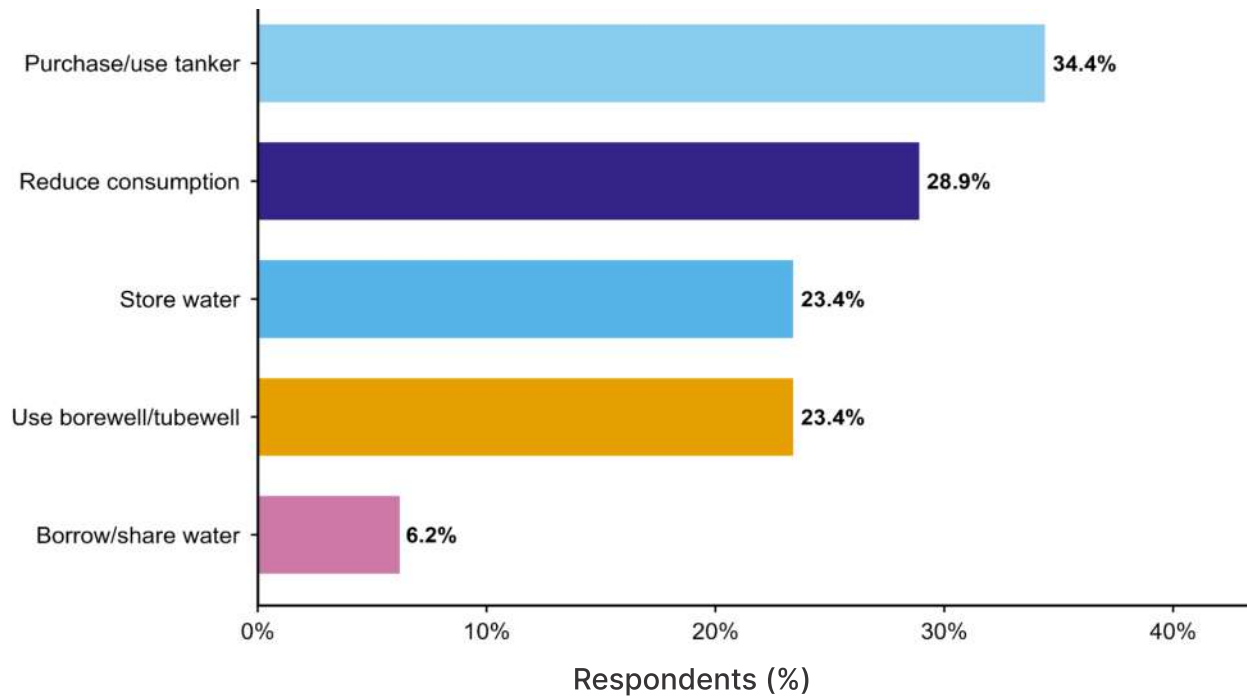


Figure 4.9: Household responses to water shortages (multiple selections allowed).

Monthly water expenditure was concentrated in the middle cost categories: 39.1% reported PKR 1,001–3,000 per month and 25.0% reported PKR 3,001–5,000, while 10.9% spent more than PKR 5,000.

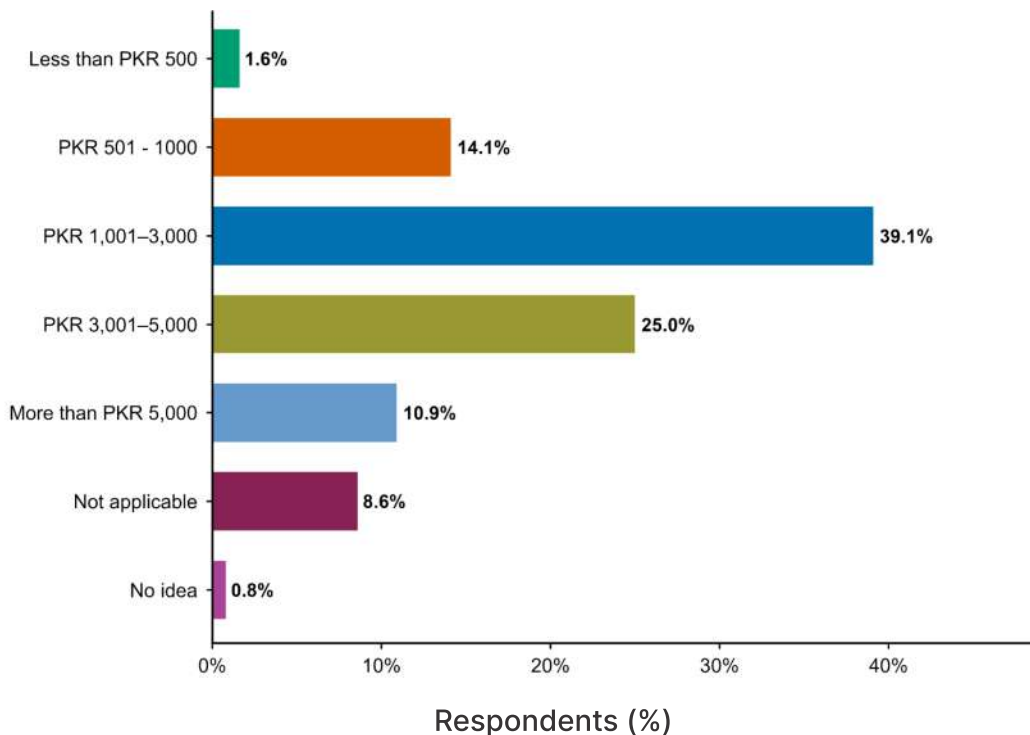


Figure 4.10: Approximate monthly household water costs reported by survey respondents.

The CDA water bill was the most common cost component (61.7%), followed by borewell electricity (41.4%), colony/apartment water bills (15.6%) and private tanker costs (11.7%).

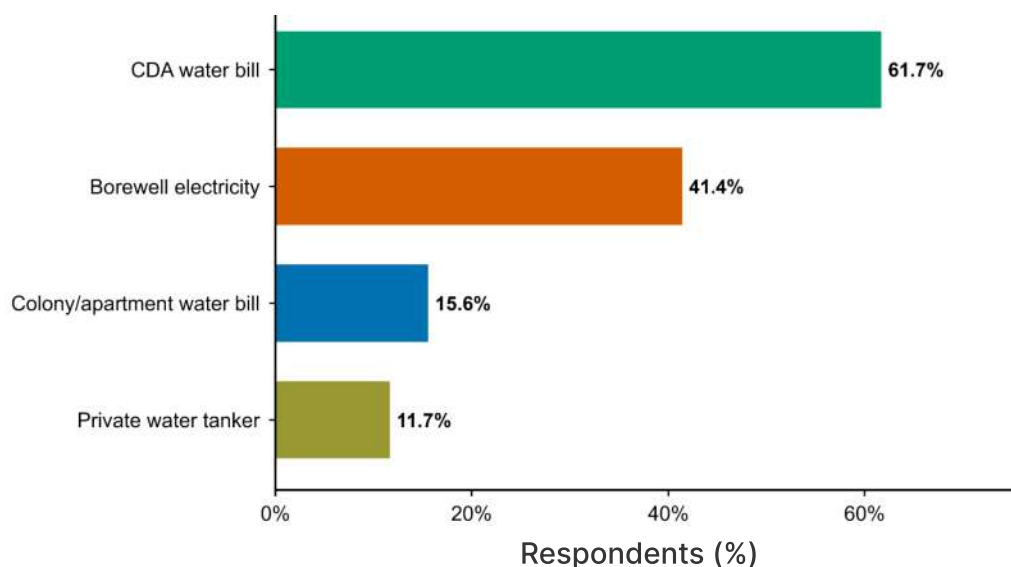


Figure 4.11: Components of monthly household water costs (multiple selections allowed).

Groundwater decline, rainfall ponding and perceived water insecurity

Perceived groundwater decline was pronounced: 75.0% of respondents stated that groundwater levels had definitely declined and a further 12.5% reported some decline.

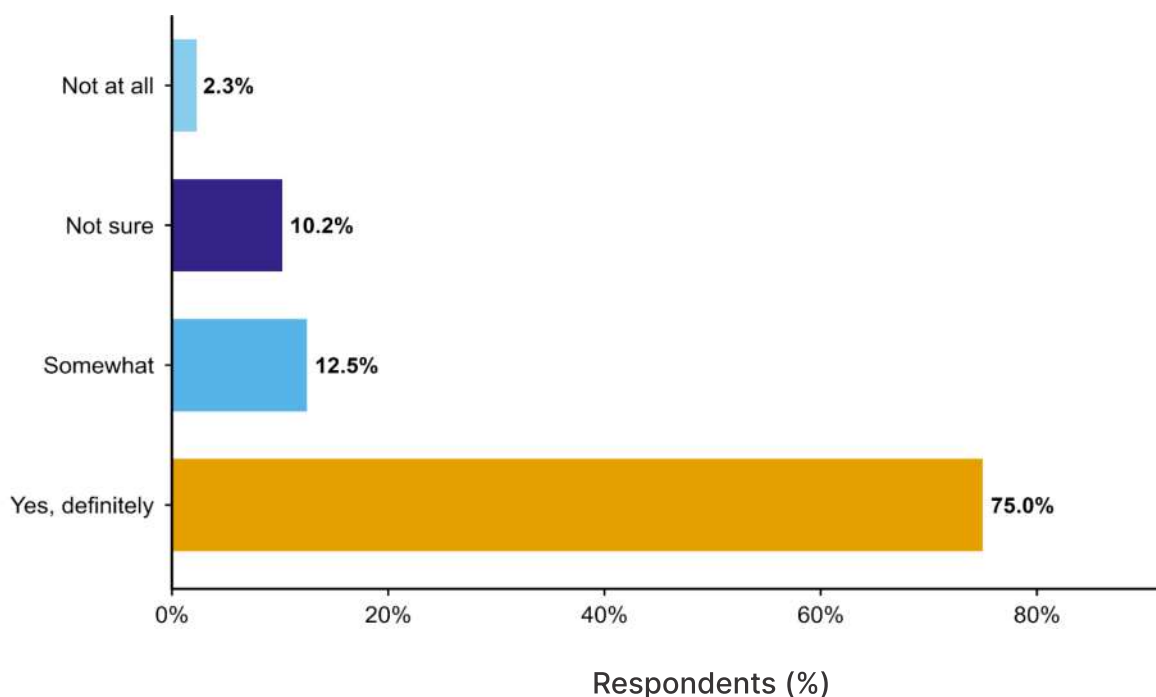


Figure 4.12: Residents' observations of groundwater decline.

Rainfall ponding was less uniformly experienced; 45.3% reported no ponding, while 19.5% reported ponding sometimes and 5.5% very frequently.

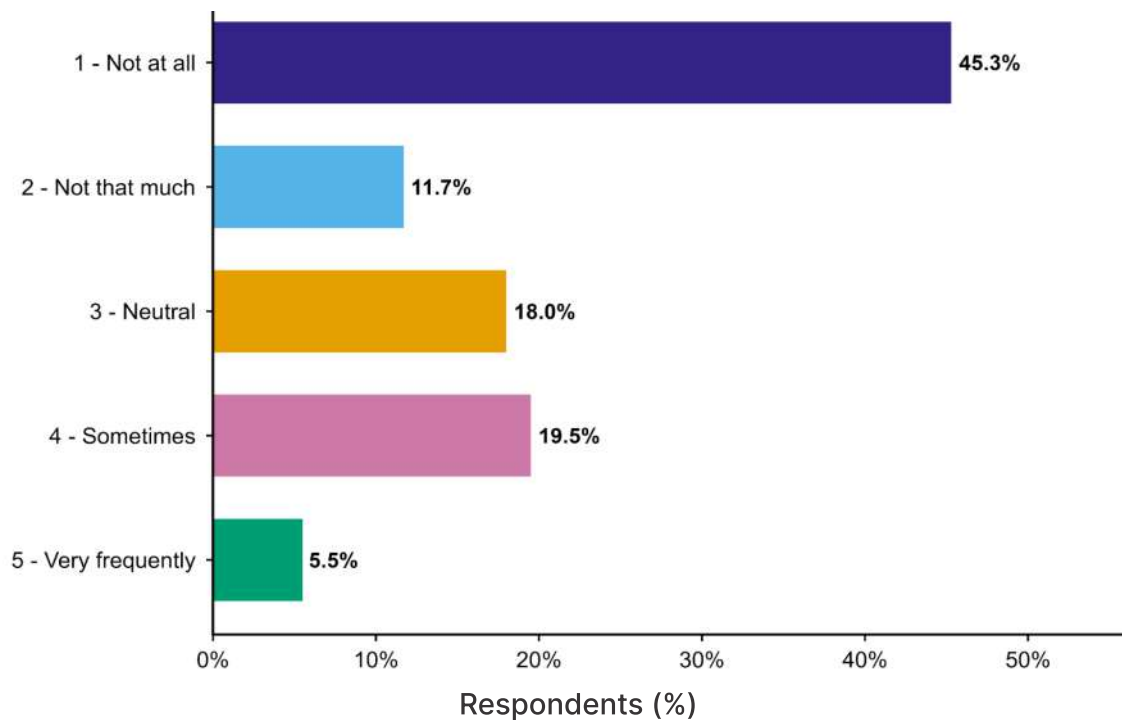


Figure 4.13: Residents' observations of flooding and water ponding during major rainfall events.

The composite Water Insecurity Index classified 60.2% of respondents as low, 34.4% as moderate and 5.5% as high.

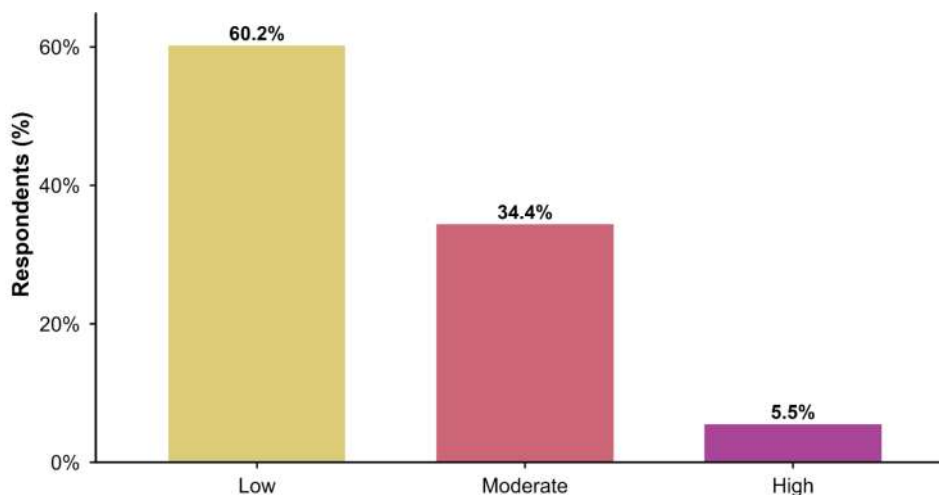


Figure 4.14: Distribution of survey respondents on the water insecurity index (low: 0–1; moderate: 2–3; high: 4–6).

Positive willingness to pay was 36.4% in the low-insecurity group, 34.1% in the moderate group and 42.9% in the high group. Because the high-insecurity category is small, this difference should be treated as descriptive rather than evidence of a strong causal relationship.

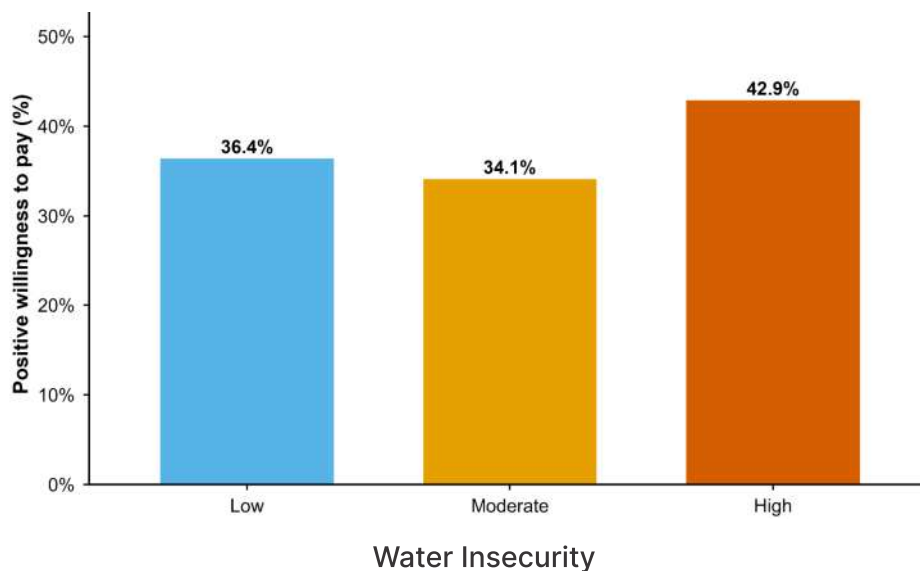


Figure 4.15: Respondents' willingness to pay across levels of water insecurity

Recharge awareness, understanding and exposure

Knowledge and direct exposure to groundwater recharge systems were generally limited. Overall, 41.4% reported having heard of or knowing about recharge wells, 33.6% showed high understanding of the concept, and 27.3% identified a valid recharge benefit.

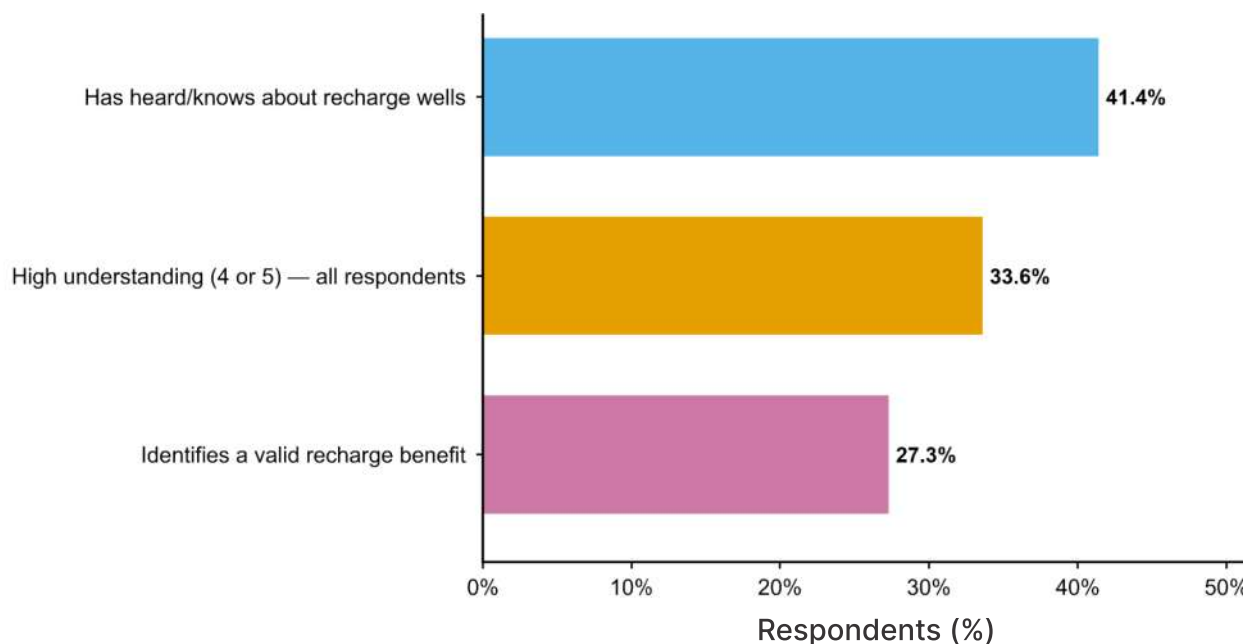


Figure 4.16: Respondents' awareness and understanding of groundwater recharge.

Direct visibility was lower: 22.7% had seen a recharge well, 13.3% had a recharge well at home or in their community, and only 12.5% were aware of CDA's 100-well programme.

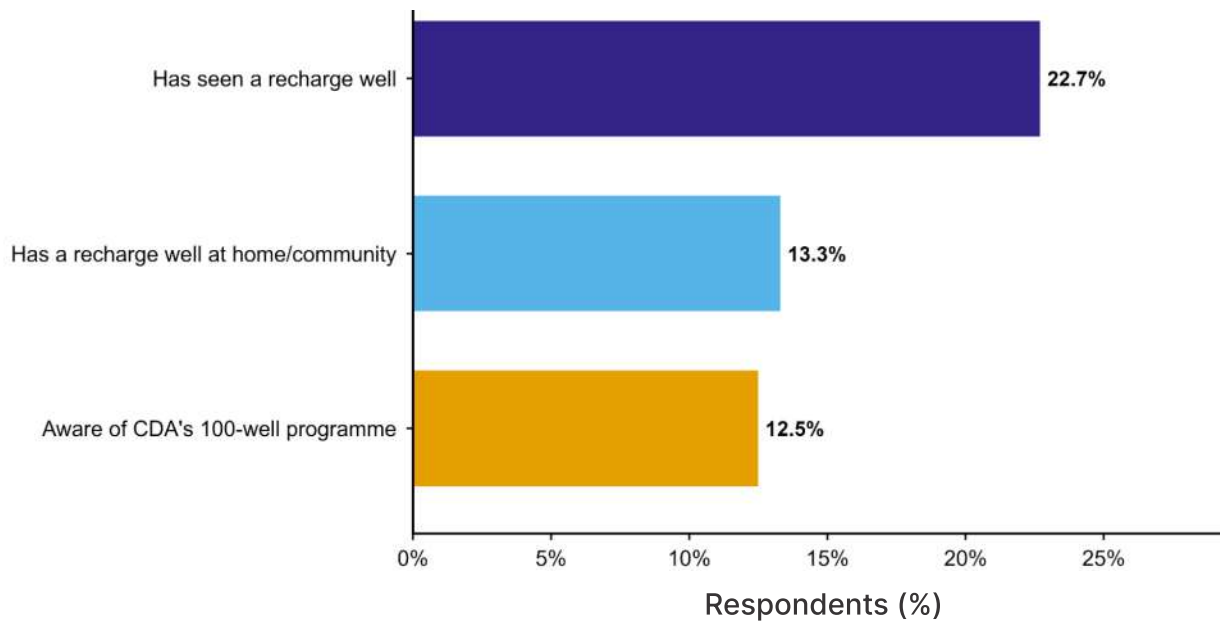


Figure 4.17: Respondents' awareness and visibility of recharge infrastructure and CDA's recharge programme.

The Recharge Awareness and Exposure Index therefore classified 65.6% of respondents as low, 23.4% as moderate and only 10.9% as high.

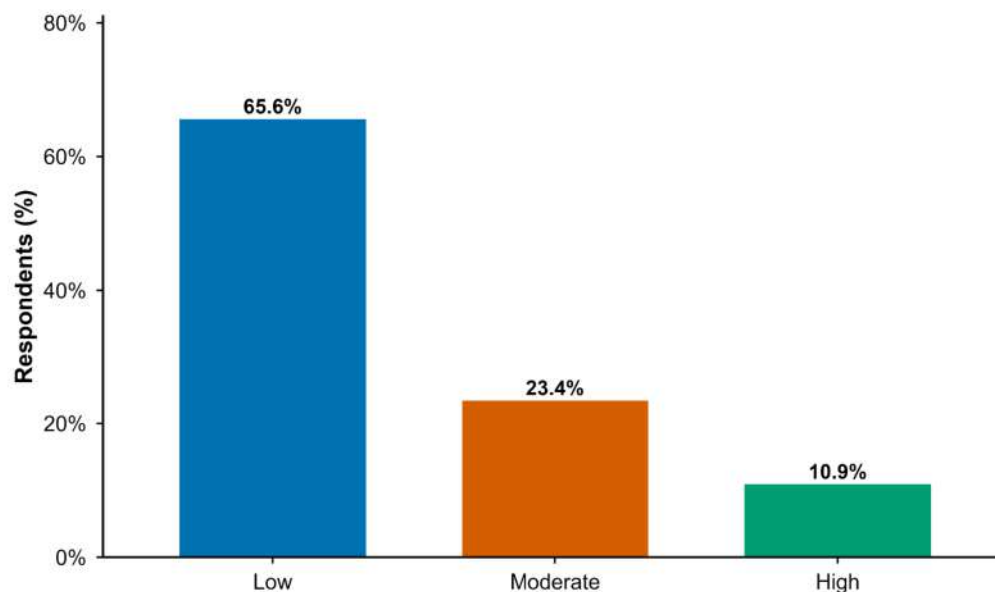


Figure 4.18: Distribution of respondents on the recharge awareness and exposure index (low: 0–2; moderate: 3–4; high: 5–6).

Awareness also varied by age: it was highest among respondents aged 18–25 (71.4%), declined through the middle-age groups to 21.4% among those aged 46–60, and increased again to 50.0% among respondents aged 60+, indicating a non-linear age pattern.

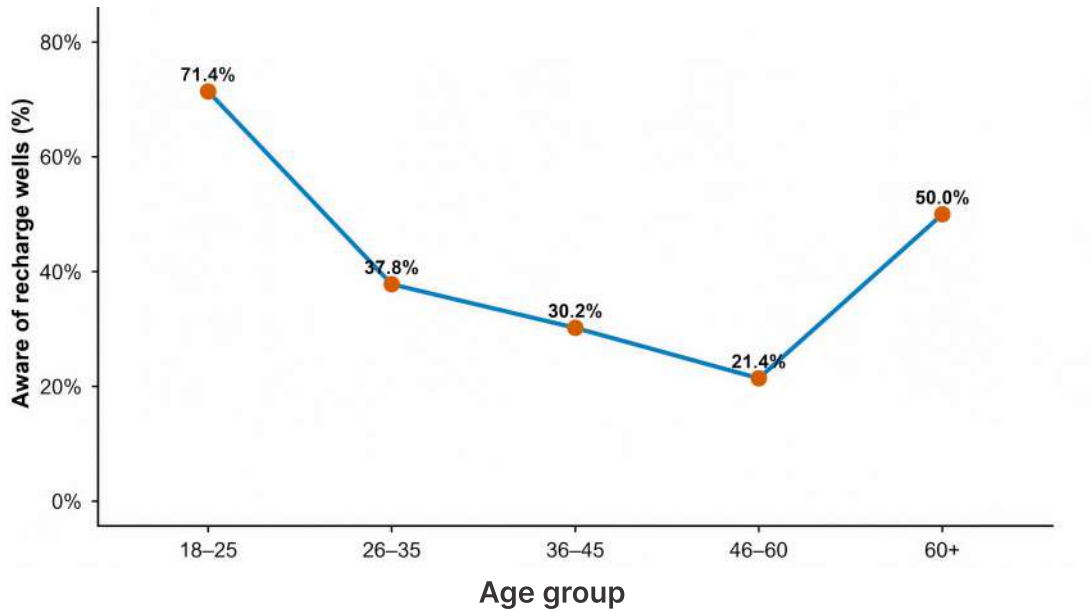


Figure 4.19: Recharge awareness across age groups.

Confidence, adoption willingness and willingness to pay

Interest in recharge solutions was stronger than financial commitment. High willingness to invest was reported by 53.1% of respondents and 38.3% expressed high confidence that recharge wells could improve water availability, but only 35.9% stated a positive willingness to pay.

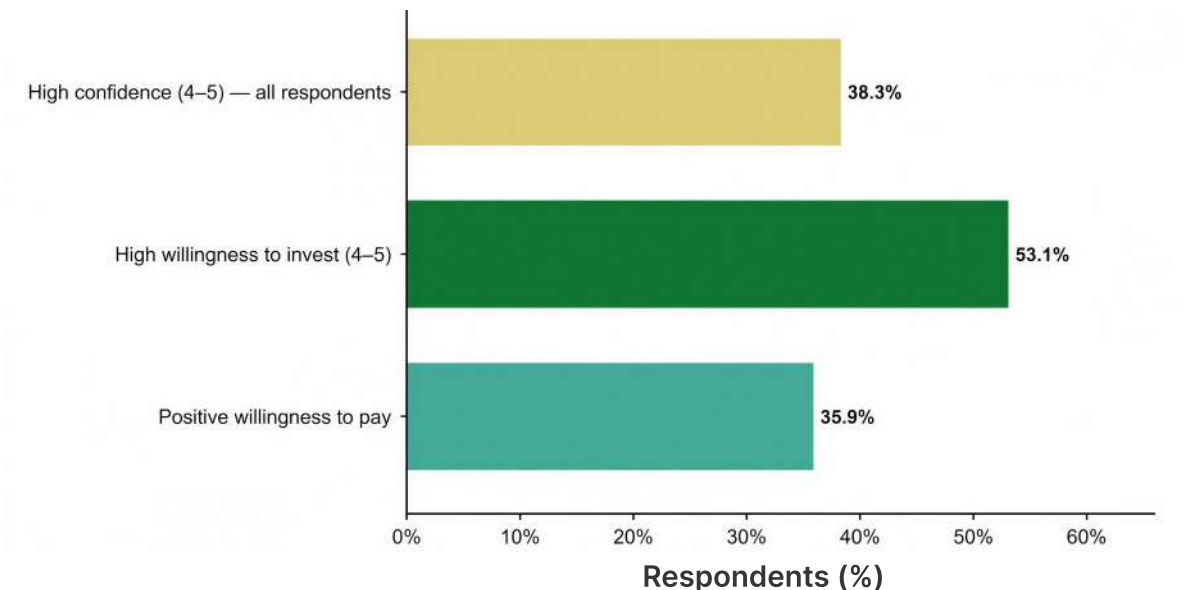


Figure 4.20: Respondents' confidence in groundwater recharge, willingness to adopt, and willingness to pay.

In the detailed payment distribution, 64.1% were not interested in spending any money; 25.8% were willing to pay up to PKR 50,000, 7.0% up to PKR 100,000 and 3.1% up to PKR 300,000. The Adoption Readiness Index similarly showed that 59.4% had low readiness, 22.7% moderate readiness and 18.0% high readiness.

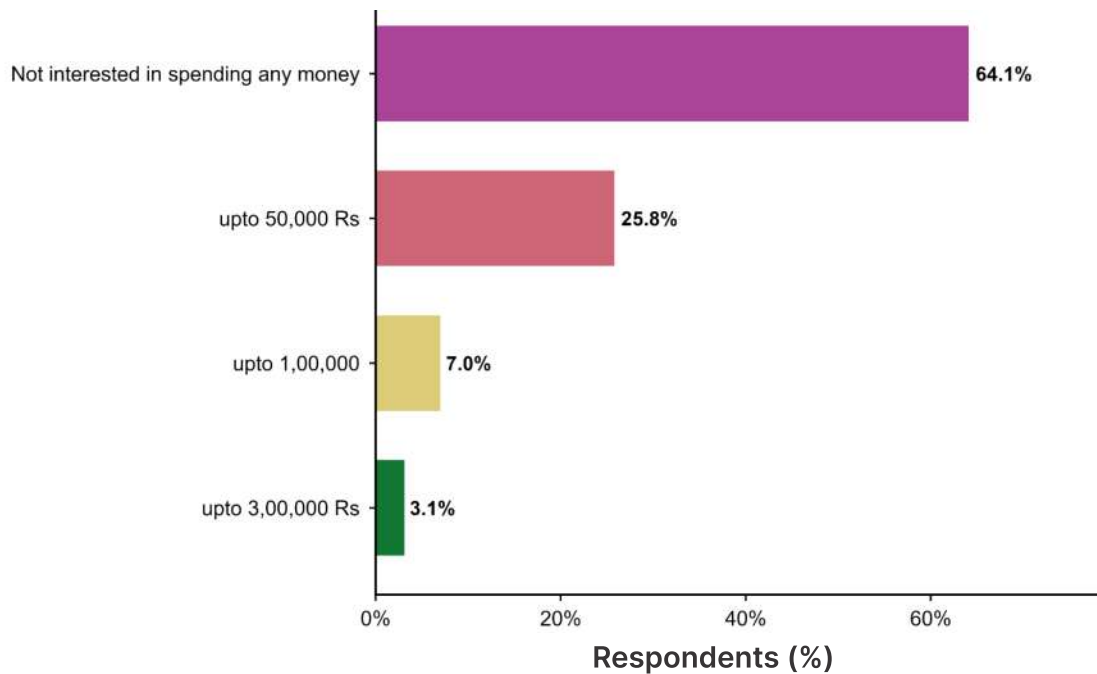


Figure 4.21: Distribution of respondents' stated willingness to pay for groundwater recharge solutions

Adoption motivators, payment gap and priority barriers

Awareness and guidance emerged as the dominant adoption support need, selected by 77.3% of respondents. Financial incentives or subsidies ranked second (41.4%), followed by successful community examples (28.1%), technical support/maintenance (27.3%), and official CDA endorsement (15.6%); only 0.8% selected 'not interested'.

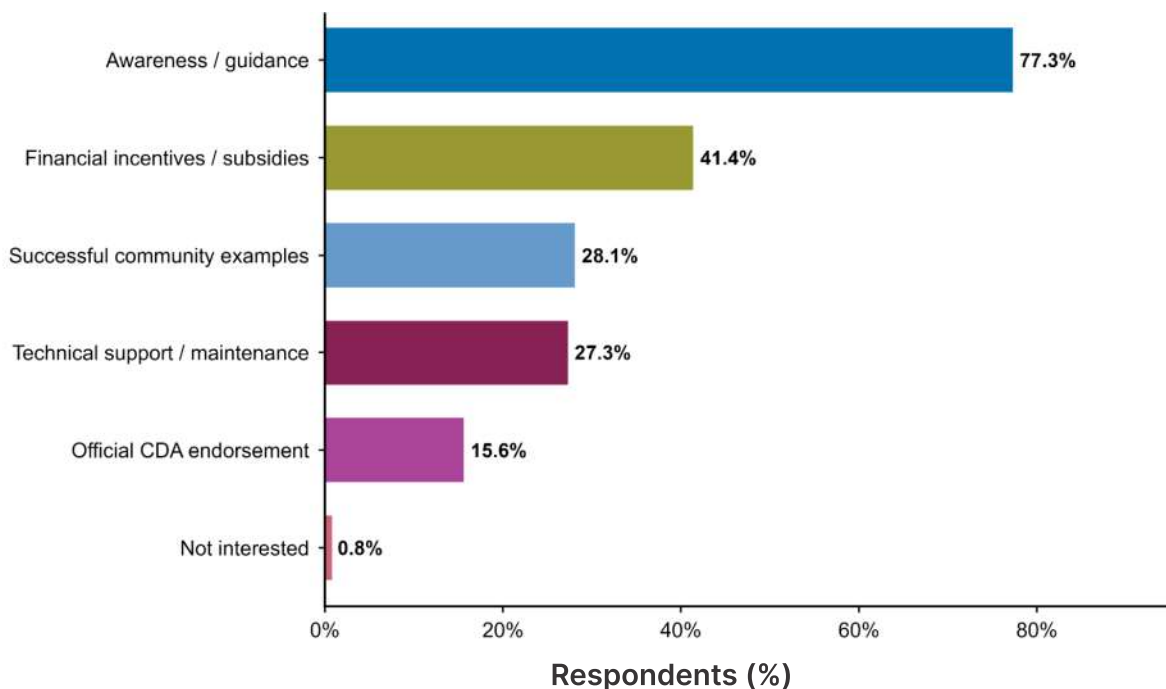


Figure 4.22: Factors motivating respondents to adopt groundwater recharge solutions (multiple selections allowed).

Recharge Solution Adoption vs. Stated Payment Intention

To understand whether positive attitudes toward groundwater recharge translate into financial commitment, respondents' willingness to invest in a groundwater recharge solution at their home or property was compared with their stated willingness to pay for a solution that fully addresses water shortage issues. Because the payment question referred to water solutions more broadly rather than recharge specifically, the comparison should be interpreted as an indication of the gap between recharge adoption willingness and broader payment intention, rather than as a direct measure of willingness to pay for recharge.

The results show that 29.7% of respondents expressed both positive willingness to invest in a recharge solution and a willingness to spend on a water-security solution, while a further 23.4% were positive toward recharge adoption but indicated no willingness to spend. This latter group represents an important potential adoption gap: respondents appear receptive to groundwater recharge in principle, but this interest has not translated into stated financial commitment.

A further 6.2% expressed low willingness to invest in recharge but were willing to spend on a solution to water shortages, while 40.6% expressed both low recharge willingness and no payment intention. The 6.2% should not be interpreted as contradictory: these respondents may be willing to pay for water-security solutions generally without necessarily preferring groundwater recharge.

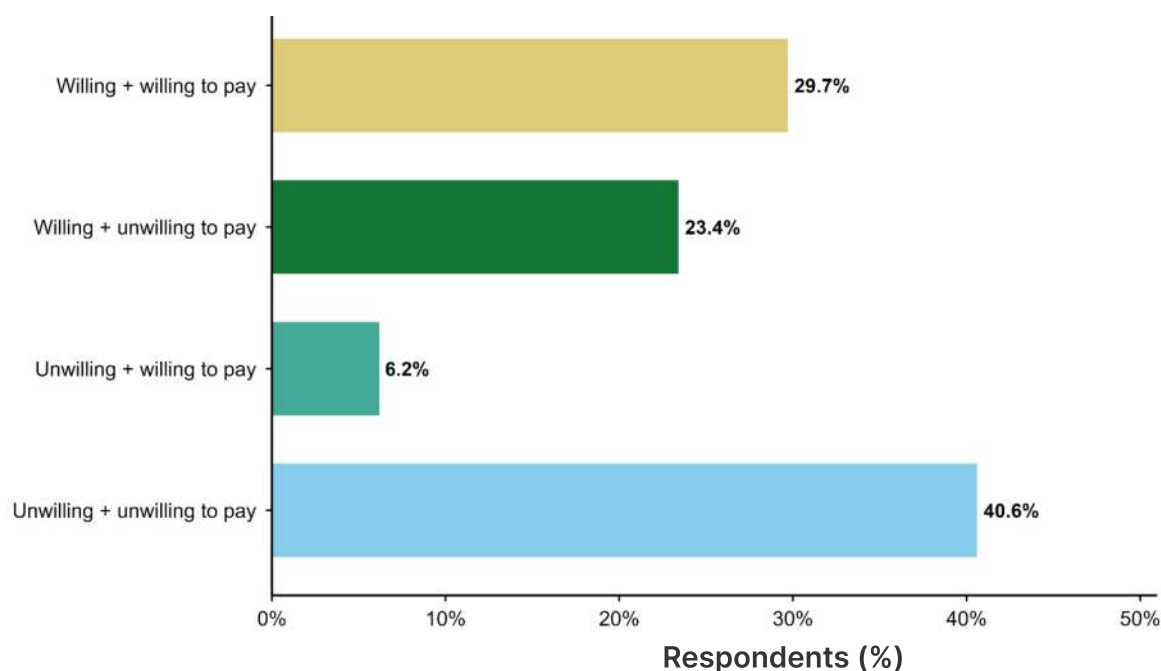


Figure 4.23: Recharge solution adoption vs. stated payment intention.

Among the 30 respondents willing to adopt but unwilling to pay, the most commonly identified motivator for adoption was increased awareness and guidance (80.0%), followed by financial incentives or subsidies (43.3%), technical support and maintenance (36.7%), successful community examples (20.0%), and official CDA endorsement (10.0%). This suggests that converting interest into uptake may require more than affordability alone. Clear guidance, practical implementation support, and greater familiarity with recharge solutions may be particularly important.

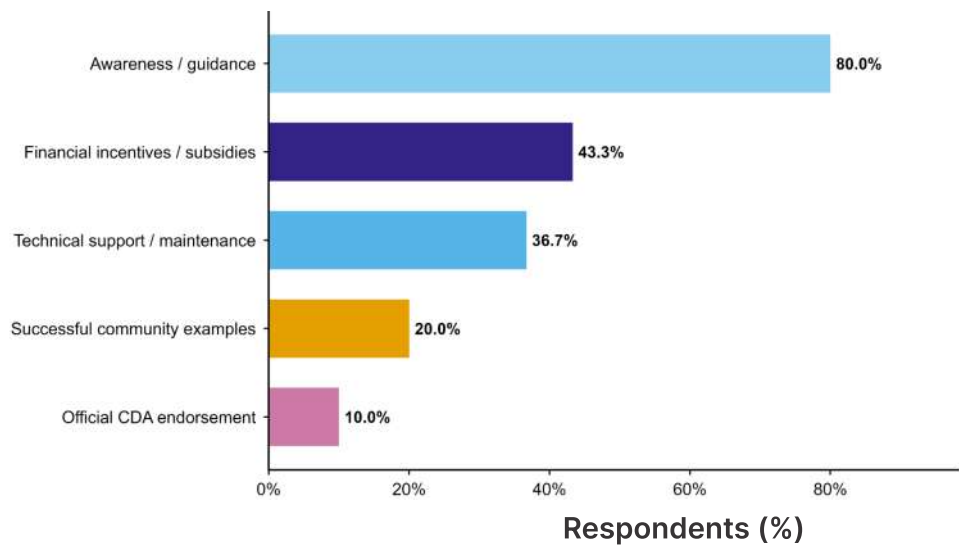


Figure 4.24: Barriers to adoption among respondents willing to adopt recharge solutions but unwilling to pay (n = 30).

Integrated relationship between awareness and adoption readiness

The clearest integrated pattern is the association between recharge awareness/exposure and adoption readiness. Mean adoption-readiness scores increased from 0.79 among respondents with low awareness/exposure to 2.07 among those with moderate awareness/exposure and 2.50 among those with high awareness/exposure, on a 0–3 scale. This progression is consistent with the broader survey findings: awareness/guidance was the most frequently selected adoption motivator, while the majority of respondents were classified as having low awareness/exposure and low adoption readiness.

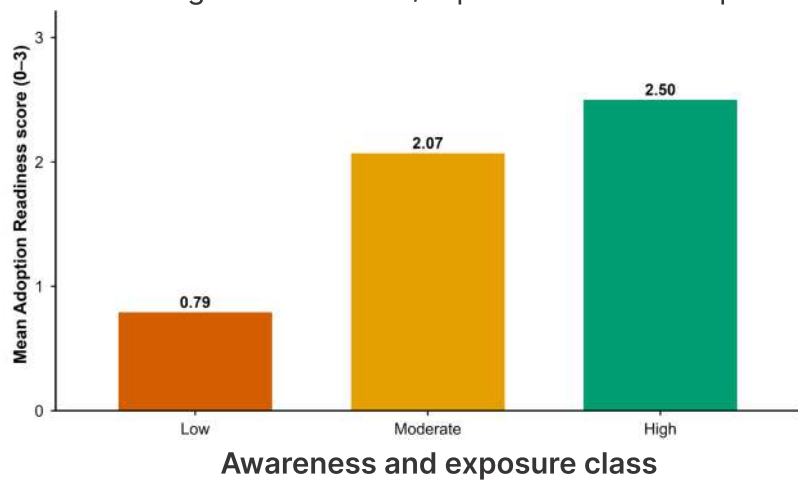


Figure 4.25: Relationship between adoption readiness and recharge awareness and exposure.

The results therefore support prioritizing awareness, practical demonstrations and technical guidance alongside financial incentives. The figures establish descriptive associations; statistical tests would be required before making claims of significance or causation.

4.2.2 Key Insights

The survey provided valuable visibility into how Islamabad residents experience water stress, how they perceive groundwater recharge, and what may influence future adoption. Several clear themes emerged:

- High awareness of groundwater decline, but limited exposure to recharge: The survey portrays a population that is highly conscious of groundwater decline but has limited direct exposure to recharge infrastructure and only moderate confidence in recharge solutions.
- Households face recurring water stress and associated costs: Households commonly depend on both CDA supply and groundwater, experience recurring shortages, and use coping measures that carry direct household costs.
- Willingness to invest is higher than willingness to pay: Although more than half of respondents show high willingness to invest in principle, actual stated willingness to pay is considerably lower.
- Awareness and guidance are the strongest pathway to adoption: The most consistent pathway toward improved adoption is stronger awareness and guidance, supported by visible community examples and technical assistance.
- Financial support remains important: Targeted financial incentives can help reduce the gap between willingness to adopt and willingness to pay.
- Adoption requires more than physical infrastructure: Programme design should focus not only on the construction of recharge systems but also on communication, demonstration, technical support and mechanisms that reduce the financial barrier to household adoption.

4.3 Institutional Perspectives

Groundwater management is shaped by the decisions, experiences and constraints of many different actors. Government agencies, researchers, major groundwater users, communities, private-sector actors and development organizations all play a role in the management of this resource. This section brings together perspectives gathered during the project to provide practical context alongside the technical and survey findings.

4.3.1 National Perspectives

The project engaged with a range of stakeholders across Pakistan to understand groundwater challenges from different perspectives. These included government and public institutions, technical and research experts, major groundwater users, development organizations and community members.

Government and Institutional Perspectives

Discussions with government stakeholders showed that groundwater depletion and the need for recharge are increasingly recognized as urgent management challenges. In Peshawar, PDA Director General **Muhammad Naeem Khan** expressed support for groundwater recharge efforts and connected the team with **Tariq Mahsud, Deputy Director Roads Management**, for further engagement. Departmental discussions pointed to substantial groundwater decline in parts of the city and an identified need for technical expertise to support the design of recharge interventions. Similar recognition is evident in Islamabad, where CDA has already developed approximately 100 recharge wells and taken policy steps to encourage rainwater harvesting and recharge.

The experience in Islamabad also demonstrates why construction alone is not enough. Site visits and discussions with operational staff showed that recharge performance depends on factors such as catchment design, the volume of runoff reaching a well, filtration and continued upkeep. Managing a distributed network of infrastructure also creates significant maintenance demands, with deterioration and clogging reducing performance over time. Academic experts reviewing the systems reinforced this concern. Future programs therefore need to strengthen design optimization, monitoring, maintenance and clear long-term responsibility, while practical issues such as protecting equipment from theft or damage also need to be considered. The opportunity is to build on the foundation already created by CDA while strengthening the systems around it so that infrastructure continues delivering value over its lifetime.

Technical and Research Perspectives

Technical discussions reinforced that there is no single recharge-well design suitable for every location. Shahid Iqbal of IWMI highlighted substantial variation in lithology and aquifer conditions across Pakistan, meaning that approaches need to be selected according to local hydrogeology. Direct recharge can be particularly valuable in dense urban environments where paved surfaces restrict natural infiltration or where deeper groundwater systems cannot be adequately replenished through shallow infiltration alone.

Academic experts similarly emphasized the importance of understanding aquifer depth, confinement, site conditions and potential pollution pathways before selecting a recharge approach. Water quality was a recurring concern: the quality of recharge water, proximity to sewers and other pollution sources, and appropriate filtration all need to be considered from the design stage. These discussions reinforced the project's decision to incorporate filtration and water-quality monitoring rather than treating recharge simply as the movement of surface water underground.

These technical requirements sit within a wider management challenge. Dr. Dilshad Arshad, Head of Hydrology at PCRWR, highlighted the continued absence of effective consumption-based water pricing and the slow implementation of groundwater protections despite increasing policy recognition of the resource. His observations underline an important distinction: recharge can replenish groundwater, but it cannot indefinitely compensate for unmanaged extraction. Recharge, extraction management, monitoring and regulation ultimately need to progress together.

Groundwater quality also varies considerably across Pakistan, adding another layer to this technical challenge. In coastal Sindh, seawater intrusion and salinity pose a particular threat to freshwater aquifers, particularly around Karachi, where recent studies have documented groundwater salinization associated with seawater intrusion (Naseem & Bano, 2025). In major urban and industrial centers, the pressures are different. In Faisalabad, groundwater-quality assessments have identified significant spatial variation in drinking-water suitability, while research focused specifically on industrial and urban effluents has linked groundwater deterioration to pollution from these sources (Akram et al., 2026; Quddoos et al., 2024).

Microbial contamination represents a broader national concern. PCRWR's National Water Quality Monitoring Programme assessed drinking-water sources across 29 cities and found that a majority of monitored sources were unsafe for drinking, with microbiological contamination among the major water-quality concerns reported nationally (Pakistan Council of Research in Water Resources [PCRWR], 2021). These regional differences reinforce an important point: groundwater management cannot focus on quantity alone. Local water quality, pollution pathways and aquifer conditions must also determine how groundwater is protected, monitored and recharged.

Perspectives from Major Groundwater Users

Engagement with universities, residential developments and industries showed how directly groundwater stress is already affecting major urban users. Two average-sized universities in the Islamabad Capital Territory reported substantial dependence on groundwater and seasonal shortages, particularly in high-demand residential areas such as student hostels. Apartment developments similarly reported summer supply constraints, whether dependent on municipal supply or private bores. Yet in many of these same locations, rooftop and surface runoff is routinely discharged during the monsoon. This creates a clear mismatch: **sites can experience water scarcity during one part of the year while allowing potentially useful water to leave the property during another.**

Industrial discussions revealed a similar opportunity. Large facilities commonly depend heavily on groundwater, while sustainability teams are increasingly focused on water stewardship, efficiency and environmental standards. Groundwater recharge, however, remains comparatively unfamiliar and often has no dedicated budget. Interest increased when recharge was presented as part of broader groundwater management, suggesting that credible demonstration projects with measurable performance could help translate general sustainability interest into investment.

The consequences of depletion also extend beyond cities. A **farmer managing agricultural land in Sargodha and Khushab** described markedly different groundwater conditions across the two locations. Where groundwater was deeper, drilling, pumping and energy costs were substantially higher, while land benefiting from recharge associated with a nearby river had much shallower groundwater. For smaller farmers, continued decline can eventually make groundwater financially inaccessible. Although agriculture was outside the direct focus of this pilot, the experience illustrates a wider consequence of depletion: **as groundwater levels fall, physical scarcity increasingly becomes an affordability and access problem.**

Development and Financing Perspectives

Discussions with development organizations highlighted the need to connect technical and institutional requirements with workable financing. Climate-adaptation funders are increasingly interested in interventions that demonstrate measurable outcomes rather than infrastructure alone. One potential pathway is collaboration in which the government provides institutional support and policy direction, development finance helps absorb initial capital costs and demonstration risk, and specialized private actors contribute design, technology, implementation and maintenance capacity.

Over time, however, groundwater solutions will require models that make continued monitoring, maintenance and performance financially sustainable rather than dependent on repeated one-off projects. This means shifting attention from simply **how many systems are constructed to how much measurable and sustained impact those systems deliver.**

Community Perspectives

To complement discussions with institutional and technical stakeholders, local residents were invited to share their views on proposed groundwater-management measures and the water challenges they experience. Responses ranged from brief expressions of support or opposition to more detailed comments.

Rainwater harvesting received broad support, although not everyone favored a blanket requirement for every home. Most respondents reacted positively to CDA's proposed requirement for rooftop rainwater harvesting, describing it as a useful measure for conserving water, reducing pressure on groundwater and making better use of rainfall. Among those who raised concerns, the main issues were cost, feasibility for existing or smaller homes, and maintenance. Several respondents therefore favored more targeted approaches—for example, making systems mandatory for larger houses, introducing them at street or community level, or supporting adoption through incentives and standardized designs. A smaller group opposed the requirement altogether or remained unsure about its feasibility.

Charging private groundwater users produced a much more mixed response. A substantial group supported the idea, generally viewing charges as a way to discourage excessive extraction and improve groundwater management. At the same time, opposition was clearly visible, with respondents describing charges as unfair, an additional burden on households, or inappropriate where users already bear the cost of installing and operating their own bores. Others were neutral or uncertain. More detailed responses suggest that acceptance could depend heavily on implementation: participants called for transparent fee structures, metering and monitoring, fair enforcement, subsidies or exemptions where appropriate, and visible use of revenues for improved water management.

When residents described the water problems they wanted authorities to address, water availability and reliability featured prominently. Respondents mentioned water shortages, declining groundwater levels, inadequate or irregular supply, old and leaking pipelines, and shortages during summer. Water quality and contamination were also raised, alongside inadequate management of rainwater and insufficient maintenance of existing infrastructure. Some respondents specifically called for more recharge wells, filtration facilities and monitoring systems.

These concerns were reflected in what residents wanted CDA to prioritize. Responses emphasized improving existing water supply and infrastructure, ensuring access to clean water, increasing recharge and storage, monitoring groundwater and water use, and maintaining existing systems more effectively. Some participants also stressed that underserved and peripheral areas should receive greater attention rather than improvements being concentrated only in established sectors.

Finally, public trust emerged as an important part of implementation. Awareness and education were among the most frequently suggested ways of encouraging participation, including campaigns and greater use of social media. Many residents also called for transparent data and policies, fair enforcement, incentives and direct community involvement in decision-making. Taken together, the responses suggest that residents are not necessarily resistant to stronger groundwater management: **support is considerably easier to build when people understand the intervention, consider it practical and fair, and can see how their participation contributes to better water security.**

4.3.2 International Perspectives

International engagements provided useful comparisons with countries where groundwater recharge and management have evolved through different regulatory, technical and community models.

United States: From Recharge Infrastructure to Aquifer Management

The United States—particularly groundwater-dependent western states such as California and Arizona—provides an example of groundwater management evolving beyond individual interventions towards management of the aquifer itself. California's **Sustainable Groundwater Management Act (SGMA)** has established a framework under which groundwater sustainability is planned around groundwater basins through Groundwater Sustainability Agencies.

A key lesson from this approach is the importance of aquifer mapping and modelling. Aquifers do not follow city, district or other administrative boundaries established above ground. Understanding their physical extent and connectivity allows groundwater to be managed at the scale of the actual resource, supporting larger regional and state-level decisions about extraction, recharge and priority interventions.

A second, distinct lesson is the importance of **continuous monitoring and water accounting**. Mapping establishes what resource is being managed; monitoring shows how that resource is changing. Reliable measurement of groundwater levels, extraction, recharge and quality allows water balances to be developed and interventions to be evaluated over time. As groundwater-management systems mature, this evidence can also provide the basis for incentives, recharge accounting, water credits or other mechanisms that reward measurable contributions to groundwater sustainability.

The U.S. experience also highlights the importance of protecting aquifers before damage occurs. U.S.-based groundwater remediation consultant Roohi Toosi described how regulatory requirements create strong incentives for businesses and landowners to prevent and remediate groundwater contamination. His experience demonstrates why prevention is preferable to remediation: contamination underground can be substantially more difficult and expensive to contain and reverse than contamination of many surface-water systems. Excessive extraction and resulting land subsidence can also cause long-term damage, while even recharge water needs to be compatible with the receiving aquifer. Monitoring therefore needs to protect not only groundwater quantity, but also water quality and the long-term integrity of the aquifer.



Figure 4.26: Project team engaging with groundwater stakeholders and visiting groundwater recharge sites in the United States.

India: Building Recharge from the Ground Up

Closer to home, Bengaluru provides an example of how recharge can scale through community participation and the development of a local ecosystem. S. Vishwanath and the Biome Environmental Trust have pursued an ambitious campaign to build one million recharge wells in Bengaluru, with more than 250,000 completed at the time of the team's engagement.

A particularly important feature of the approach has been the involvement of existing well-digger communities. As declining groundwater reduced demand for traditional wells, well diggers were trained to construct recharge wells instead, creating a local delivery network and new livelihood opportunities. Communities, institutions and gated developments have also been encouraged to understand their water budgets and combine recharge with rainwater harvesting, wastewater reuse, metering and demand management.

Demonstration played an important role in building adoption. Even relatively small systems allowed users to see how much rainfall was available and how much was otherwise being lost. As awareness and uptake increased, government requirements helped reinforce and expand the approach. Bengaluru therefore demonstrates that community-led adoption and local delivery networks can **create early momentum, build confidence and expand recharge at the local level**. As these approaches prove their value, they can also help build the case for stronger government involvement—supporting the development of policies, monitoring systems and institutional structures needed for wider groundwater management.

Brazil: Designing for Long-Term Performance

Experience from other recharge programs also provides an important warning about long-term sustainability. **A 2025 systematic review of managed aquifer recharge in Brazil (Capeleto de Andrade et al., 2025)**, identified clogging as a recurring operational challenge capable of reducing recharge capacity and contributing to failure in infiltration basins and injection wells.

This finding closely reflects concerns encountered during the team's own observations in Islamabad. Sediment accumulation, pollution and inadequate maintenance can progressively reduce infiltration, meaning that even technically sound infrastructure can lose effectiveness if operation and maintenance are neglected. O&M therefore needs to be treated as an integral part of recharge-system design, with responsibility, resources and monitoring planned from the outset rather than after construction.

4.3.3 Key Lessons

The stakeholder perspectives reinforce that groundwater recharge cannot succeed through infrastructure alone. Long-term impact depends on combining **site-specific design, monitoring, maintenance, regulation, financing and public participation**.

The national perspectives show that Pakistan already has growing institutional interest, technical expertise and clear demand from groundwater-dependent users, but these elements remain fragmented. International examples show how some of these gaps can be addressed through basin-scale management and monitoring, community-led adoption, and sustained O&M.

Together, these perspectives suggest that the next step is not simply to build more recharge wells, but to develop a broader **groundwater-management ecosystem** that connects infrastructure with the institutions, data, financing and users needed to sustain it.

4.4 Conclusions

Taken together, the technical assessment, community survey and stakeholder perspectives provide a more complete picture of Islamabad's groundwater challenge. The findings show that the opportunity for recharge is significant, but effective groundwater management requires more than physical infrastructure alone: solutions must respond to local aquifer conditions, be measurable and maintained over time, and be supported by the institutions and communities that depend on the resource.

These findings provided the evidence base for the project's approach and, more broadly, for considering how Islamabad can move from individual recharge interventions towards more coordinated and data-driven groundwater management.

CHAPTER 5

MAKING GROUNDWATER RECHARGE MEASURABLE

The second objective of the project was to develop and deploy a monitoring system capable of measuring recharge performance and associated groundwater conditions. The system was installed at two existing CDA recharge wells located at the Nokia Networks office in H-8 and Iqra University in H-9, Islamabad, connecting field sensors with a digital platform through which the resulting data can be viewed and analyzed

5.1 The Monitoring System

The monitoring system captures four groups of parameters:

- Rainfall: Measures rainfall at the site, providing the input against which recharge events can be assessed.
- Recharge flow: Measures the rate at which water passes through the recharge system and uses this to calculate the total volume of water recharged over time.
- Groundwater level: Tracks changes in groundwater levels at each site over time.
- Water quality: Monitors pH, electrical conductivity (EC), turbidity, and dissolved oxygen (DO).

Together, these parameters provide a practical picture of both **how much water is being recharged and the condition of the water entering the system**. This configuration was selected for the conditions and monitoring needs of the two project sites. For future sites, the monitoring setup can be adapted based on local hydrogeology, water source and pollution risks, with additional or different parameters included where required.

The intervention did not alter the underlying recharge design or pathway of either CDA well. Physical works were limited to the remodelling required for monitoring, installation of instrumentation, and associated supporting infrastructure.



Figure 5.1: Snapshots of recharge well remodeling and upgrades undertaken to enable sensor installation, IoT-based monitoring and dashboard integration.

5.2 The Digital Dashboard

Data collected by the monitoring system is brought together through a digital dashboard, giving water managers at CDA a consolidated view of recharge-system performance and surrounding groundwater conditions. Rather than looking at individual measurements in isolation, the dashboard allows multiple parameters to be viewed together and tracked over time.

The dashboard provides access to:

- **Rainfall recorded at the site**
- **Recharge flow rates and cumulative recharge volume**
- **Groundwater levels and changes over time**
- **Selected water-quality indicators**

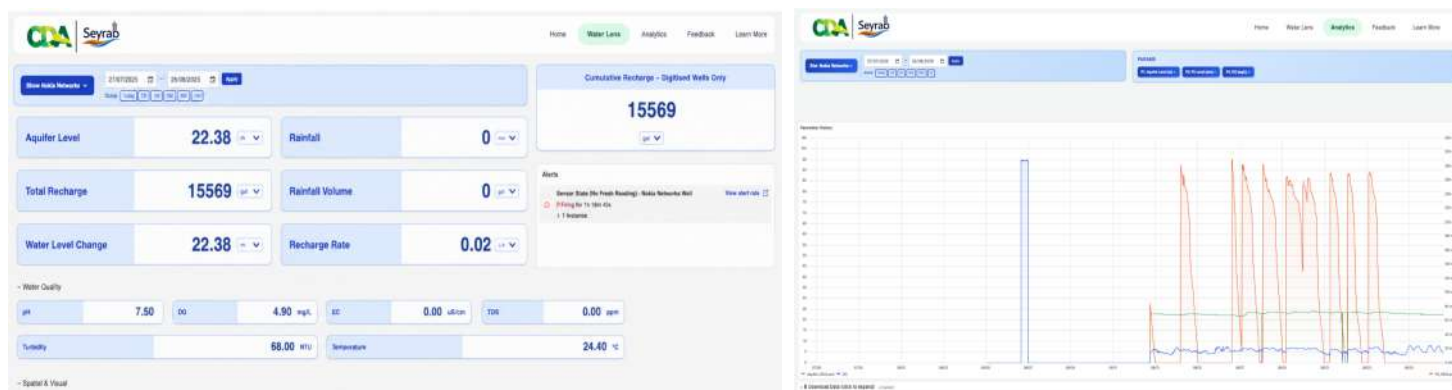


Figure 5.2: Snapshots of the digital dashboard

By combining these datasets and layering in historical trends, the dashboard allows managers to move beyond isolated readings and start exploring how parameters relate to one another. Some examples of typical analyses include:

- Overlaying rainfall and recharge data to see how much of the available stormwater is actually being captured on a given site.
- Plotting recharge activity against groundwater-level trends over time, on either an individual-site or aggregated basis.
- Comparing performance metrics — flow rates, volumes, water quality — across different sites, seasons or design types.
- Screening for anomalies or shifts in any tracked parameter that may warrant closer investigation.

These represent only some of the analyses possible and are not exhaustive. As the monitoring record grows, additional relationships, trends and performance indicators can be explored depending on the specific management questions CDA needs to answer.

With CDA approval, selected information could also be made available to the public in the future — for example, the cumulative amount of water recharged — to demonstrate the contribution of recharge systems and build greater public awareness of groundwater recharge.

5.3 What This Enables

Making recharge measurable changes how the infrastructure can be understood, managed and improved. Key benefits include:

- **Performance verification:** Managers can determine whether a recharge system is functioning as expected and how much water it is actually contributing over time.
- **Maintenance and early warning:** Changes in recharge rates, turbidity, pH or other indicators can help flag clogging, deterioration or other operational issues before performance declines significantly.
- **Water-quality protection:** Continuous tracking of selected quality parameters provides an additional safeguard against introducing unsuitable water into the aquifer.
- **Better investment decisions:** Measured performance allows future interventions to be compared on the basis of actual results rather than construction alone, helping identify which sites and designs provide better value.
- **Greater confidence for adopters:** Residents, institutions and private users can see measurable evidence of what recharge systems are delivering, making the benefits easier to evaluate.
- **Improved planning at scale:** As more sites are monitored, individual data points can begin to form a wider picture of recharge performance and groundwater conditions across the city.
- **Stronger groundwater management:** Over time, a larger monitoring network can support more targeted interventions, better prioritization of high-stress areas, and more informed decisions around groundwater planning and regulation.

At the site level, monitoring helps answer a simple question: is **the system working as intended?** At the city level, the same approach can gradually provide the evidence needed to manage groundwater more strategically.

CHAPTER 6

PRACTICAL GUIDANCE FOR RESIDENTS: MOVING TOWARDS ADOPTION

If your home, apartment building, institution or business depends on groundwater, **protecting the aquifer is directly connected to protecting your own future water supply.** The government has an important role to play, but groundwater is a shared resource, and the people and organizations extracting it can also help replenish it.

Recharge gives you a way to make better use of water already available on your property—particularly rainfall that would otherwise flow into drains—while contributing to the long-term health of the groundwater resource you and your community depend on.

6.1 Why Recharge?

If you extract groundwater but allow most of the rainfall falling on your property to drain away, you are missing out on a big opportunity to safeguard your groundwater resource.

A properly designed recharge system can provide several benefits:

Protect your long-term water supply: Replenishing groundwater can help slow local declines in the water table. As groundwater becomes deeper, your bore may need to pump from greater depths, increasing pumping costs and eventually requiring deeper drilling.

Make use of water you already receive: Rooftops and other suitable catchments can collect substantial rainfall. Recharge allows suitable excess water to become part of your groundwater resource instead of simply leaving the property through drains.

Store water for the dry season: Rain may arrive during only part of the year, but groundwater can store that water underground and make it available later through existing groundwater supplies.

Protect the aquifer itself: Excessive groundwater extraction can compact underground sediments. This can cause land subsidence—the gradual sinking of the ground—and permanently reduce some of the spaces within the aquifer that previously stored water. Maintaining healthier groundwater levels helps reduce these long-term risks.

Contribute beyond your property: Groundwater does not follow property boundaries. Water returned underground can contribute to the wider aquifer shared with surrounding homes and communities.

Recharge can also complement conventional rainwater storage. Tanks are valuable when you want to capture water for direct use, but storing large volumes requires space and additional infrastructure. An aquifer provides enormous natural underground storage, with minimal evaporation losses and without requiring an equivalent-sized tank. The two approaches do not need to compete: store what you can practically use and safely recharge suitable excess water that would otherwise be lost.

6.2 Is Recharge Suitable for Your Property?

Before investing, consider these basic questions:

- **Do you have water to recharge?** Is suitable rainfall runoff or another potentially usable water source currently leaving the property?
- **Does your area have sufficient underground storage for recharge?** Do the soil, geology and underlying aquifer provide suitable conditions for water to infiltrate and be stored?

Having excess water does not automatically mean recharge will work. **Water availability and underground storage potential both matter.** A professional assessment can determine whether your property is suitable and what kind of intervention makes sense.

6.3 Before You Build

A recharge system creates a pathway between water at the surface and the subsurface. Getting the location, design and water quality wrong can therefore create problems that are difficult to reverse.

- Understand your site: Groundwater depth, geology, soil conditions, slope and drainage should be assessed before choosing where to recharge.
- Choose the right recharge method: Shallow infiltration and deeper/direct recharge are fundamentally different. Deeper systems can move water towards the aquifer much faster and therefore require greater safeguards. For these systems, subsurface investigations such as electrical resistivity tomography (ERT) may help identify suitable geological conditions and locations.
- Understand your water source: Clean rooftop rainfall presents very different risks from runoff collected from roads, parking areas or other potentially contaminated surfaces. The filtration and treatment required should reflect where the water comes from.
- Identify pollution risks: Keep recharge systems away from sewer lines, septic tanks, waste disposal areas and other contamination sources. This becomes especially important for direct recharge compared to shallow recharge, because contaminants may have less soil through which to be naturally filtered before reaching groundwater.
- Protect your drinking-water supply: Do not simply use the same bore from which you extract drinking water as your recharge bore. Contaminated recharge water could create a direct pathway towards the water you later consume.
- Protect your building: Maintain an appropriate distance from foundations. Concentrating water too close to a structure can saturate surrounding soil and, depending on local conditions, contribute to seepage, settlement or foundation problems.
- Seek professional support: Recharge design should respond to your individual site rather than simply copying a system installed somewhere else.

A useful rule to remember is: the more directly you connect surface water to the aquifer, the more carefully you need to control what enters it.

6.4 Operation and Maintenance: Protecting Your Investment

Building the system is only the beginning. If a recharge system is not maintained, sediment and debris can clog its filters and infiltration pathways until very little water can pass through. The infrastructure may still be there, but the investment may effectively stop performing.

Owners should therefore:

- clean collection and filtration areas before the rainy season;
- remove sediment and debris after major rainfall events;
- inspect the water filters and water pathways regularly; and
- investigate any noticeable decline in flow or recharge performance.

Maintenance is also about **protecting water quality, not just maintaining flow**. Damaged filtration, accumulated contaminated sediment or polluted water entering the system can create a pathway for contaminants to reach groundwater. For deeper recharge systems in particular, this could affect the aquifer used by your own bore and potentially the wider groundwater resource shared with your community.

For this reason, **responsibility for inspection, cleaning and maintenance should be decided before the system is built**. A recharge system that cannot be maintained safely over its lifetime should not be treated as a one-time construction project.

6.5 The Bigger Picture

Recharge starts with protecting **your own water security**—making better use of the water available to you and helping safeguard the aquifer on which your property depends. But groundwater is shared, so responsible action also benefits the people around you.

One property cannot restore an aquifer. But when households, housing societies, universities, offices and businesses each manage their water responsibly, individual actions begin to add up. **The government can build and manage public infrastructure, but protecting a shared groundwater resource ultimately requires all of us who depend on it to become responsible stewards of it.**

CHAPTER 7

THE WAY FORWARD: FROM PILOT TO GROUNDWATER MANAGEMENT

The pilot has shown how monitoring can make recharge infrastructure more useful to water managers. CDA can now see how much water is being recharged at the two sites, how groundwater levels are changing, and whether the systems require attention.

The next step is to build on this work at a larger scale. For Islamabad, that means improving the infrastructure already in place, expanding monitoring, developing a better understanding of the aquifer, and directing future recharge investment towards the areas where it is most needed. Beyond Islamabad, the same approach can be adapted for other groundwater-dependent cities in Pakistan.

7.1 A Five-Step Pathway for Islamabad

CDA already has a substantial base to work from, including approximately 100 recharge wells across the city. The priority should now be to get more value from these assets while developing the information needed to plan future investment.



Figure 7.1: Proposed roadmap for scaling from pilot recharge wells to citywide groundwater management in Islamabad.

7.1.1. Protect and assess existing recharge assets

The existing recharge wells should first be assessed to determine which are working effectively, which require rehabilitation, and which have limited recharge potential because of their location, catchment or condition.

Priority systems can then be repaired or upgraded, with clear arrangements for inspection and maintenance. This is important because clogged, damaged or poorly maintained systems may continue to exist physically while contributing very little recharge and may even be a contaminant risk to the aquifer.

The immediate objective should be to protect the investment already made before adding new infrastructure at scale.

7.1.2. Build a citywide groundwater monitoring network

Monitoring should gradually be expanded beyond the two pilot sites to selected recharge wells and groundwater observation points across Islamabad.

Depending on the purpose of each site, monitoring could include groundwater levels, rainfall, recharge volumes, selected water-quality parameters and system performance. Not every recharge well needs the full monitoring package used in this pilot. A smaller number of strategically located observation points can provide wider groundwater information, while more detailed monitoring can be installed at important recharge sites.

This would give CDA a clearer picture of both individual infrastructure performance and wider groundwater trends across the city.

7.1.3. Map and model Islamabad’s groundwater system

Monitoring becomes far more useful when individual measurements are connected to an understanding of the aquifer itself. Moving from site-level monitoring to citywide groundwater management therefore requires a clearer picture of the **shape, structure, characteristics and behavior of Islamabad’s aquifer system**.

A citywide assessment could combine ERT and other hydrogeological investigations with groundwater-level monitoring, recharge data, rainfall, land use and available information on municipal and private groundwater abstraction. Together, these inputs can support a groundwater model that not only shows where stress is occurring, but also begins to quantify the city’s groundwater balance.

A key objective should be to translate observed changes in groundwater level into estimates of changes in groundwater storage—for example, **what a one-foot decline represents in volumetric terms**.

For a simple unconfined aquifer, conceptually:

$$\text{Change in groundwater storage} = \text{Aquifer area} \times \text{Change in groundwater level} \times \text{Specific yield}$$
$$(\Delta V = A \times \Delta h \times S_y)$$

I.e. Groundwater Level → Groundwater Volume

Once the aquifer boundaries and relevant storage properties are established, this relationship can be used to estimate:

$$1 \text{ ft change in groundwater level} \rightarrow X \text{ million gallons change in groundwater storage}$$

***For confined or more complex aquifer systems, the appropriate storage parameters and groundwater model would need to reflect the local hydrogeology.**

Combined with estimates of **municipal and private groundwater abstraction**, observed drawdown and measured recharge, this can help quantify the groundwater balance and identify persistent imbalances between abstraction, recharge, and other groundwater inflows and outflows. Mapping can also provide water managers with a better understanding of **aquifer connectivity and groundwater flow direction**, allowing monitoring data from individual sites to be interpreted within the wider groundwater system.

Over time, this should allow CDA to answer the following fundamental questions with greater confidence:

- How much groundwater is being lost?
- Where is the greatest pressure occurring?
- How much additional recharge or reduction in extraction is required?
- How does groundwater move through the aquifer, and where and how will different interventions have the greatest benefit?

This approach also reflects an important lesson from U.S. groundwater management: groundwater needs to be **managed holistically at the aquifer or basin level**, rather than according to administrative boundaries alone. For Islamabad, understanding both how much water the aquifer holds and how water moves through it would provide the basis for determining where to intervene, what type of intervention is appropriate, and what impact can reasonably be expected.

7.1.4. Target high-capacity recharge where it will have the greatest impact

Future recharge programmes should focus not only on the number of wells constructed, but on how much useful recharge those systems can deliver.

Larger, optimised recharge systems should be considered in areas where groundwater demand and recharge potential are both high. Priority locations are likely to include areas with major public groundwater extraction, large institutions and other concentrated groundwater users. The CDA scale-up concept similarly identifies groundwater dependence, extraction points, runoff availability, hydrogeological suitability and the ability to monitor and maintain systems as key considerations.

Site selection should consider:

- groundwater dependence and declining water levels;
- available runoff or another suitable recharge-water source;
- topography, climatology, and hydrogeological suitability;
- water-quality and pollution risks; and
- the ability to operate and maintain the system over time.

These larger systems would complement, rather than replace, the existing network of smaller recharge wells.

7.1.5. Use the data to manage the groundwater balance

The purpose of monitoring is not simply to produce more data. It is to support better decisions. As CDA develops a stronger understanding of groundwater conditions, recharge performance and extraction, this information can begin to guide where new infrastructure is built, where maintenance is required, and where groundwater use may need to be better controlled.

It can also support future decisions on groundwater-related requirements for new development, rainwater harvesting, metering, incentives for recharge and, where appropriate, groundwater abstraction or pricing measures.

The long-term measure of success should therefore not only be the number of recharge wells constructed. More important questions are how much water is being recharged, how much is being extracted, whether groundwater levels are stabilising, and whether public investment is being directed towards the areas where it can make the greatest difference.

7.2 Taking the Approach Beyond Islamabad

The same overall approach can be applied in other parts of Pakistan, but the physical solution will need to change from one location to another. Groundwater conditions vary substantially across the country, including differences in hydrogeology, water quality and pollution risks.

Expansion should begin by identifying cities where four basic conditions exist:

- Groundwater is an important part of the local water supply.
- Groundwater levels or availability are under increasing pressure.
- A suitable source of water is available for recharge.
- Local aquifer conditions provide meaningful recharge and storage potential.

Once a priority city has been identified, local conditions should be assessed before any particular recharge design is selected. This should include hydrogeology, available recharge-water sources, water quality, pollution risks and land-use constraints. The next step should be to demonstrate suitable recharge approaches through monitored pilots. These projects can establish whether the intervention works under local conditions and generate the evidence needed for government, funders and other users to consider larger investments.

As programmes grow, cities will also need the systems around the infrastructure: technical standards, monitoring and data systems, operation and maintenance arrangements, local technical capacity and clear institutional responsibilities. Funding can then move progressively from demonstration towards larger public programmes, donor-supported expansion and private participation. The objective should not be to reproduce the same recharge-well design in every city. The more useful model to replicate is the overall approach: **understand the groundwater system, recharge where appropriate, measure performance, and use the data to improve management.**

High-rainfall cities may have strong potential for monsoon runoff recharge. Dense urban areas may require engineered systems because natural infiltration has been reduced by development. Industrial areas may require stronger water-quality safeguards, while locations affected by salinity or contamination may need to prioritise groundwater protection before recharge.



Figure 7.2: Proposed framework for scaling smart groundwater management beyond Islamabad.

7.3 What Government and Development Partners Should Support Next

The next phase will require investment not only in recharge infrastructure, but also in the systems needed to plan and manage it properly.

Priority areas for support include:

- groundwater mapping and modelling;
- groundwater observation and monitoring networks;
- rehabilitation and monitoring of existing recharge infrastructure;
- high-capacity demonstration systems in priority groundwater-dependent areas;
- operation and maintenance arrangements;
- technical standards for recharge design, monitoring and water-quality protection;
- institutional and technical capacity; and
- groundwater accounting systems that bring together recharge, extraction and groundwater-level data.

Development partners can play an important role in funding the early stages of this work, particularly activities such as mapping, monitoring, modelling and demonstration projects that help reduce uncertainty before larger public investment is committed. The stakeholder consultations undertaken through this project similarly highlighted the value of development finance in supporting early capital costs and demonstration risk, while government provides institutional direction and specialised actors contribute implementation and technical capacity.

The government can then use the resulting information to prioritise its own investment, improve standards and regulation, and bring major groundwater users into future programmes where appropriate.

Long-term financing also needs to cover operation and maintenance. A recharge system that is built but not maintained will eventually lose performance. Monitoring equipment and groundwater data systems likewise require continued operation after the initial project ends.

7.4 Moving Towards PPPs and Groundwater Management Services

As groundwater monitoring, data collection, and accounting systems become more robust, new models for delivering groundwater services may become feasible. Rather than contracting only for the construction of individual recharge wells, cities could eventually contract specialised operators to **replenish, monitor and help manage groundwater as part of the water-supply system**, with performance linked to measurable outcomes.

Over time, these models could help integrate recharge, water supply, maintenance and aquifer health into the same management framework. For groundwater-dependent cities, this could create an important pathway for mobilising private capacity and investment while the government sets the targets, safeguards the resource and works towards a sustainable balance between extraction and replenishment.

7.5 The Long-Term Goal: Managing the Groundwater Balance

The longer-term objective is straightforward: Islamabad, and eventually other groundwater-dependent cities, should be able to understand whether groundwater use and replenishment are moving towards balance.

At its simplest:

$$\text{Change in groundwater storage} \approx \text{Recharge} - \text{Groundwater abstraction} \pm \text{Other groundwater inflows/outflows}$$

In practice, developing this picture requires long-term monitoring, hydrogeological assessment and better information on groundwater extraction. It will therefore develop gradually rather than through a single project.

The value of reaching this point is that groundwater management becomes more proactive. Instead of waiting for water levels to fall, wells to fail or shortages to become severe, authorities can identify areas of concern earlier, determine where recharge or demand-management measures are needed, and track whether those interventions are working.

The two monitored recharge wells developed through this project provide a practical starting point. The next opportunity is to connect individual sites into a wider system that allows CDA—and, over time, other cities in Pakistan—to manage groundwater on the basis of measured conditions rather than assumptions.

CHAPTER 8

PROJECT SUSTAINABILITY: FROM A TWO-WELL PILOT TO A LASTING GROUNDWATER VENTURE

The team behind this project had identified groundwater depletion as a major challenge for Pakistan's cities and saw better groundwater management as an important part of the solution. Groundwater can provide a valuable buffer against the variability of surface water supplies—but its long-term security depends on better monitoring and management, including active recharge where technically and environmentally appropriate. Through the collaboration with CDA and support from the U.S. Mission to Pakistan in partnership with the Pakistan-U.S. Alumni Network (PUAN), this project created an opportunity to put that thinking into practice and test the approach in a real municipal setting.

The project became more than a demonstration of two monitored recharge wells. It helped validate the approach, generate practical evidence and experience, and identify the technical and operational requirements that could guide future pilots and larger-scale applications. These learnings, together with the experience and momentum built through the project, helped create the foundation for continuing the work beyond the original grant through **Seyrab Water Systems**, a dedicated water-technology company focused on smart groundwater recharge, monitoring and management. The U.S. Mission to Pakistan in partnership with the Pakistan-U.S. Alumni Network (PUAN), played an important role as an early believer in this work, providing support at a stage when the approach was still being tested and refined and helping create the opportunity to demonstrate it on the ground.

Today, this work is continuing through Seyrab Water Systems through new pilot projects, research collaborations, and engagement with government institutions, development organizations, communities and private-sector partners in Pakistan and internationally. This is an important part of the project's sustainability: the knowledge, capacity and momentum created through the project are continuing beyond the grant and being used to generate further action.

That is the larger legacy of this pilot: two monitored wells became a starting point for something much bigger—a locally rooted effort to make groundwater measurable, manageable and ultimately more secure for the cities and communities that depend on it.

To learn more about Seyrab Water Systems and its ongoing work,

🌐 Visit: <https://seyrab.com/>

✉ Contact the team at: hi@seyrab.com

REFERENCES

- Pakistan Council of Research in Water Resources. (2019). Water security issues of agriculture in Pakistan. Pakistan Council of Research in Water Resources.
- Lytton, L., Ali, A., Garthwaite, B., Punthakey, J. F., & Saeed, B. (2021). Groundwater in Pakistan's Indus Basin: Present and future prospects. World Bank.
- Akram, M. F., Anjum, L., Arshad, M., & Anwar ul Haq, M. (2026). Groundwater quality assessment for drinking purpose in Faisalabad City using GIS and water quality index. Polish Journal of Environmental Studies. <https://doi.org/10.15244/pjoes/215759>
- Capital Development Authority. (2026, March 18). Notification / Public notice for installation of rooftop rainwater harvesting in Islamabad. Government of Pakistan.
- Pakistan Council of Research in Water Resources. (2023a). Hydrological assessment of surface and groundwater resources of Islamabad, Pakistan. Ministry of Water Resources, Government of Pakistan.
- Pakistan Council of Research in Water Resources. (2023b). Rainwater harvesting for groundwater recharge in Islamabad. Ministry of Water Resources, Government of Pakistan.
- Capeleto de Andrade, L., Hirata, R., Goodarzi, L., & Suhogusoff, A. (2025). Systematic review of managed aquifer recharge in Brazil. *Discover Water*, 5, Article 75. <https://doi.org/10.1007/s43832-025-00276-0>
- Naseem, S., & Bano, S. (2025). Impact of seawater intrusion on coastal aquifers of Karachi, Pakistan. *International Journal of Economic and Environmental Geology*, 16(2), 26–35. <https://doi.org/10.46660/ijeeg.v16i2.543>
- Pakistan Council of Research in Water Resources. (2021). Drinking water quality in Pakistan: Current status and challenges. Ministry of Water Resources, Government of Pakistan.
- Quddoos, A., Muhmood, K., Naz, I., Aslam, R. W., & Usman, S. Y. (2024). Geospatial insights into groundwater contamination from urban and industrial effluents in Faisalabad. *Discover Water*, 4, Article 50. <https://doi.org/10.1007/s43832-024-00110-z>



FROM INVISIBLE RESOURCE TO MANAGED ASSET

Islamabad's Journey Towards
Sustainable Groundwater Management

