

Urban Water-Supply Development in North India: Infrastructure Expansion, Service-Delivery Gaps and Planning Implications

Gurbaz Singh¹, Dr. Kuldip Singh²

¹ *Research Scholar, Guru Ram Das School of Planning, Guru Nanak Dev University, Amritsar, Punjab, India, 143005*

² *Associate Professor, Guru Nanak Dev University, Amritsar, Punjab, India, 143005*

Abstract—Urban water-supply development in North India has acquired a broader purpose as infrastructure programmes have moved from extending physical provision towards household coverage, resource security and dependable service. This paper reviews that development through the Five-Year Plan framework, JNNURM, AMRUT and AMRUT 2.0, read alongside URDPFI guidance and national service-level benchmarks. Government plans, mission records, Census publications, groundwater assessments and municipal project documents accessed up to date form the evidence base. Regional programme data establish the scale of approved investment; Amritsar and Ludhiana then illustrate how successive funding arrangements are reshaping existing systems. Census baselines and project population projections are considered separately, followed by a transparent calculation of population-related demand. The published record identifies intermittent supply, historical distribution losses and pressure on groundwater resources, while major bulk-water projects provide a basis for source substitution and network improvement. Planned assets and approved continuous-supply pilots are distinguished from demonstrated household service. The analysis shows that the contribution of additional capacity depends on the population served, delivery losses, non-residential requirements and the readiness of downstream networks. Planning priorities include coordinating construction packages, reserving land for water infrastructure, managing demand, protecting alternative sources and financing operation and maintenance. The review supports a regional policy interpretation with two city illustrations; it does not infer uniform service conditions across North India.

Index Terms—Urban water supply, North India, Infrastructure development, Five-Year Plans, AMRUT, URDPFI, Groundwater, Service-level benchmarks.

I. INTRODUCTION

Urban water-supply development involves more than the addition of wells, treatment plants and pipelines. It also concerns where a city grows, how much water different activities require, and whether public investment produces a dependable service at the household connection. These relationships are especially relevant when an established groundwater-based system is being connected to a new surface-water source. Older distribution networks continue to shape the service even after the source and treatment arrangements change.

The policy history helps explain how such investments have become possible. Five-Year Plans provided a national framework for infrastructure provision, while successive urban programmes introduced project funding, municipal reforms and service objectives. The Eleventh and Twelfth Plans connected urban infrastructure with institutional capacity and finance [2], [4]. AMRUT 2.0 subsequently placed water balance, wider connection coverage and resource efficiency within the mission framework [5]. The resulting infrastructure is best understood as a cumulative system assembled through several funding periods.

This paper therefore begins with national policy and its relevance to North India. Regional AMRUT 2.0 records provide investment context before Amritsar and Ludhiana are introduced as illustrations. The discussion asks how programmes support expansion,

how urban growth and source conditions affect demand planning, and what published evidence reveals about the distance between infrastructure provision and intended service. The central argument is that source augmentation, local distribution and municipal operation need to be planned together.

II. SCOPE AND DOCUMENTARY APPROACH

The study is a policy and infrastructure review supported by secondary quantitative analysis. Its regional context includes Punjab, Haryana, Himachal Pradesh, Rajasthan, Uttar Pradesh and Uttarakhand, together with Delhi, Chandigarh, Jammu and Kashmir and Ladakh. This is an operational definition for the review. These jurisdictions differ considerably in settlement form and water resources; a common national scheme does not imply a common physical solution.

Sources comprise official Five-Year Plan documents, scheme guidelines, URDPFI, service-level benchmarks, AMRUT project records, municipal disclosures, Census 2011 handbooks, the Central Ground Water Board (CGWB) assessment and a published study of Amritsar's water system.

The analysis follows the sequence from policy provisions to financed assets, population-related requirements and documented service conditions. Approved costs, grounded projects, physical progress and operating performance are kept distinct. Census counts provide demographic context; project estimates and projections provide the inputs for the demand scenarios. Amritsar and Ludhiana are selected because both have substantial bulk-water

projects under a shared Punjab programme [10]. They illustrate how policy is implemented within an existing urban system.

III. POLICY DEVELOPMENT FROM FIVE-YEAR PLANS TO URBAN MISSIONS

A. Public provision and targeted urban programmes

India's early planning approach placed drinking water within public health. The government's historical account records the National Water Supply Programme in 1954 during the First Five-Year Plan [1]. Later programmes became more differentiated by settlement size and sector. The Integrated Development of Small and Medium Towns (IDSMT) programme, introduced in 1979–80, supported town infrastructure. The Eighth Plan period brought the Mega City scheme and the Accelerated Urban Water Supply Programme (AUWSP) in 1993–94 [2]. AUWSP used central–state cost sharing for towns with populations below 20,000 and was absorbed into the Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) from 2005–06 [3].

These earlier instruments show how urban water provision developed within a wider settlement policy. Their relevance is historical and institutional: a scheme for small towns cannot be used as evidence of direct assistance to a metropolitan city. Nor does a program's existence establish which works were completed locally. Table I sets out the main transitions relevant to the present review, with the later Plans supplying the clearest link between investment and service reform.

TABLE I. SELECTED PLAN PERIODS AND URBAN WATER POLICY MILESTONES

Period or instrument	Documented emphasis	Implication for water-supply planning
First Plan, 1951–56; programme launched 1954	National Water Supply Programme under the health sector [1].	Established water provision as a public development responsibility.
1979–80 and the Sixth–Seventh Plan period	IDSMT supported infrastructure in small and medium towns [2].	Located water investment within town development.
Eighth–Ninth Plans, 1992–2002	Mega City scheme and AUWSP began in 1993–94 [2], [3].	Different programme channels addressed different settlement categories.
Tenth Plan, 2002–07	Urban Reform Incentive Fund; JNNURM launched in December 2005 [2].	Linked project assistance with municipal reform.
Eleventh Plan, 2007–12	JNNURM implementation and urban institutional reform [2].	Connected capital works with governance and financial capacity.
Twelfth Plan, 2012–17	Metering, demand management, accountability and feasible 24×7 service [4].	Made operational improvement an explicit planning concern.
AMRUT, launched 2015	Water supply and household connections in 500 cities [5].	Placed network access among the principal urban investment priorities.
AMRUT 2.0, launched 2021	Water connections across statutory towns; water-balance planning [5].	Related new works to resource availability and service objectives.

B. Infrastructure finance and municipal responsibility

The Jawaharlal Nehru National Urban Renewal Mission (JNNURM), launched on 3 December 2005, brought infrastructure support and reform commitments into a mission framework. Its Urban Infrastructure and Governance component addressed mission cities, while UIDSSMT provided a channel for other towns. Earlier programmes were reorganised within this arrangement [2], [3]. The planning significance was that a project proposal increasingly needed an institutional setting: an implementing body, a financing arrangement and a basis for maintaining the asset.

The Twelfth Plan carried this concern into more explicit service commitments. Its urban development chapter called for utility accountability, improved city water databases, demand management and a route towards service-level benchmarks. Box 18.10 also connected metering and reduced wastage with feasible 24×7 supply [4]. Read together, these provisions treat operation as part of infrastructure development. An asset adds useful capacity only when a responsible organisation can run, maintain and renew it.

C. AMRUT and water security

The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) was launched on 25 June 2015, followed by AMRUT 2.0 on 1 October 2021. The latter connects City Water Balance Plans with City Water Action Plans and State Water Action

Plans. Its reform agenda includes lower non-revenue water, reuse of treated used water and improved continuity [5]. These requirements widen the basis of project selection. A city must consider how much water is available and how efficiently it is used, as well as the number of households needing connections.

The successive programmes consequently add responsibilities to the same urban system. A new treatment plant may supply mains built under earlier schemes; a reservoir project may depend on a separately financed transmission link. Their combined effect is determined at these interfaces. Coordination between schemes is therefore a substantive planning task, particularly where source substitution and local service improvements proceed under different contracts.

IV. INFRASTRUCTURE EXPANSION IN THE REGIONAL AND PLANNING CONTEXT

A. The regional programme footprint

The AMRUT 2.0 portal records approved water-supply projects across the northern jurisdictions considered here (Table II). The figures establish the geographical spread and financial scale of the programme. They describe approved portfolios, rather than expenditure, commissioning or service achieved [6]. Differences in city numbers, project packaging and existing assets also limit direct comparisons between states.

TABLE II. APPROVED WATER-SUPPLY PROJECTS UNDER AMRUT 2.0

State or Union Territory	Number of projects	Approved project cost (₹ crore)
Punjab	157	3,818.94
Haryana	61	2,470.30
Himachal Pradesh	17	298.86
Rajasthan	178	5,099.47
Uttar Pradesh	437	18,829.99
Uttarakhand	26	687.40
Delhi	1	12.73
Chandigarh	2	43.77
Jammu and Kashmir	65	621.89
Ladakh	2	155.33

Source: AMRUT Universe, state-wise approved projects[6]. Only the water-supply category is shown; other sectors are excluded.

Infrastructure expansion can take several forms within this programme setting: securing a source, enlarging treatment and conveyance, improving

storage, extending distribution or providing connections. These interventions solve different constraints. A settlement outside the network needs access; an already connected locality with unreliable supply may need rehabilitation and operating changes. Reading approved investment by function is thus more informative for planning than treating every water project as an equivalent addition to service.

B. URDPFI and the distinction between design and service

The Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines, 2014 link water provision with settlement planning. Table 8.26 provides reference levels of 135 litres per capita per day (lpcd) for cities with sewerage existing or contemplated, and 150 lpcd for metropolitan and mega cities. These are planning supply levels, not observations of consumption. Table 8.36 also differentiates component design periods, including 15 years for treatment units and 30 years for transmission mains [7]. A long-term network therefore need not require every mechanical or treatment component to be installed at its ultimate capacity immediately.

Population estimates need to correspond to the area actually intended to receive the service. Municipal limits, an urban agglomeration and a project service area can include different populations. The same care applies to land use. Residential density influences local pipe loading, while institutions, markets and industrial premises create additional demands. A citywide volume is a useful starting point, but spatial allocation determines whether that water can reach the places where it is required.

C. Legal responsibilities and service benchmarks

Section 44(b) of the Punjab Municipal Corporation Act, 1976 includes construction and maintenance of means for public and private water supply among obligatory municipal functions [8]. The provision gives the city illustrations a statutory setting. Contractors may undertake construction or operation, while municipal arrangements still need to connect those contracts to service responsibility. URDPFI also carries National Water Policy 2012 recommendations on integrated urban water and sewage management, reuse and water accounts [7]. Policy guidance, planning norms and statutory obligations serve related but distinct purposes.

TABLE III. NATIONAL WATER-SUPPLY SERVICE-LEVEL BENCHMARKS

Indicator	Benchmark	Meaning for interpreting infrastructure expansion
Water-supply connection coverage	100%	A main in a street does not by itself establish household connection coverage.
Per capita water supply	135 lpcd	Installed capacity and delivered quantity are different measures.
Extent of metering	100%	Metered supply supports a verifiable water account.
Extent of non-revenue water	20%	Loss control and revenue accounting accompany augmentation.
Continuity of water supply	24 hours/day	Continuous service depends on the functioning system.
Quality of water supplied	100%	Compliance concerns the supplied water, not only the source selected.
Complaint redressal efficiency	80%	Service management includes response to reported problems.
Cost recovery in water-supply services	100%	Operating finance affects the durability of service.
Collection efficiency of water charges	90%	Revenue collection differs from the amount billed.

Benchmark values: National Urban Digital Mission, Water & Sewerage Knowledge Standard, Appendix 2 [9].

The 135 lpcd service benchmark and the 150 lpcd metropolitan planning reference are retained separately in the calculations below. Neither can be multiplied mechanically by hours of supply to

estimate daily consumption. Moving towards continuous supply changes availability and system operation; it does not mean that every connection draws water throughout the day.

V. CITY ILLUSTRATIONS AND THE CHANGING SCALE OF DEMAND

A. Why Amritsar and Ludhiana are relevant

Amritsar and Ludhiana illustrate an important form of infrastructure expansion: the replacement of dispersed groundwater production with canal-based bulk supply, combined with investment in reservoirs and conveyance. The World Bank approved support for the Punjab Municipal Services Improvement Project (PMSIP) in March 2021. The programme also

addresses municipal capacity and envisages operation under city-level oversight [10]. Its bulk-water investments sit alongside AMRUT-funded local works; they should not be counted as a single national mission or assumed to have identical scopes. The cities also bring different demand considerations into the same policy setting. Amritsar's religious and visitor functions add a temporal dimension to demand, while Ludhiana's industrial and commercial activity makes the allocation between potable and non-potable uses particularly relevant. These characteristics guide the interpretation of infrastructure needs. No visitor-water volume or industrial share is assigned without a corresponding quantified source.

B. Population context and project projections

TABLE IV. POPULATION BASELINES AND THE GROWTH ASSUMED IN PROJECT DOCUMENTS

Population measure	Amritsar	Ludhiana
2011 Census population	1,159,227 Municipal Corporation + outgrowths	1,618,879 Municipal Corporation
2025 project population estimate	1,451,000	2,300,000
2055 project population projection	2,211,000	4,000,000
Increase within the project series, 2025–55	760,000	1,700,000
Percentage increase within the project series	52.4%	73.9%
Implied annual compound growth, 2025–55	1.41%	1.86%

Sources: Census 2011 district handbooks [13], [14] and municipal project descriptions [11], [12]. Growth and annual rates are the authors' calculations using the project endpoints.

The project series implies a larger absolute and proportional increase in Ludhiana over 2025–55. At an unchanged per capita allowance, population growth alone increases the corresponding daily requirement by the same percentage. The result

concerns demand embedded in project projections; it is not an observed growth rate for 2011–26. The 2011 counts are included to establish historical scale, with their different Census units made explicit.

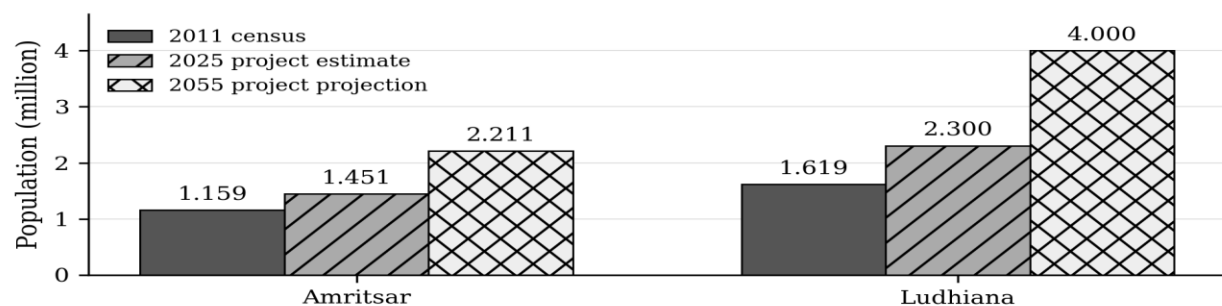


Fig. 1. Census population context and the populations used in bulk-water project descriptions.

Sources: [11]–[14]. The 2011 bars are Census counts; the other bars are project estimates and projections. Separate bars avoid presenting these different series as a continuous observed trend.

C. Demand determinants beyond population

Population is the largest readily reproducible input, but it does not explain the full requirement. New peripheral development increases the area and length of network to be served. Densification concentrates demand on existing mains. Household connection growth may increase recorded municipal consumption even without an equivalent increase in residents, because people previously using other sources enter the public system. Each process has a different implication for investment.

Land use also changes the timing and composition of demand. Visitor concentrations, hospitals, educational institutions, hotels and markets require allowances related to their activities. Industrial process demand should be assessed separately from workers' domestic requirements and from industries' own abstraction. Seasonal peaks, usable storage,

treatment availability and delivery losses affect production and distribution requirements. These factors explain why population-based calculations are informative for screening but insufficient for detailed hydraulic design.

D. Groundwater pressure and the reason for source substitution

The 2023 Central Ground Water Board assessment gives stages of extraction of 178.11% for Amritsar district and 221.04% for Ludhiana district, against 163.76% for Punjab (Fig. 2). These ratios compare annual extraction with annual extractable groundwater resources. The same assessment places Amritsar Urban and Ludhiana City among over-exploited assessment units [15]. District values include agricultural and other abstraction; they cannot be read as municipal pumping ratios.

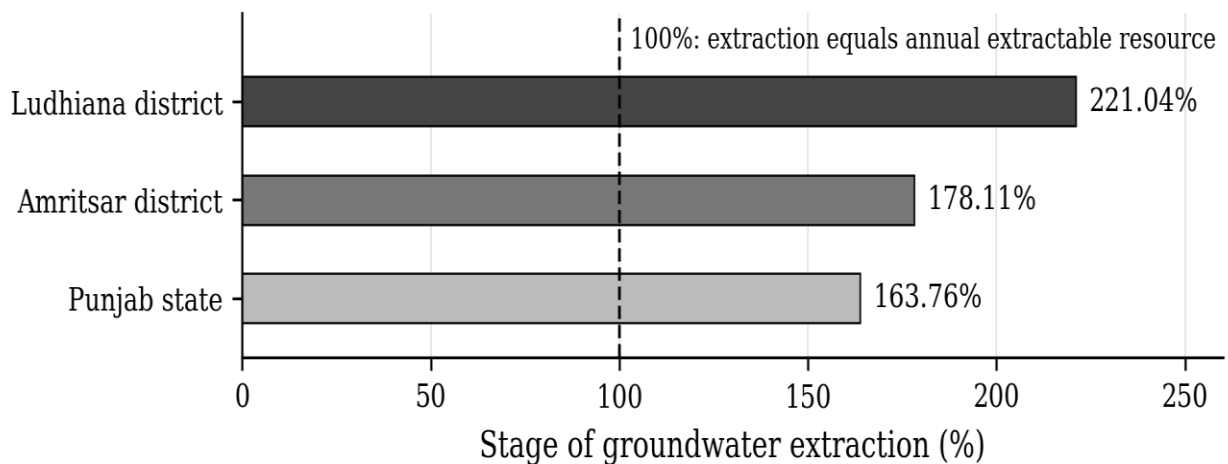


Fig. 2. Groundwater extraction relative to annual extractable resources in 2023.

Source: CGWB, National Compilation on Dynamic Ground Water Resources of India, 2023, Punjab district table [15]. This is a resource-pressure indicator, not a measurement of depth to groundwater or a time trend.

Depth changes provide a different type of evidence. Amritsar's municipal project description reports a decline of 10–15 metres between 1984 and 2016 [11]. Ludhiana's note describes a fall exceeding 20 metres over the preceding forty years, without specifying calendar endpoints [12]. These statements support the published rationale for reducing dependence on groundwater, but their different periods do not support a direct comparison of annual decline rates.

The source shift can reduce municipal abstraction if canal water replaces existing pumping. It cannot, by

itself, reverse district-wide depletion, where irrigation forms the dominant extraction category in the CGWB accounts [15]. The planning objective is therefore to secure urban supply while reducing avoidable groundwater demand. Canal access introduces its own requirements for raw-water protection, treatment and interruption management; source substitution changes the risk profile rather than removing the need to manage it.

VI. HOW INFRASTRUCTURE PROGRAMMES ARE RESHAPING THE TWO SYSTEMS

A. Bulk supply and complementary works

TABLE V. PUBLISHED BULK-WATER PROJECT COMPONENTS

Component	Amritsar	Ludhiana
Proposed source	Upper Bari Doab Canal	Sidhwan Canal through the Sirhind canal system
Treatment plant location and capacity	Vallah; 440 MLD	Bilga; 580 MLD
Transmission network described	112 km	165 km
Reservoir works described	45 new overhead service reservoirs	70 new reservoirs and rehabilitation of 66 existing reservoirs
Municipal background description of daily supply	8–10 hours	10 hours

Sources: municipal proposed project descriptions [11], [12]. Capacities and works describe project scope; supply hours describe the background systems. MLD = million litres per day. As the both projects are under construction, these figures do not certify present operating output or continuity.

The components in Table V address distinct parts of the service chain. Treatment provides controlled bulk-water production; transmission moves it across the city; reservoirs provide local storage and support distribution. Their contribution to demand depends

on the distribution networks and connections that receive the water. Capacity at a plant outlet is consequently an enabling input to household service, with benefits determined by the completeness and operation of the connected system.

TABLE VI. SELECTED AMRUT WATER INVESTMENTS COMPLEMENTING BULK SUPPLY

Scheme and recorded item	Amritsar	Ludhiana
AMRUT grounded water projects, number	5	1
AMRUT water project cost, ₹ crore	75.03	40.00
AMRUT 2.0 reservoir project, ₹ crore	44.75 for 12 reservoirs	Not included in the selected entries
AMRUT 2.0 continuous-supply pilot, ₹ crore	20.8462	20.08
Portal stage of continuous-supply pilot	Notice Inviting Tender issued	Detailed Project Report approved

Sources: AMRUT grounded-project statement dated 2 March 2026 [16]; AMRUT 2.0 city lists [17], [18]. Values are project costs, not audited expenditure. Amritsar's reservoir entry is shown as DPR approved. Sewerage, reuse and other sectors are excluded.

These entries show how a large bulk-water programme is accompanied by more local investments in storage and continuous-supply pilots. The scope of each package matters: Ludhiana's ₹400 crore sewerage entry in the AMRUT statement cannot be counted as drinking-water investment [16]. Equally, reservoir numbers in separate project descriptions should not be added without confirming that their scopes are distinct. A common asset register prevents both omissions and double counting.

B. The implementation sequence

A dated implementation report shows why construction sequencing deserves attention. In March 2025 the World Bank reported 77% progress on Amritsar's treatment-plant works and about 40% on transmission and reservoirs. For Ludhiana, it recorded the August 2024 contract signing and contractor mobilisation [19]. The percentages describe that reporting period. They illustrate different rates of progress within and between projects, rather than the construction position in September 2026.

The practical implication is that service depends on connected packages becoming usable together. Early completion of one component does not establish readiness of the whole supply route. Programme monitoring becomes more useful when it identifies the remaining link needed to serve each zone: a transmission connection, reservoir, rehabilitated main or household connection. This approach connects construction progress to the intended public benefit.

VII. POPULATION-RELATED DEMAND AND PUBLISHED SERVICE GAPS

A. Demand calculation and interpretation

The municipal project populations permit a transparent estimate of the population-related requirement. Two reference allowances, 135 and 150 lpcd, are used to show the effect of the service

benchmark and metropolitan planning norm [7], [9]. The calculation is a scenario based on published inputs; it does not reconstruct either detailed project report. For population P in persons and allowance q in lpcd:

$$Q_{\text{net}} = P \times q / 10^6 \quad (1)$$

$$Q_{\text{gross}} = Q_{\text{net}} / (1 - L) \quad (2)$$

Q_{net} and Q_{gross} are expressed in MLD. L is an assumed fraction of production lost before delivery of the modelled demand. The 20% and 40% values below are sensitivity assumptions, not measured loss rates. This physical delivery-loss fraction is also distinct from non-revenue water, which includes apparent losses and unbilled authorised consumption. The model excludes separately assessed non-residential allowances, peak factors, treatment-process use and reserve capacity.

TABLE VII. POPULATION-RELATED WATER REQUIREMENTS UNDER STATED ASSUMPTIONS

Scenario (MLD)	Amritsar 2025	Amritsar 2055	Ludhiana 2025	Ludhiana 2055
Net at 135 lpcd	195.89	298.49	310.50	540.00
Gross at 135 lpcd; $L = 20\%$	244.86	373.11	388.13	675.00
Net at 150 lpcd	217.65	331.65	345.00	600.00
Gross at 150 lpcd; $L = 20\%$	272.06	414.56	431.25	750.00
Gross at 150 lpcd; $L = 40\%$	362.75	552.75	575.00	1,000.00

Authors' calculations from project populations [11], [12]. Values are rounded to two decimals. Project estimates and projections are used as stated; all loss fractions are assumed.

At 150 lpcd, the projected population increase adds 114 MLD to Amritsar's net requirement and 255 MLD to Ludhiana's between the project years 2025 and 2055. The assumed delivery-loss fraction then changes the production needed to meet those requirements. For the 2055 populations, lowering that fraction from 40% to 20% reduces the calculated gross requirement by 138.19 MLD and 250 MLD respectively. These are scenario differences, not estimates of recoverable water.

The published capacity and population figures also merit a consistency check. At the 2055 population and 150 lpcd, Amritsar's population-related gross requirement with 20% assumed loss is 414.56 MLD, close to the stated 440 MLD capacity before other allowances. For Ludhiana, the same assumptions give 750 MLD against a stated 580 MLD plant. Even its

135 lpcd scenario gives 675 MLD. These calculations show how strongly the interpretation depends on the adopted norm, loss allowance, service population, staging and any supplementary supply. They do not establish an actual operating deficit or invalidate an approved design.

The useful planning conclusion is to read ultimate population, present construction scope and service targets together. If an investment serves only a phase of development, that phase needs an explicit population and service-area definition. If it is intended to serve the ultimate population, its complete water balance must reconcile the allowances and all contributing sources. This is a design-accounting issue exposed by the published summary figures.

B. Service gaps supported by published records

TABLE VIII. DOCUMENTED CONDITIONS AND THEIR SERVICE IMPLICATIONS

Evidence and date	Published condition	Interpretation
Municipal background descriptions; undated [11], [12]	Amritsar: 8–10 hours/day; Ludhiana: 10 hours/day.	The described systems fall short of the 24-hour benchmark; their access date is not a new measurement.
Singh and Sharma, published 2011 [20]	Amritsar water-balance estimate reported losses of about 62% of production.	Historical evidence that distribution losses constrained useful supply; not a current NRW estimate.
Ludhiana municipal notices carrying 15 September 2026 restoration dates [21]	Local interruptions associated with tubewell/transformer faults and pipe leakage.	Evidence of specific reliability events; no citywide frequency or affected-population rate is inferred.
AMRUT 2.0 city entries, accessed September 2026 [17], [18]	Continuous-supply pilots listed at preparation or procurement stages.	The entries establish planned interventions; they do not demonstrate operating 24×7 service.

The evidence in Table VIII supports a focused discussion of continuity, historical losses and local reliability. In the Amritsar study, water production and consumption were partly estimated because metering was limited [20]. Its value here is to establish that network inefficiency was a documented concern before the current bulk-water projects. Carrying the reported percentage forward as a present loss rate would erase both the age and the measurement limits of that study.

The September 2026 Ludhiana notices provide a more recent, but narrower, observation. They show that equipment faults and leaking mains can interrupt specific localities [21]. Such notices are useful evidence of service events, though they cannot establish average daily supply or compare performance across cities. Similarly, source-quality concerns cited in the World Bank's project rationale explain the case for improved treatment [10]; they are not a measurement of current household water-quality compliance.

No numeric shortfall is assigned to indicators without comparable published measurements. The review therefore makes no claim of current citywide failure in metering, collection efficiency, pressure or water quality. The service findings remain attached to the locations, periods and definitions for which evidence exists. This preserves a clear distinction between documented conditions and the planning actions that follow from them.

VIII. PLANNING IMPLICATIONS

A. Link development areas to the complete water system

Land-use plans and water action plans should identify the same service areas and population assumptions. Each proposed urban extension needs a traceable supply route from an available source to a household connection. For densification, local mains and storage require attention even where aggregate treatment capacity appears adequate. Reserving land for reservoirs and corridors at the planning stage can reduce conflicts during construction and protect the ability to expand the network.

A practical investment sequence follows hydraulic zones. Bulk conveyance, usable storage, distribution rehabilitation, valves, metering and connections can then be scheduled around the zones that each package serves. Works financed through PMSIP, AMRUT or municipal funds need compatible interfaces and commissioning arrangements. This helps turn separate construction contracts into an operating service.

B. Treat loss reduction as part of capacity planning

The demand scenarios show why augmentation and efficiency belong in the same appraisal. Production requirements rise when more water is lost before delivery, even if population and the service allowance remain unchanged. Metering at treatment

outlets and zone entries, together with reliable consumer records, provides the basis for distinguishing physical leakage from apparent losses and unbilled use. Investment in repairs can then be judged alongside additional production rather than being confined to routine maintenance budgets.

For continuous supply, the operating plan needs to address pressure, storage use, repair response and water-quality control throughout the network. A 24×7 label attached to a project title is insufficient to describe these operating conditions. Pilot areas offer a manageable scale for establishing dependable operation, provided the scope and achieved service are reported for the actual population served.

C. Manage demand according to urban function

Population-based requirements should be supplemented by land-use-specific allowances with an explicit accounting boundary. Amritsar's visitor-serving areas warrant attention to concentrated and seasonal demand. In Ludhiana, process uses and other non-potable requirements create a case for appropriately treated reuse where the required quality can be maintained. Potable demand, industrial self-supply and reclaimed-water delivery should appear separately in the city account to avoid double counting.

Demand management also has a spatial dimension. Network extensions need to include peripheral and low-income settlements in connection planning. A citywide increase in production can coexist with unequal access if the distribution and connection programme does not reach those areas. Connection policy, local network capacity and affordability therefore belong in the same planning decision.

D. Make source substitution measurable and resilient

The intended groundwater benefit of canal-based supply depends on actual substitution. A source-transition plan should identify which municipal wells are retired, which remain available for authorised contingency use, and how routine pumping changes. Groundwater protection must also extend beyond the utility because the regional aquifer serves other users. The district extraction findings make this distinction especially important in Punjab.

Canal-based systems require arrangements for interruptions, raw-water quality changes, power failures and treatment outages. Storage, backup

power, emergency interconnections and suitable reserve sources should be evaluated together. The objective is a dependable supply under operating stress, with contingency measures proportionate to the consequences of an outage. Source diversification and groundwater conservation can thus be pursued without assuming that a change of source guarantees continuity.

E. Finance and report the service that assets are intended to provide

Operating costs need a place in the investment decision from the outset. Electricity, chemicals, skilled staff, testing, repairs and replacement of equipment continue after construction funding ends. A service arrangement is more credible when revenue collection, public support and affordable access are considered against those recurring obligations. Contracts should define the interface between bulk delivery and municipal distribution, including responsibility for failures that cross organisational boundaries.

Reporting should connect expenditure and physical completion with commissioning and service performance. Coverage, quantity, continuity, water quality and complaint handling are most useful when their population base and reporting period are stated. Zone-level reporting can make unequal service visible while retaining a citywide account. This follows the movement in national policy from providing infrastructure towards maintaining the service it is intended to deliver.

IX. CONCLUSION

Urban water-supply development in North India can be understood as a cumulative process shaped by national planning, urban missions and local implementation. The Five-Year Plan framework established and subsequently broadened the role of public infrastructure provision. JNNURM connected investment with reform, while AMRUT and AMRUT 2.0 placed greater emphasis on household access and water security. Regional project records demonstrate the continuing breadth of this investment effort, although approved portfolios cannot stand in for achieved service.

Amritsar and Ludhiana illustrate how that framework operates when expanding cities move towards canal-

based bulk supply. Their project populations imply substantial additional demand over the design horizon, and published groundwater findings explain the pressure to reduce dependence on aquifers. Municipal background descriptions, historical water-balance evidence and specific service notices support discussion of gaps in continuity and network reliability within clearly stated periods.

The planning implication is to connect new bulk capacity with growth areas, distribution readiness, demand management and long-term operation. The scenario calculations make the sensitivity to population and delivery losses explicit; they also show why published capacity figures require interpretation alongside complete design assumptions. Infrastructure expansion contributes most clearly to urban water security when a functioning route to household service, a sustainable source arrangement and an accountable operating system develop together.

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