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District Drinking Water Planning for Sustainability in Maharashtra: Between Local and Global Scales

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Abstract: Sustainable rural drinking water is a widespread aim in India, and globally, from the household to district, state, and national scales. Sustainability issues in the rural drinking water sector range from increasing water demand to declining groundwater levels, premature deterioration of village schemes and services, inadequate revenues for operations and maintenance, weak capacity of water operators, frequently changing state and national policies, and destabilizing effects of climate change. This paper focuses on the special role of district-scale drinking water planning, which operates at the intersection between bottom-up water demand and top-down water programs. After surveying the challenges associated with bottom-up and top-down planning approaches, we present recent efforts to strengthen district and block drinking water planning in the state of Maharashtra. A combination of district interviews, institutional history, village surveys, GIS visualization, and planning workshops were used to advance district planning goals and methods. Results assess bottom-up processes of water demand; top-down water programs and finance; and intermediate-level planning at the district and block scales. Discussion focuses on potential improvements in district planning methods in Maharashtra.

Keywords: rural drinking water; district planning; sustainability; slipback; scale

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1. Introduction

Sustainable rural drinking water is a widespread aim in India, and globally, from the household to village, district, state, and national scales. In December 2019, the Government of India launched the Jal Jeevan Mission to provide functional household tap connections for all by 2024 [1]. This is a highly ambitious goal. As of July 2021, only 40.1% of rural households nationwide had taps, though that number is growing rapidly [2]. It varies greatly among states, from a high of 100% to a low of 10.6% (Figure 1). The state of Maharashtra has a record of innovative drinking water programs and is the focus of this paper. It has been reported that 64.3% of rural households have tap connections, albeit with considerable variability across districts that ranged from 38.3–100% coverage (Figure 2).

Tap connections are important, but they are not the only measure of access to safe drinking water. Do rural households receive the full 55 L per capita per day (lpcd) required by current national standards? Do they receive this amount year-round, or do they require tankers in dry months and drought years? Do villages provide equal service to different classes, castes, and tribal habitations? Do they collect sufficient and equitable water tariffs? Do women and girls still have to fetch water from distant wells or ponds? Is the water of good quality? Maharashtra reports generally good rural water quality, though some 6597 water sources had biological, fluoride, nitrates, iron, hardness, or other contaminants in 2020 [3]. Are rural water schemes maintained and sustained, or do they "slip back" to substandard levels of service?

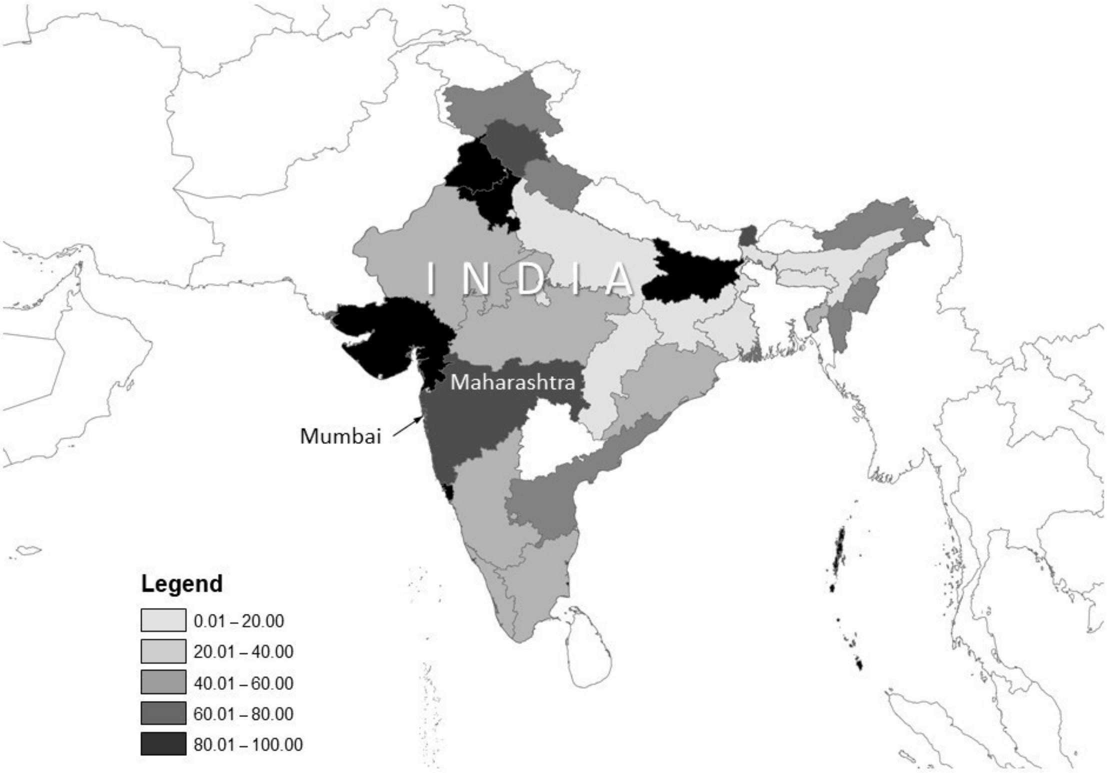

Figure 1. Percent of households that have 100% household tap connections by State. Map by author with 2018 DIVA-GIS GADM base map and State water data from National Jal Jeevan Mission dashboard, 7 July 2021.

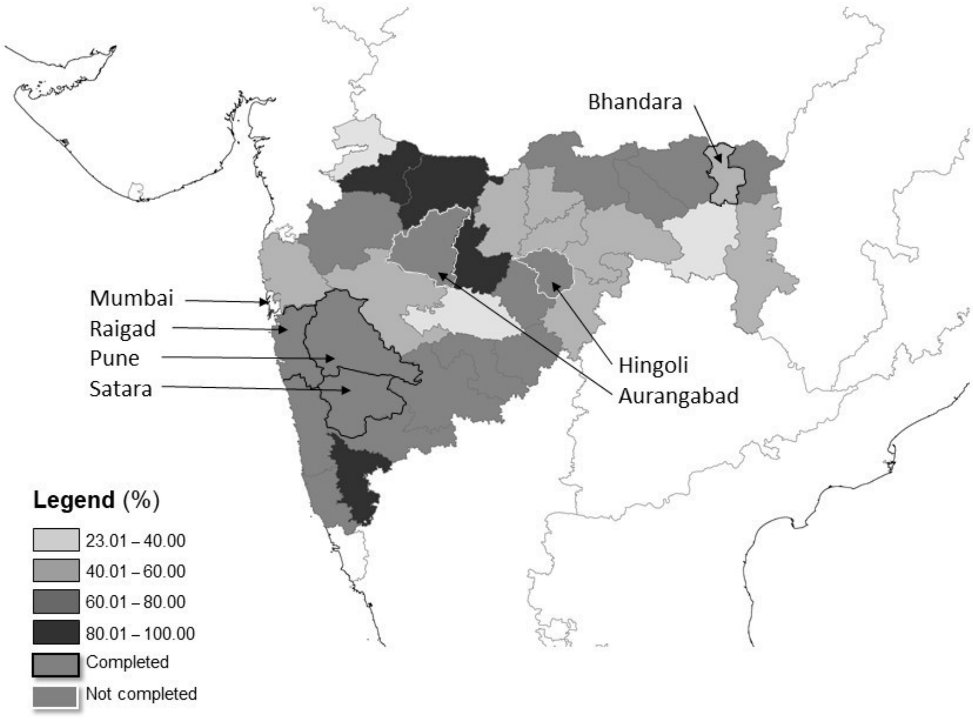

Figure 2. Map of Maharashtra indicating percentage of households reported to have 100% tap water connections. Map by author with water data from National Jal Jeevan Mission dashboard, 7 July 2021.

These are some of the key questions related to rural drinking water sustainability in India today. It should be noted that India is urbanizing rapidly, and that the boundaries between urban and rural are eroding. The Census of India defined rural places as those having fewer than 5000 residents, less than 75% of the male workforce engaged in non-agricultural activities, and population densities of less than 400 per square kilometer. An increasing number of settlements qualify as rurban or peri-urban. The national standard for rural domestic water service is 55 lpcd; while in peri-urban areas, it is 70 lpcd; and in urban areas 135 lpcd.

India's Integrated Management Information System (IMIS) reported that 1451 rural schemes in Maharashtra were non-functional in 2020 [3]. While that number represents less than 1% of the total, it indicates the types of sustainability problems that arise in villages. Sustainability in the rural drinking water sector is defined as the ability of a scheme to deliver a planned level of water service for the design life of the scheme, which is influenced by financial, institutional, environmental, technological, and social factors. The millions of new Jal Jeevan Mission piped-water supplies and tap connections under construction will need to address these sustainability factors in the coming years.

Access to safe and sustainable rural drinking water supplies in India and states such as Maharashtra has been addressed in two broad lines of research. At the larger scale, national and international agencies have monitored drinking water access with aggregate statistical databases such as those cited above. Developed at great expense and effort, these databases track progress toward drinking water goals and help identify problem areas [4]. In addition to monitoring progress toward universal access, they have been used to identify problems of sustainability in water schemes, known as "slipback", where projects fail before reaching the end of their design life, and water services revert to substandard levels. A related set of scientific databases in Maharashtra map local water availability, depletion, recharge, and quality, which shed additional light on the environmental sustainability of water sources e.g., [5].

A second line of research employs qualitative case study methods to identify socio-economic differences in access to safe drinking water and sanitation. It draws attention to systematic inequalities in access based on gender, class, caste, and legal settlement status at the household, village, and urban scales [6–8]. Detailed ethnographic studies deal with complex local problems faced in households and small numbers of villages. Although these studies provide valuable insights, they are sometimes difficult to generalize to the thousands of villages in any given district and to the many tens of thousands of villages in a state. Even so, the cumulative weight of qualitative case studies has had important impacts on drinking water policies designed to increase inclusion and empowerment of women and lower caste groups in Village Water Supply Committees and other means [9–11]. These steps have led to further evaluation of the actual vis-à-vis nominal significance of social mobilization and participation in drinking water planning. In addition to shedding light on discriminatory practices, this line of critical water research has assessed the local socio-economic impacts of neoliberal policies for water finance, e.g., service fees, volumetric pricing, full cost recovery, and private sector involvement. Those policies strive in principle for financial efficiency and sustainability but can exclude the poor [12]. Those impacts are increasingly addressed by subsidies, lifeline water rates, and other pro-poor protection policies. These developments have contributed to the reassertion of state support vis-à-vis private sector control, and to hybrid public–private water programs [13].

In both research literatures—large-scale data monitoring and small-scale case studies—relatively limited attention has been devoted to the intermediate level of water governance at district and block scales [14]. Districts in Maharashtra are known as Zilla Parishads while blocks are known as Panchayat Samitis. These levels of government collect and assess local data on water sources, access, technical systems, and services on the ground. Local public officials known as Gram Sevaks collect data on villages, known as Gram Panchayats, and report that information to Block Development Officers, who report in turn to District Zilla Parishad headquarters. District water engineers then supervise the preparation of Detailed

Project Reports for new schemes to improve village services, tailored to local water sources, infrastructure alternatives, and trends in water demand. Districts and blocks thus operate at an 'intermediate-level' between the centralized state and local village scales of rural drinking water planning.

There is a long history of top-down national and state water planning in India and many other countries. In recent decades, water agencies at all scales have declared that greater emphasis should be placed on bottom-up water planning approaches. The water planning literature has given less attention to the roles of intermediate scales of governance. This research on rural drinking water planning in Maharashtra examined all three perspectives: bottom-up, top-down, and intermediate-level planning. In light of recent policy trends, one might expect an increasing role for bottom-up planning. On the other hand, one might expect the legacy of centralized colonial and postcolonial planning to remain strong. Although there is little literature on it to date, one would expect the intermediate scales of districts and blocks to play important roles in aligning local village needs with state and national resources.

This research surveys the full range of bottom-up to top-down approaches. It gives special attention to understanding the current and potential role of intermediate-level planning. Our central argument is that intermediate-level governments can and should play an important role in rural drinking water governance. However, our initial observations on district drinking water planning were mixed. All districts currently prepare Annual Action Plans, as mandated by national and state programs. Those plans take the form of simple spreadsheets that list physical schemes requested by villages or their political representatives. The spreadsheets have no accompanying narrative or rationale for prioritizing projects. They provide limited information on current levels of water service, no explanation for service deficiencies, and little context for proposed projects. They do not specify the villages that need help with financial management, technical support, or community-based water management. Thus, the second argument advanced in this study was that district planning can be strengthened in ways that link drinking water sustainability at the local scale with program resources at the state, national, and international scales.

This research on understanding and strengthening district drinking water planning began in 2015 and continued through 2020. It involved a novel form of collaboration between an independent university-financed research team, the Government of Maharashtra's Water Supply and Sanitation Department, and the World Bank's Jalswarajya II (JS2) Project Management Unit based in Mumbai. Strengthing district water planning was one component of the JS2 project. The larger project involved 148 pilot projects in water-stressed and water quality-affected villages and 45 peri-urban villages. It developed a new monitoring and evaluation software system for the Government of Maharashtra.

Affiliation with the JS2 program enabled the district planning research team to work directly with Government of Maharashtra officials to investigate, develop, and refine planning concepts and methods at the state, district, block, and gram panchayat levels. When this research began, rural drinking water planning followed formal *Guidelines* written for the National Rural Drinking Water Program (NRDWP), which had been launched in 2009 and revised in 2013 [15]. As the research ended in late 2019, the Government of India's Jal Shakti (Water) Ministry launched the entirely new Jal Jeevan Mission, which called for piped-water supplies and functional household tap connections (FHTC) in all homes by 2024 [1]. The planning research team was able to arrange meetings at the State and District levels to show how methods developed in the JS2 research pre-positioned the Government of Maharashtra to address planning requirements of the new Jal Jeevan Mission.

This paper presents the results of research on district rural drinking water planning in Maharashtra. It begins with a conceptual framework that introduces the three core concepts of "sustainability", "planning", and "scale" as they apply to the rural drinking water sector in India and the state of Maharashtra. We then describe the research methods employed. These included district reconnaissance visits and repeat interviews; institutional history and analysis; mobile app survey development and testing; sustainability metrics and prioritization; data cleaning, GIS visualization, and interpretation; and plan formulation. These methods linked new planning tools (mobile app and GIS mapping) with templates for annual action planning and multi-year strategic planning.

The research results section is organized by scale. It begins with findings on bottom-up planning processes at the household and village scales, followed by lessons drawn from the analysis of top-down planning processes at international, national, and state scales. The major new findings involve the intermediate scale of district and block planning, which lie in-between the bottom-up and top-down processes. Those results include the feasibility of using a mobile app tool, a pragmatic framework for prioritizing village needs, GIS visualization, and plan preparation. The discussion section considers these advances in planning theory and practice at the district and block levels, the limitations and constraints encountered, and implications for drinking water sustainability in the Jal Jeevan Mission.

2. Key Concepts and Conceptual Framework

Research on sustainable rural drinking water planning at multiple scales requires an understanding of three core concepts: (1) sustainability, which is the drinking water objective; (2) planning, which is a means for meeting that objective; and (3) scale, which defines the contexts of planning and sustainability. These three concepts have special meanings in the rural drinking water sector in India.

2.1. Sustainability and "Slipback"

We begin with sustainability because it is a characteristic of the initial drinking water situation, and the aim of drinking water planning. India participates in various international sustainable development programs. For example, U.N. Sustainable Development Goal number 6 commits nations to, "Ensuring availability and sustainable management of water and sanitation for all" [16]. This is the primary sustainability goal in the water sector. At the national level in India, sustainability is conversely related to "slipback", which is the process by which water systems fail and revert to substandard conditions. Slipback often refers to physical failure, e.g., of a storage tank, pump, or distribution lines. It is also well recognized that causes of slipback involve more than infrastructure failures. A detailed study in Gujarat state by Marianna Novellino [17] employed the Dutch WASH Alliance's "FIETS" sustainability framework to identify multiple types and causes of slipback. This study did not apply the FIETS framework directly, but its research questions addressed each component of the FIETS acronym.

2.1.1. Financial

Financial components of sustainability include capital investment to build a water system and recurring revenues to operate, maintain, and replace those assets over time [18]. In India, major capital investment for larger physical infrastructure, such as deep wells, storage tanks, and pipe distribution networks often comes from the state. Operations and maintenance are local responsibilities that employ various financial mechanisms such as connection fees and monthly or yearly tariffs. Direct and indirect government grants help gram panchayats build and manage local water supply systems (e.g., through 15th Finance Commission Grants, state devolution grants, receipts from property taxes, etc.). Metering is rare but increasing. Financial slipback occurs when residents are unable or unwilling to pay or collect water fees. Unwillingness to pay may indicate problems of system design, management, and/or social inequalities in affordability and service [12,19]. In this study, field research questions focused on the adequacy of local connection fees, service fees, estimated O&M costs compared to fees collected, and funds allocated to asset management.

2.1.2. Institutional

The institutional components of sustainability include clear and transparent rules, roles, responsibilities, and accountability of actors involved in water management. These actors range from political leaders to bureaucrats, private entities, civil society organizations, as well as the water users themselves. Institutions may exist formally on paper or be what Elinor Ostrom termed "rules-in-use", which are unwritten practices [20]. In either case they need to be sustained on the ground if a water system is to operate for decades, long after it has been designed and built. A widespread institutional challenge in India involves frequent changes in water policies and officers [21]. At the local level, institutional rules are developed by Village Water Supply Committees (VWSCs), which are sub-committees of Gram Panchayats, but sometimes have limited capacity. Rules are implemented by village water operators, who are often semi-skilled or part-time workers with low wages. Institutional sustainability research questions in this project asked villages to rank their satisfaction with the performance of water operators and VWSCs.

2.1.3. Environmental

Environmental dimensions of sustainability and slipback in the hard rock basalt region of Maharashtra often involve groundwater depletion. Groundwater levels drop as pumping increases especially in irrigated areas. Watershed degradation reduces groundwater recharge. It also accelerates erosion, sedimentation, and flooding. Coastal districts of Maharashtra have problems with saltwater intrusion. Inland districts are drought-prone due to high rainfall variability [22]. Long-term climate change is increasingly perceived, but it has rarely been analyzed in the Maharashtra drinking water sector [23]. When a District Collector makes a drought declaration, eight measures are considered to conserve water. When existing water supplies fall below 20 lpcd, the state adopts the eighth option of providing water tankers to reach that minimum standard.

To understand and address these environmental problems, the Maharashtra Groundwater Survey and Development Agency (GSDA) is installing observation wells and analyzing water level data in each village. GSDA has prepared groundwater prospect maps at 1:50,000 scale for the entire state. At the local level, it has published groundwater recharge potential maps for every village. Community-based aquifer management is expanding under the auspices of JS2 and other government and non-governmental efforts. Our field research questions in the environmental category dealt with source water protection, annual rainfall anomalies, months of reliable groundwater water supply, and days of tanker water supply in a year.

2.1.4. Technological

Physical infrastructure is a key aspect of technological sustainability, and it is changing in important ways. A generation ago rural communities relied on handpumps, which were subject to failure or obsolescence, especially in areas of increasing groundwater demand. Attention then turned to community standposts which were supplied by ground surface reservoirs and located within a standard walking distance from residential dwellings. The shift toward piped water supply and tap connections was underway in more prosperous neighborhoods and villages. In 2019, the Jal Jeevan Mission mandated this technology for all households, recognizing that it is not always feasible in especially remote and hilly locations. A typical piped water supply relies upon one or more tubewells or a nearby surface reservoir. Water is pumped through a rising main to an elevated storage reservoir. From there it flows through plastic pipes to different zones of a village, often for an hour each day or every other day. Residents store tap water in plastic water tanks either at ground level or in tanks on their roofs for later use. While piped water technologies provide higher levels of household service, they depend upon higher quality construction, operation, and maintenance—or they slipback [17,24]. Common failures involve distribution line breaks, delayed pump maintenance, and water tank failures. Field research questions in this field focused on the frequency and reliability of water service (days per week, hours per day); and the frequency and duration of system failures.

2.1.5. Social

Social factors affect the sustainability of drinking water systems. They include traditions of community collaboration, equity, and effective leadership [6]. Countering those ideals are inequitable patterns of water service for different caste, ethnic, or class groups; and heavy burdens on women and girl children to fetch water [7,8,10]. Conflicts between different political parties, clans, and family groups also affect the sustainability of local water systems. Some social problems such as caste discrimination are observable in the field but not readily admitted by officials as they are sensitive, illegal, or addressed by other departments. Health problems for women (e.g., spino-muscular problems associated with water carrying) and children (e.g., diarrheal disease) are not included in drinking water databases [25]. Correlations can be made between levels of water service, demographic, and socio-economic data. Demographic shifts include seasonal migration and the growth of "floating populations". Estimating population growth rates is reported to be a major challenge for rural drinking water systems. Three methods are used in Maharashtra (arithmetic, geometric, and graphic extrapolation), but they are all based on dated 2011 Census data. Additionally, it is difficult to determine the relative importance of distance, settlement dispersal, and social status for different levels of water service. Field research questions on social aspects of sustainability included estimated population, floating population, and women's time spent fetching water.

2.1.6. Summary

Taken together, these five topics help assess the sustainability of drinking water systems, patterns of slipback, and criteria for designing more sustainable systems. To date, villages have focused most on the sustainability of groundwater sources and physical infrastructure. Financial and social factors are recognized but not proactively addressed. Longer-term issues of environmental sustainability related to land use, land cover, and climate change receive less attention, though that is starting to change with advances in drinking water planning [17,23].

2.2. Planning

Drinking water planning is a hybrid field that involves several subfields in different disciplines. There are few professional rural drinking water planners. Professional planners tend to focus more on urban land use than rural water issues. Although some rural water planners work in universities, there are no formal degree programs, which means that persons charged with preparing plans often lack an understanding of basic planning theory and methods. They draw upon practical experience more than professional training. Rural drinking water planning in India is highly influenced by large scale government financed programs and the guidelines prescribed therein, as well as technical manuals prepared by central and state engineering organizations. That said, several types of planning have relevance for rural drinking water.

2.2.1. Physical Planning

The largest group of water planning practitioners in India come from civil and environmental engineering in middle level positions. Civil engineers have training in applied hydrology, systems design, soils, construction specifications, cost analysis, and contracting [26]. A generation ago Maharashtra and other states drew as much upon public health engineers for water and sanitation programs as civil engineers. These days, civil engineers take the lead in site planning and design for water supply, drainage, and wastewater systems.

2.2.2. Community-Based Planning

Graduates in the social sciences and rural development provide leadership in community-based planning. This work includes social survey methods, water needs assessment, and social mobilization. Community planners work intensively with villages to identify problems, priorities, local preferences, and constraints [27]. They may work for NGOs or as public officials. In recent decades, national and state drinking water programs have prescribed active community participation in planning, construction, and maintenance. District offices have employed social mobilization specialists on contract, and have also contracted Implementation Support Agencies, usually NGOs, for community mobilization and capacity building.

2.2.3. Water Resources Planning

This field is dominated by civil engineers and hydrogeologists in bureaucratic organizations responsible for water management, irrigation systems, and groundwater surveys. Their work shapes state policies on water resource estimation and allocation. Drinking water is the first priority use in Maharashtra water policy, though irrigation is the largest and most powerful water use sector. Current policies call for integrated multi-use water planning to address increasing water demand especially in drought years. In practice, different water departments undertake their own planning methods for projects as per their own agency guidelines and available funds.

2.2.4. Financial Planning

Much of the planning in water agencies involves program finance, budgeting, revenues, expenditures, and accounting. Economic planners often have backgrounds in public administration, including the elite national and state administrative services. They focus on allocating scarce resources among projects that address various socio-economic objectives. Notwithstanding the distinguished tradition of economic development planning in India, it is interesting to note that the Indian Administrative Service curriculum does not currently include modules on planning theory and methods [28].

This research on drinking water priorities contributes indirectly to financial planning. It conducted repeated interviews with bureaucrats, engineers, and community planners to clarify drinking water supply problems, needs, and emerging alternatives. In focusing on district-scale planning the research adopted the principles that: (1) all villages in a district should be considered, rather than a sample of villages; (2) local-village needs should be prioritized based on primary data collected from the villages; (3) village conditions should be rated for ease of comparison and prioritization; (4) these conditions should be mapped with consistent color codes for visual identification of priority villages and clusters; and (5) the respective planning roles of districts and blocks should be clarified and supported.

2.3. Scale

In the rural drinking water context, “scale” refers primarily to “levels” of water management and governance, from the household to village, block, district, state, national, and international levels [29,30]. There is emerging concern at the global level as well about effects of climate change on drinking water supply, e.g., by the United Nations Intergovernmental Panel for Climate Change (IPCC). The emphasis on levels of water governance differs from quantitative measures of scale in the hydrologic and ecological sciences (e.g., of hydrologic response in relation to watershed size). We briefly introduce the major levels of water governance here, beginning with the smallest, and say more about them in the results section of the paper.

A significant body of rural drinking water scholarship focuses on the household scale as the smallest level of analysis. It is also recognized that intra-household water roles and burdens vary. The Census of India aggregates household data on water, sanitation, housing and demographics to the village level. The term village has three distinct meanings. It refers at the smallest scale to local habitations or clusters of homes. Officially, it refers to larger gram panchayats, which are recognized as local self-governments under the constitution of India. Gram Panchayats may have one or more revenue villages, which is the level of census data collection and mapping.

Blocks, also known as talukas or tehsils, are larger scale local governments that comprise roughly a hundred villages. Districts or Zilla Parishads are the next highest level. They may have roughly a dozen blocks and over a thousand villages. The 73rd Amendment to the Constitution of India strengthened all three of these local levels of government—districts, blocks, and gram panchayats—which are collectively known as Panchayati Raj Institutions by devolving more subjects to them, including rural drinking water and sanitation.

India has a federal system of government comprising 36 states and union territories. Constitutionally, water is primarily a state subject. The central government retains control over interstate and international waters, as well as water issues of national concern. States have control over all other aspects of water resources planning, which has historically focused on irrigation agriculture, industrial water use, and the scientific agencies that support them. Maharashtra officially devolved drinking water and sanitation responsibilities to local governments over a century ago, but it retained control over large-scale funding programs through its Water Supply and Sanitation Department (WSSD). Notwithstanding many policies aimed at decentralization and devolution over the past century, the Government of India has likewise retained a substantial level of control over planning for local drinking water systems. As might be expected, these dynamic relationships have a direct bearing on the operation of bottom-up, top-down, and intermediate-level planning processes.

2.4. Summary

These three components—planning for sustainability across scale define the conceptual framework employed here for research on the district level of drinking water planning in Maharashtra.

3. Methods and Tools

Having introduced the key concepts of sustainable rural drinking water planning, we proceed to the research methods employed. They are grouped under six main headings.

3.1. District-Level Reconnaissance and Repeat Interviews

The first season of field research involved extended field visits and semi-structured interviews in three initial case study districts—Raigad (3 visits), Pune (8 visits), and Aurangabad (6 visits) (Figure 2). Raigad is a coastal district. Pune district had the most visits because it has the state headquarters for the Ground Water Survey and Development Agency and other scientific organizations. Aurangabad faces frequent droughts. Three districts were added in subsequent field seasons to assess the prospects for streamlining planning methods in group workshops—Satara, Bhandara, and Hingoli. Interviews with district officers identified commonalities and variations in current planning practices. They helped refine our initial assumptions and arguments about district level planning and governance. Interviews with new district officers appointed during the study period gave an indication of the range and varieties of official approaches to planning. In addition to district CEOs and Deputy CEOs for Water and Sanitation, interviews included district engineers, social mobilizers, groundwater specialists, and GIS officers in the Ground Water Survey and Development Agency. These interviews helped identified positions that are currently filled with contract vis-à-vis permanent employees. Detailed organization charts were prepared for the array of drinking water officers and responsibilities at district, block, and village scales. Reconnaissance visits to selected Jalswarajya 2 case study villages in each district involved meetings with gram panchayat officers including the current sarpanch (elected leader); visits to existing water facilities; and discussion of current water management issues and options. In many cases, the village visits involved block as well as district officers.

3.2. Institutional Analysis and History

There is a large amount of literature on the evolution of local governance in India. Debates about devolution or decentralization of government functions date back to colonial times from 1857 onwards [31,32]. In addition to this secondary literature, we reviewed the primary evidence of current national and state policy documents, statutes, and planning reports. Some of these materials argue for districts as the principal level of intermediate governance, while others prefer blocks. A separate study has retraced the historical geography of these rural drinking water institutions in India [21]. It highlighted the role of the state in drinking water supply, identified the five enduring levels of water governance, and underscored the challenges associated with frequent changes in officer postings and policies. This institutional analysis shaped the organization of this study's findings in three major sections presented later in the paper: (1) bottom-up planning at the household and village levels; (2) top-down planning from the international, national, and state scales; and (3) intermediate-level planning at the district and block scales, which in theory link bottom-up water needs with top-down government support.

3.3. Mobile App Survey Development

As noted above, we began with the observation that existing planning spreadsheets include a minority of the villages in each district and provide little information on current levels water service or sustainability. This research began by developing modified spreadsheets in collaboration with district and block officers that gave greater emphasis to water problems and services. Those methods helped refine survey questions and ranking methods. However, it was soon realized that the use of spreadsheets for thousands of villages posed significant logistical challenges for data entry, data quality control, and aggregation. That led to the adoption of the KoBoToolbox mobile app for humanitarian assistance surveys [33]. Draft survey templates were developed with drop-down menus and radio buttons to streamline data entry and avoid transcription errors. After testing with district and block officers, and translation into Marathi, training workshops were held with gram sevaks who are local officers responsible for individual villages (Figure 3).

Figure 3. Gram sevak training session in Raigad District (author photo).

Each gram sevak is responsible for several villages. They filled out one mobile app survey for each of their villages. Gram sevaks adjusted to challenges of poor internet reception in remote areas by using offline methods. Intensive gram sevak training workshops supported by district and block officers proved effective in eliciting surveys from over 80% of the villages in four of the original six case study districts—Raigad (83%), Pune (86%), Satara (86%), and Bhandara (87%) (Figure 3). Two districts showed interest but did not complete the surveys due to other commitments (Aurangabad and Hingoli).

3.4. Sustainability Metrics and Prioritization

The village survey included a broad range of water service and sustainability questions for planning purposes. We later adapted that survey to Jal Jeevan Mission requirements in 2020. Sustainability metrics were grouped the following categories:

- Village name and demographics—including population estimates.
- Service delivery—including months of water service per year, days per week, and hours per day, both in the dry pre-monsoon months and the rest of the year.
- Operations and maintenance—including fees and costs.
- Water management capacity—of operators and VWSCs.
- Liquid waste management—which sometimes worsens as water supply improves.
- Water innovations—special activities developed in the village.
- Water source protection—including GSDA well safety card.
- Water quality problems—identifying major categories of contaminant problems (physical, chemical, and biological).
- Water asset management—including records of asset condition, assessment, and replacement.
- Village aspirations—goals for improving water service.
- Village action plan—status of plan preparation by villages.

The following eight key variables were selected for ranking from 1 (best) to 5 (worst) to help prioritize villages for different kinds of technical, social, and financial support.

- Groundwater availability—from 12 mons/yr (best = 1) to 8 mons/yr (worst = 5)
- % Household tap connections—from 100% (best = 1) to 0–40% (worst = 5)
- PWS days/week (summer)—5 or more (best = 1) to once a week (worst = 5)
- PWS h/day (summer)—3 h/day (best = 1) to less than $\frac{1}{2}$ h/day (worst = 5)
- PWS h/day (non-summer)—3 h/day (best = 1) to less than $\frac{1}{2}$ h/day (worst = 5)
- Tanker provision—none (best = 1) and some (worst = 5)
- LPCD—more than 41 lpcd (best = 1) to less than 39 lpcd (worst = 5). These values now have to be updated to the new standard of 55 lpcd.

Gram sevaks enter the overall condition for each question in each village. The mobile app then assigns numerical scores to those conditions, which is a further advantage over field spreadsheet methods that enter scores rather than conditions. The scores range from 1 (best) to 5 (worst). The numerical values are then analyzed as individual variables, and summed to produce aggregate rankings with 8 being the best possible aggregate score (all "1 s") and 40 being the worst possible aggregate score (all "5 s").

3.5. Data Cleaning, GIS Visualization, and Communication

In the current iteration, significant data cleaning is needed to remove duplicate and partial records caused by multiple data entries for a village. Data cleaning occurs in spreadsheet downloads, which are then analyzed and uploaded into GIS database (.dbf) files. The eight individual variables are charted and mapped, as are the aggregate distributions of scores. These tools help visualize priorities for groundwater source strengthening, infrastructure investment, O&M support, and water management support. Singh et al. have published an example of this analysis [34].

3.6. Plan Formulation

A simple template was developed for preparing written drinking water plans. The written plans have three parts: (1) an annual action plan based on the newly prioritized villages; (2) an expanded program of socio-economic support for O&M, asset management, and water operator training; and (3) a multi-year strategic plan for goals that require from three to five years to complete (e.g., the Jal Jeevan Mission's tap connections for all by 2024 policy).

3.7. Synthesis

These research methods shed light on current practices of bottom-up, top-down, and intermediate-level planning for drinking water sustainability. Interventions, such as the mobile app, prioritization methods, GIS visualization, and plan preparation offered insights into planning innovations and constraints.

4. Results

Results from this research are organized under the three broad headings of bottom-up, top-down, and intermediate-level approaches to sustainable drinking water planning. Collectively, they shed light on all three processes, with special emphasis on the intermediate district and block scales. They also help answer core research question about ways for strengthening the role of districts and blocks in linking bottom-up water demands with top-down program resources.

4.1. Bottom-Up Planning Results

The principle of subsidiarity argues that water issues should be addressed at the most local competent scale. Bottom-up planning processes have the benefits of local knowledge and local empowerment.

4.1.1. Household Scale

This research did not collect primary data at the household scale, due to our focus on districts that have thousands of villages and tens of thousands of households. However, we did analyze census data collected at the household scale both for demographic context and for key drinking water and sanitation variables (e.g., water supply source, latrine type, and drainage) with an emphasis on peri-urban revenue villages [35]. Interestingly, that research showed that water and sanitation services were positively correlated with the number of households in peri-urban villages and towns. The 2021 Census results will soon displace 2011 data and shapefiles, which will enable a renewed focus on household level data aggregated to village and larger scales. When doing so, it is important to consider research on household water (in)security, which has important implications for planning problems and processes [36].

4.1.2. Village Scale

Villages have very deep roots in Indian history [37]. Some national leaders such as Mahatma Gandhi regarded them as the foundation or building block of society [38]. Other leaders like Jawaharlal Nehru and Babasaheb Ambedkar were more critical of village conditions and governance. This research surveyed revenue village drinking water conditions and problems in four districts, with a response rate of over 80% in each case [34]. For planning purposes, this constitutes a successful demonstration of village data collection by local gram sevak officers. The Maharashtra Water and Sanitation Department has indicated its interest in extending the mobile app data collection method for Village Action Plans under the new Jal Jeevan Mission.

That said, research at the village scale identified several planning challenges, including complications in the meaning of the term "village", which as noted above has three main uses in India [39]. The gram panchayat is the most local level of official government in India. It is thus the main legal entity for local planning, and must address institutional and financial aspects of sustainability. However, in spatial terms it is also the largest and most heterogenous sense of the term village. Gram panchayats consist of one or more revenue villages, a concept that arose in the pre-independence period for tax assessment and collection purposes. From the late-19th century onwards, Census of India returns have aggregated household data to the revenue village level. In recent decades, GIS shapefiles have been prepared for revenue villages, which are indeed the only local shapefiles available on an all-India basis. Mapping was shown to be a valuable and largely untapped asset for drinking water planning, but it requires strategies for linking revenue village data with gram panchayat planning needs [39]. The third and smallest meaning of the word village refers to habitations or wadis. A gram panchayat may have from several to a dozen or more habitations. Habitations have special relevance for sustainable drinking water planning due to their site-specific social, spatial, technological, and environmental conditions. Habitation water data are collected in the Government of India's IMIS database. But habitations are not consistently listed or enumerated across the many different national, state, and district agency databases, which greatly complicates or precludes comparative analysis at the local scale. The Jal Jeevan Mission's IMIS database currently tracks water service at all three scales of village water planning [2,3]. Bottom-up data integration across habitations, revenue villages, and gram panchayats in the IMIS database will be a long-term planning priority [39].

4.1.3. Transition to Intermediate-Level Block and District Scale Results

Bottom-up village needs are aggregated to the block level by Block Development Officers, and then to the district level in annual action plans. These represent extensions of the bottom-up approach. However, the institutional analysis and history undertaken in this study revealed that district and block plans are also the products of top-down processes. Before proceeding to intermediate level planning that links bottom-up and top-down approaches, we need to review findings regarding the legacy and logic of top-down drinking water planning.

4.2. Top-Down Planning Results

While many policies have promoted decentralization and devolution, this research observed a strong legacy of top-down planning. Top-down planning includes international, national, and state government agencies and policies, sometimes in collaboration with international and national NGOs. Many if not most of these large-scale organizations advocate bottom-up drinking water planning in principle. However, research on their institutional history reveals that even this subsidiarity principle has involved top-down processes [21]. During the colonial period, for example, state statutes listed drinking water and sanitation as a local government responsibility. National reports on devolution likewise listed water and sanitation as local subjects. However, the center and state have retained a high degree of oversight and control. They have also varied on which of the three levels of Panchayati Raj local government has primacy—the district, block, or gram panchayat. As a separate study reviewed these long-term institutional processes, this section concentrates on current top-down policy results [21].

4.2.1. International Water and Sanitation Planning

National and state documents sometimes refer to international drinking water standards, policies, and monitoring data. For example, the U.N. World Health Organization's (WHO) *Guidelines for Drinking-Water Quality* are often cited. Now in its fourth edition these *Guidelines* establish water quality standards and testing methods for rural and urban drinking water quality, which have informed those adopted in India. For example, 20 lpcd is deemed "minimal access" and 50 lpcd "intermediate access". In 1990, WHO and UNICEF created a Joint Monitoring Programme (JMP) to track progress toward universal access to safe drinking water and sanitation in rural and urban households, schools, and health care facilities [40]. The JMP was later emulated and superseded by the much more detailed IMIS database developed by the Government of India's National Informatics Centre [3]. More recently, U.N. Sustainable Development Goal Number 6 calls for access to safe water and sanitation for all, and is frequently noted in national policy documents. Interestingly, we did not observe instances where international deliberations on global climate change were linked with rural drinking water and sanitation in Maharashtra [23]. Drinking water sustainability at the national level in India is connected more with human health, socio-economic well-being, and equity than with global environmental change.

4.2.2. National Rural Drinking Water Planning

The strongest examples of top-down planning were observed in documents and procedures prepared at the national level. India has a long tradition of national economic planning, dating back to the government of the first Prime Minister Jawaharlal Nehru. The Government of India Planning Commission prepared five-year plans and planning reports that addressed every sector, including those related to water and the environment. Although the Planning Commission was dissolved in 2014, top-down planning continues.

As a federal system of government, the Indian constitution deems most water issues to be State subjects. The Government of India has had many blue-ribbon reports about devolving subjects such as drinking water and sanitation to state and local governments [31]. Devolution gained significant recognition with the 73rd Amendment to the Constitution in 1992, which gave increased authority to the three levels of Panchayati Raj Institutions (district, block, and gram panchayat), a step that coincided with related liberal reform policies.

Notwithstanding these announced trends toward decentralized governance, the Government of India has maintained a strong top-down planning role in rural drinking water and sanitation programs. The two national drinking water programs pertinent to this study have laid out prescriptive planning guidelines, reinforced by massive federal funding and state cost-sharing. The National Rural Drinking Water Program (NRDWP), launched in 2009 prepared revised *Guidelines* in 2013 that called for Village Water Security Plans, District Water Security Plans, and State Annual Action Plans. It specified the principles and criteria for preparing those plans. Interestingly, we did not observe examples of village water security plans in our field work. We found that district Annual Action Plans took the form of standardized lists of proposed schemes compiled for funding under the NRDWP. Significantly for this research, the NRDWP specified that project contracting was to be undertaken directly by gram panchayats, rather than by district agencies. But when the center devolved national block funding to the states in 2016–17, the State of Maharashtra increased its top-down Mukhyamantri Rural Drinking Water Programme funding, which gives a stronger role to districts than to gram panchayats.

Another important development at the national level involved reorganization of diverse water agencies under the umbrella of a single Jal Shakti Ministry in 2019. Integrating the rural drinking water department with irrigation, hydropower, and environmental agencies will take time, but it would hopefully precipitate more comprehensive policy approaches to sustainability at the national level. It also remains to be seen if it contributes to institutional integration and sustainability at the intermediate-level.

In the interim, the national Jal Jeevan Mission's *Operational Guidelines* replaced the NRDWP in December 2019. Given their fast-track implementation, these guidelines may go even further in a top-down direction by prescribing detailed surveys to be used when preparing village, district, and state annual action plans [1]. These surveys are similar to those in our mobile app, but place less emphasis on water service delivery. The new JJM program boldly specifies the planning objective: piped water supply and household tap connections that deliver 55 lpcd for all. To its credit, JJM gives increased attention to environmental drainage of gray water, which tends to increase with the adoption of household tap connections. Funding for drainage improvements is made available under the Swachh Bharat Mission, which is managed under the same national ministry. The Jal Jeevan Mission's financial incentives include 50% cost sharing for piped water supply schemes in most states to be disbursed over a period of four years. The Government of India has thus specified the goals, standards, technologies, planning methods, funds, and timeline for local water planning and implementation. This fast-track approach to a high level of piped water service is ambitious on many levels, but its speed raises concerns about the sustainability of the groundwater supplies, piped water systems, and tap connections a decade after construction (cf. [24]).

4.2.3. State Rural Drinking Water Planning

Water is a state subject in India, and states such as Maharashtra have multiple water programs and agencies. Rural drinking water comes under the Water Supply and Sanitation Department (WSSD), headquartered in Mumbai, with offices in each of the state's 36 districts. The state has primary responsibility for implementing national and state rural drinking water programs. It does so in part through the Water and Sanitation Support Organization (WSSO) for administrative support, the Ground Water Surveys and Development Agency (GSDA) for scientific support, and the Maharashtra Jeevan Pradhikaran (MJP) for engineering support on larger projects. This research involved multiple consultations and briefings with state officials in each of these organizations, and close study of state drinking water policies.

Over the five-year period in this study, state drinking water programs, policies, leadership changed relatively often. The Government of Maharashtra undertook a major loan with the World Bank called the Jalswarajya II Project. In some years, it expanded the state's Mukhyamantri Rural Drinking Water Programme. It navigated shifts in the Government of India's NRDWP and JJM drinking water programs; and its conclusion of the massive Swachh Bharat Mission sanitation program which eclipsed drinking water planning up till 2019. As state and national water funding programs expanded, decentralization policies were offset by top-down procedures and controls [41].

State bureaucratic leadership changes asynchronously on shorter timescales of 2–3 years. Senior civil servants hold their appointments for an average of only 2–3 years, after which they may be transferred to other locations and agencies. The process of frequent officer rotation has its own logic, which has a long history, but it can work against the sustainability of programs that may take 5–10 years to achieve. In operational terms, the Maharashtra state government operates through written rules known as Government Resolutions/Orders that stipulate how statutes should be interpreted and implemented. Federal and state election cycles also affect project targets, as election rules constrain new policies or projects during elections to limit political interference. Each of these processes operates with different frequencies. Collectively, they create a highly dynamic, frequently changing, sometimes turbulent, planning environment. To implement programs in a dynamic context, policy direction tends to flow from the center to the states, and from the states to districts and villages in a rapid hierarchical top-down manner.

It is important to underscore that states such as Gujarat, Maharashtra, and Telangana have independently developed innovative drinking water programs. The Jalswarajya I and II programs of the Government of Maharashtra and World Bank are good examples [13]. Jalswarajya II (2014–2020) created a pay-for-results program that required pilot projects to demonstrate results for the release of funds. It launched a new state monitoring and evaluation database, and called for strengthening intermediate-level district water planning as described below.

4.3. Intermediate-Level District and Block Planning Results

The core thesis in this research is that that intermediate-level district and block governments play a pivotal planning role in coordinating village water needs with state financial and technical resources. This thesis has three parts, first, that districts and blocks already perform this intermediating role albeit in varying ways and degrees in different districts; (2) they can perform this role more fully if supported by the types of planning tools and methods employed in this study; and (3) they may be able to perform this role more fully if constraints identified in the study are reduced.

To understand this level of governance, it is useful to visualize the spatial relationships among districts, blocks, and villages. Figure 4 depicts those three levels of government in the Pune District case study, which is one of 35 districts in Maharashtra. Pune district has 13 rural blocks or talukas and 2 urban blocks. It is noteworthy that the western tier of blocks follows the relatively high elevation hilly terrain of the Sahyadri mountains (also known as the Western Ghats), which has high rainfall, steep slopes, and rapid runoff. Villages are relatively small in size and population. The central blocks in Pune District have mesic rainfall conditions, and higher levels of population. Eastern blocks are semi-arid with extensive less-densely populated villages. There are similar rough correlations between block boundaries, climate, terrain, water resources, and population density in other districts of Maharashtra. The following sections discuss strengths and weaknesses of water planning at the district and block scales.

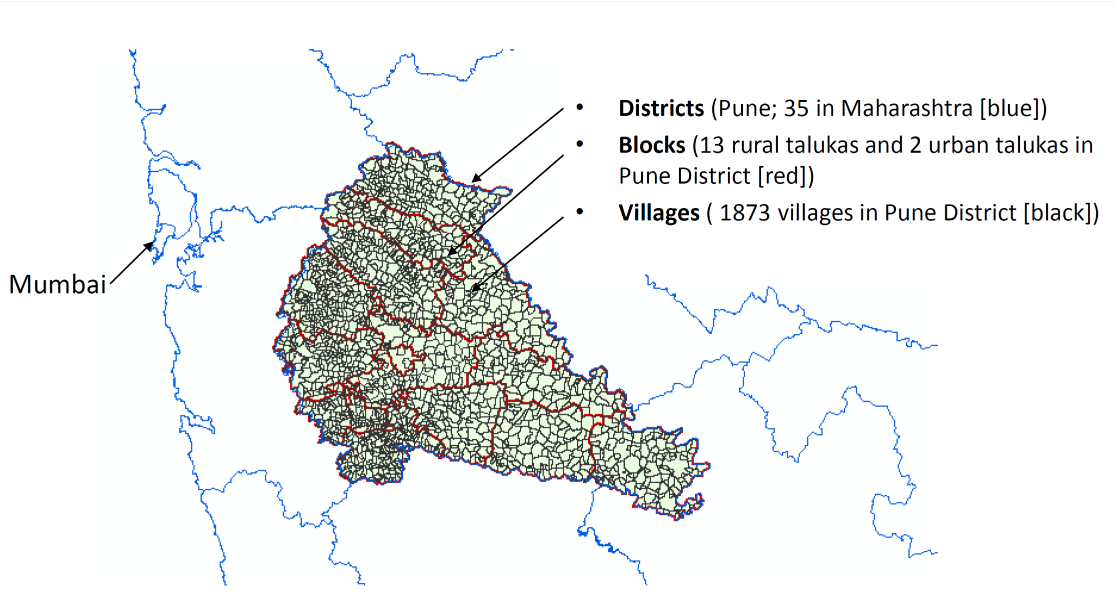

Figure 4. Districts, blocks, and revenue villages in Pune District, Maharashtra.

4.3.1. District Drinking Water Planning

In the context described above, districts respond to bottom-up requests and top-down commands. They must be prepared to respond to the latter on short notice, and adapt to rapid changes in policy implementation. District officials report that they also receive many requests from local politicians, which they find challenging. As in state government, higher-level district officials may change positions every two to three years. District CEOs and Deputy CEOs for Water and Sanitation oversee the preparation of district Annual Action Plans and Detailed Project Reports. District Collectors prepare annual drought plans that are updated quarterly as droughts unfold.

District line staff tend to have longer postings than officers at higher levels. District staff tend to have either engineering, geoscience, or social science backgrounds relevant for preparing plans. They have good connections with large networks of local block and gram sevak officers who collect and provide enormous amounts of information on a regular basis. District staff have direct familiarity with communities and conditions on the ground, though rarely at the more detailed level of block officers. This knowledge keeps them informed about major drinking water sustainability problems from groundwater depletion to contamination and infrastructure failure.

In terms of specific planning interventions employed in this research, we found that District line officers are increasingly familiar with mobile apps for data collection. However, their ability to initiate and supervise mobile app data collection varied. Four districts were successful (Raigad, Pune, Satara, and Bhandara). Of the two that were not, one faced drought response pressures (Aurangabad), while the other had limited logistical support (Hingoli). Within the successful districts, some officers had high rates of data collection up to 100% while others struggled to achieve timely responses. In Pune District, when the district identified specific "block coordinators" among their staff, which helped achieve steady progress in data collection and provide support for those that lagged. District officers helped refine water service criteria for prioritization. All districts showed a high level of interest in GIS mapping for visualizing priority villages. In Bhandara district, officers discussed and explained conditions in villages that stood out on the maps. In Pune and Aurangabad Districts, officers helped draft multi-year strategic plans to address longer-term issues like peri-urban planning and drought planning, and identify geographic problem areas that face continuing shortages or contamination. The research team prepared written plans for demonstration purposes, which need to be replicated with district officers as authors, for which training in professional writing would be helpful.

In terms of resources, districts have most of what they need to prepare meaningful drinking water plans: staff, data, experience, and general computing equipment. However, they also face constraints. As noted above, there is no formal training in planning concepts and methods. There are opportunities for innovation in the senior ranks but serious time constraints on pursuing them. District officers have to follow detailed national and state guidelines to secure financial resources, which limits time and scope for innovation. Some middle-level district officers showed keen interest in planning workshops. At present, however, there appear to be few incentives for middle level officers to undertake new planning initiatives. The top-down tradition specifies planning formats, challenging implementation targets, and unanticipated demands that district officers must fulfill. The hierarchical aspects of institutional culture can constrain mid-level initiative and be difficult to change, but that too could be addressed through professional training and certification in planning methods. In addition, each district needs to have at least one GIS qualified planner with ready access to open source GIS software.

4.3.2. Block Drinking Water Planning

We placed less initial emphasis on blocks in the original study design. The rationale was that Maharashtra has historically emphasized the district level of Panchayati Raj governance. As per current statutes in Maharashtra, districts and gram panchayats have responsibility for water planning. Blocks do not have a legislatively stipulated role, but this study revealed their current and potential importance. The lead persons at the block level are Block Development Officers (BDO) who are highly capable. BDOs convened hundreds of gram sevaks in mobile app training and data collection workshops. They set data collection deadlines and addressed field survey challenges. Gram sevaks reporting to BDOs proved to be the ideal persons to complete mobile app data collection at the village level. They can complete most aspects of the survey from their local knowledge or by reference to readily available village sources. They have a fine-grain understanding of sustainability and slipback on the ground.

As illustrated in Figure 4, blocks have relatively coherent physiographic and climatological characteristics. Although block boundaries do not correspond to specific hydroclimatic or watershed boundaries, they are more homogeneous than districts like Pune that span from the humid high elevation Western Ghats to drought-prone plateau lands in the east. Each block has an official weather station in its headquarters town, which makes it an important scale for assessing hydroclimatic variability, drought characteristics, and water budgeting of the sort called for in Jal Jeevan Mission District Action Plans. Planning inputs and insights from block officers are thus invaluable.

Constraints at the block level are of two main types. The first involves mobile app challenges in rural areas with poor internet service. This was partially offset by downloading the app in town and filling it out offline. A second challenge underscored at the state headquarters level is local staff time. At a managerial level, BDOs face serious time constraints. At the implementation level, gram sevaks have heavy responsibilities for data collection and monitoring across all sectors of village life. A partial solution to these challenges involves designating coordinators in the district office who worked with block officers to address data collection deadlines and technical challenges. Additional steps are needed to streamline data verification at the block level and to articulate multi-year strategic planning alternatives for clusters of villages that face common problems.

5. Discussion

This study sheds light on the current and potential roles of intermediate-level block and district governments in rural drinking water planning. We found that their current role is driven in large measure by top-down national and state drinking water programs. However, those programs also call for bottom-up expression of village drinking water needs. Districts currently fulfill these bottom-up and top-down policies through annual action plans. Thus, in some measure, the planning role of intermediate-level governments is recognized and actualized. However, there is a long legacy of top-down planning at the national and state levels, the former providing funds subject to compliance with specific guidelines, and the latter controlling appointments, procedures, and resources. There has been less attention given intermediate-levels of water planning.

This research also found that district drinking water planning can be strengthened. Under the 73rd Amendment to the Constitution of India, Panchayati Raj Institutions can assert a bolder planning role and vision, with supporting data and arguments, for their jurisdictions. Key steps for strengthening district planning include: (1) a program of professional training in the theory, methods, and practice of planning methods and plan preparation; (2) focused attention to GIS training and posting of at least one GIS applications officer in each district office; (3) identifying block coordinators in the district office to ensure timely data collection, verification, and analysis; and (4) a renewed emphasis on sustainability and slipback prevention methods in the new Jal Jeevan Mission projects.

Safe drinking water is a key component of sustainability in rural environments. Villages depend upon reliable supplies that often lie beyond their immediate borders and thus require larger planning scales. Drinking water aspirations are expanding to include piped water supply and household taps that deliver more and safer water in ways that tap scarce groundwater and monsoon runoff. These goals require stronger planning at the intermediate level of blocks, districts, watersheds, and aquifers. Fulfilling the JJM guidelines for village action plans, district action plans, and a state action plans depends upon advances in planning methods and practices at each level. It is noteworthy that NRDWP requirements for more comprehensive Village Water Security Plans and District Water Security Plans were not fulfilled. Instead, district annual action plans took the form of functional spreadsheets for financial planning. Planning in the Jal Jeevan Mission also appears to be falling behind schedule in addressing detailed guidance for preparing Village Action Plans and District Action Plans. This due in part to the magnitude of the tasks, limited time and staff to complete them, and constraints posed by the COVID pandemic. National funds disbursed through top-down planning methods follow a strict calendar, and funding proposals must be submitted according to that timeline, which can constrain planning processes.

The new Jal Jeevan Mission piped-water schemes and tap connections, when constructed in the millions, faces serious challenges of sustainability that require proactive planning. Dramatically increasing rural drinking water demand is occurring concurrently with increasing agricultural and municipal and industrial water demand. These sectors interact in ways that sustain, or weaken, water quality standards and governance [42,43]. All of these challenges are amplified by climate change. They require a much stronger multi-sector and multi-use approach to water planning, which is an important topic for future research.

The results of this study suggest that block planning is a key scale to strengthen in Maharashtra. Blocks have relatively coherent hydroclimatology and terrain, compared to districts. Although they do not strictly conform with watershed or aquifer boundaries, which deserve greater emphasis in Maharashtra water planning, blocks have several key strengths. They have the staff and data-intensive methods to track local sustainability in hydrologic as well as engineering and socio-economic terms—that is, all five components of the FIETS sustainability framework. To keep track of those components, gram sevaks, water operators, and Village Water Supply Committees would benefit from enhanced training and certification. This research demonstrated that systematic water service data collection by gram sevaks is feasible. When prioritizing village needs, the study gave equal weight to each of the eight main water service variables, as an initial assessment. Future research may consider varying the weights for different water service variables, informed by participatory methods among village stakeholders.

Block scale water planning would require a shift in the Jal Jeevan Mission, Maharashtra state, and GSDA practice. It would require additional staffing and stronger professional development programs and opportunities at the block as well as district levels. This is where district scale planning becomes crucial both for supporting blocks and for aggregating local village data in ways that articulate bold district priorities. District governments have dedicated water sector staff, which is not often the case in blocks. They have district colleagues in groundwater and GIS offices as well, which are crucial at all scales.

We did not find that districts have experience in synthesizing project data into clear narrative plans. Each district has an extraordinarily rich history related to water resources [44]. Each one faces geographically specific drinking water challenges, and these challenges are changing with the growth of new industries, cities, and agricultural markets. They will encounter unanticipated hydroclimatic hazards that go well beyond current drought emergency management efforts in the Collector's office and that require multi-year strategic planning that goes beyond the scope of annual action plans.

In the future, it would be wise to shift from individual water subsectors toward multi-use water planning that coordinates drinking water planning with irrigation, industrial, urban, and environmental water uses [45]. States and districts may choose to follow the national government by creating single overarching water departments. As observed at the national level, however, creating an institutional umbrella is just the first step toward integrative planning. District and block water officers need substantial professional development, vis-à-vis training, to articulate and address complex multi-sector water challenges in district plans prepared for consideration at the state level. Current research on water-energy-food nexus may be useful [46].

India's Panchayati Raj Institutions are not likely to attain planning capability to address these challenges in the fast-track schedule of the Jal Jeevan Mission. It may require a generation, but it can be launched and supported as part of the long-term vision of the Jal Jeevan Mission. Planning for sustainability on a generational timescale requires systematic attention to the evolving reasons and remedies for project slipback, as well as progress toward piped water supplies and functional household tap connections for all.

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Informed Consent Statement: Informed consent was obtained from the government officials involved in study interviews and mobile app survey.

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