Research Paper

Habitations, villages, and gram panchayats: local drinking water planning in rural India with a Pune district case study

James L. Wescoat Jr, Riddhi Pankaj Shah, Ranu Singh and J. V. R. Murty

ABSTRACT

Improving rural drinking water services at the village level is a high priority in India. The National Rural Drinking Water Program (NRDWP) calls for village drinking water plans on an annual basis. However, planning data analysis and mapping are complicated by the different levels of local settlement that are involved. The aims of this paper are: first, to review how the term 'village' has come to refer to three different types of settlement for planning purposes in India; second, to show how each settlement type has different water data and Geographic Information System (GIS) map coverage; and third, to identify practical strategies for using these different data and mapping resources to develop rural drinking water plans. We address the first objective through a brief historical review of local government administration and drinking water database development in India. Challenges of data analysis and mapping are demonstrated through a case study of Pune district in Maharashtra. This challenge led to the identification of six practical strategies for coordinating the analysis of drinking water data and GIS mapping for planning purposes.

Key words | drinking water planning, gram panchayat, habitation, Maharashtra, Pune, village

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INTRODUCTION

India is devolving from centralized national and state water planning toward local water governance, enabled in part by the 73rd Amendment to the Constitution in 1993, which established the authority of Panchayati Raj levels of local government (Government of India 1993; Sarma & Chakravarty 2018). Panchayati Raj Institutions (PRIs) have three levels of government: the district (*Zilla Parishad*); the intermediate level block, taluka, or tehsil (*Panchayat Samiti*); and the village (*Gram Panchayat*). The Gram Panchayat (GP), in turn, is further divided into revenue villages and small habitations. Each level has a dynamic history with implications for local drinking water planning that are introduced in this first section of the paper.

Our paper focuses on rural drinking water planning at the district and local village levels of government in India (cf. Government of India 2013; Sangameswaran 2014; Verma *et al.* 2014; Hutchings *et al.* 2017). Its first objective is to show through historical methods how the 'village' became a heterogeneous level of analysis for water planning purposes. The village (*gaon*) has developed three main meanings in India: (1) the GP unit of local government; (2) the revenue village that is important in Census data collection and mapping; and (3) the habitation which is the smallest settlement for project planning purposes. A GP may include multiple villages, each of which may have multiple habitations (Figure 1).

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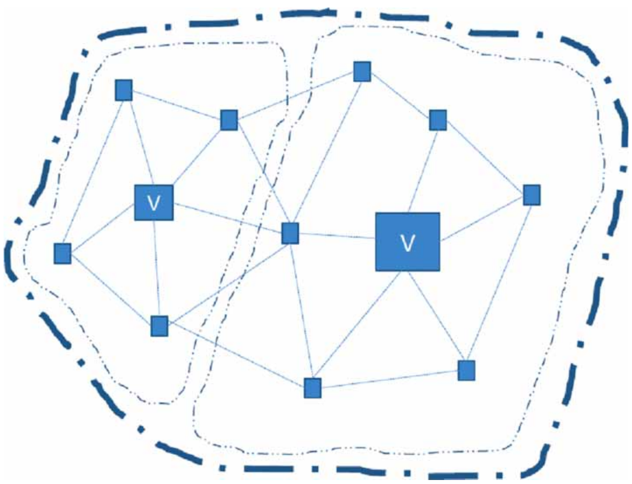

Figure 1 | Levels of local settlement within a single gram panchayat. (*Source:* authors.)

Reviewing current national and state drinking water policies and databases identifies further complications for rural drinking water planning. For example, the Government of India's IMIS (Integrated Management Information System) drinking water database collects data at the habitation level census on monthly and annual time scales; and it aggregates those data to the larger GP, but not the revenue village, level. Zilla parishad (district) databases also collect drinking water information at the habitation and GP levels. In many ways, this makes sense as the habitation is the smallest unit of settlement, and the GP is the smallest official unit of local self-government. Zilla parishads use IMIS data and field data at the habitation level to prepare district Annual Action Plans, which take the form of Excel spreadsheets (Pune Zilla Parishad, 2018).

For historical reasons, the decennial Census of India collects demographic, water, and sanitation data at the revenue village level, which is the only local planning unit to have Geographic Information System (GIS) shapefiles for all of India. States and Zilla parishads use these data for general planning reports on water and sanitation patterns and trends, but not for district Annual Action Plans.

These three levels of 'village' water management are well known among practitioners, but they need to be systematically described, historically interpreted, and practically assessed to address the challenges that they pose for rural drinking water planning. For this second objective of the paper, we selected Pune district in Maharashtra as a case study, as we have a pilot study of district drinking water planning underway there (e.g., Hui & Wescoat 2018). Using GIS mapping and database analysis, we show how Pune district's GPs, revenue villages, and habitations are related to one another and how they vary spatially in ways that pose challenges for rural drinking water planners.

Further complicating the spatial issues in local water planning are changes in settlement status that occur over time, incrementally on an annual basis and dramatically between decennial censuses. For example, growing habitations can become villages, and growing villages can become GPs.

Conversely, a GP that has two rapidly growing villages can subdivide into two GPs. Villages can add habitations in outlying areas. These changes in settlement status make time series analysis and GIS mapping difficult, as GIS shapefiles for Census villages are only updated on a decadal basis. Notwithstanding these difficulties, this paper identifies strategies for coordinating data analysis and GIS mapping at the local and district levels.

Another complexity arises from the fact that while water supply schemes are designed and implemented at the habitation level, operations and maintenance are responsibilities at the GP level. This can make it difficult to understand which schemes and services are successful and why.

A final layer of complexity comes from watershed planning units, which do not follow administrative boundaries. Watershed conditions affect groundwater availability and thus affect planning, investment, and service delivery. Planning within a safe watershed differs from that in critical and overexploited watersheds.

Examining these local water planning challenges in a district case study can help us address the third and final objective of the paper, which is to identify practical strategies for data analysis and map display that link these three levels of local water management. Although less than optimal, these strategies can help local water analysts and planners understand, navigate, and use the abundant data resources and mapping tools available in India.

EMERGENCE OF THE GP TIER OF WATER GOVERNANCE IN INDIA

Over a century ago, India was idealized as a nation of timeless self-reliant villages (e.g., Metcalfe 1830). Historians and social scientists have challenged this myth through studies

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of dynamically changing village societies and networks (e.g., Thakur 2014). Even the terminology for local village government has varied over time. The term *panchayat* has ancient roots in Vedic times that continued in medieval and early modern usage. During the colonial period, the English term 'village panchayat' became widespread (e.g., in the State panchayat acts of the 1920s). The term gram panchayat was used somewhat interchangeably and in confusing ways with village panchayat and gaon panchayat in northern India during the late 19th and early 20th centuries. GP only became the preferred official term for local self-government in federal and state policies after Independence in 1947.

Numerous proposals for local self-government and administrative decentralization were put forward during the 19th and 20th centuries. Table 1 lists major reports

Table 1 | Changing role of PRI institutions in national and state drinking water policies

Year	Government of India	State governments
1947		U.P. Panchayat Raj Act
1950	Constitution of India, art. 40 calling for the support of gram panchayats	
1957	Balwant Rai Mehta report calling for district and block planning	Bombay Village Panchayats Act (updated to 2013)
1961		Maharashtra Zilla Parishads and Panchayat Samitis Act emphasize district-level planning
1970–1980		Establishment of Water Supply and Sewerage Boards (called Public Health Engineering Departments in some states), e.g., Maharashtra (1972)
1972	Accelerated Rural Water Supply Program	
1978	Ashok Mehta Committee on Panchayati Raj institutions	
1986	National Rural Drinking Water Mission launched. L.M. Singhvi Committee recommended gram sabhas as the principal PRI level	
1992	73rd Constitutional Amendment establishes the three levels of PRI governance. 11th Schedule lists 29 topics including water and sanitation as PRI subjects	
1994		Maharashtra District Planning and Metropolitan Planning Committees Act
1998		Maharashtra District Planning Committees Act
1999	Sector Reform Program launched in 67 districts with a focus on decentralization, community participation, and a demand-driven approach	
2002	Swajaldhara water reforms program launched and emphasizes the GP level	
2009	NRDWP is launched and emphasizes PRI roles	
2013	NRDWP *Guidelines* are updated, emphasis on PRI roles remain, especially at the GP level	
2015	Fourteenth Finance Commission devolution recommendations	
2016		MRDWP (2016) launched by the Maharashtra government emphasizes the Zilla Parishad (ZP) level of planning
2018		Government Resolution dated 9 March 2018, resuming the control of NRDWP projects from the GP to ZP level for the design and construction of schemes. Responsibility for operation and maintenance rests with GPs

and policies at the federal and state level since Independence. Mahatma Gandhi was a strong advocate for village self-government as the foundation of Indian society and democracy (Nadkarni Sivanna & Suresh 2017). However, framers of the Constitution such as Dr B.R. Ambedkar and others emphasized national and state governance and made a limited reference to village panchayats in Article 40 of the Constitution.

As in most federal systems of the government, water resources are deemed a state subject, with the exception of interstate and international river issues. After 1950, each state developed its own legislation on the structure and function of Panchayati Raj institutions in the water sector. Even before the 73rd Amendment in 1993, Panchayati Raj policies listed drinking water and sanitation as local subjects. At the same time, national and state programs have continued to stipulate which data and formats are to be used in Annual Action Planning, which is why the local data issues discussed here are so important.

The main findings from this brief historical analysis are, first, that local governance at the district and block levels had an ancient but politically tenuous status until 1993, and second, that proposals for local control have involved more than a century of debates and experiments that affect local planning. The next section of the paper focuses on these issues through a case study of Pune district in Maharashtra.

ANALYTICAL AND SPATIAL CHALLENGES OF LOCAL WATER PLANNING IN PUNE DISTRICT

The GP level of government has subdivisions that affect local drinking water planning, in part through the different types of analysis and mapping that are possible in each of those subdivisions. To illustrate these issues, we present a case study of Pune district in Maharashtra (cf. Hui & Wescoat 2018).

Maharashtra has 36 districts, including Pune district, each of which is divided into blocks or *talukas* (*tehsils*). Pune district has one urban taluka and 13 rural talukas. As of 1 April 2018, the district had 1,401 gram panchayats, 1,877 villages, and 9,207 habitations (Government of India IMIS 2018). Two-thirds of all GPs in Pune district have one village, while about one-third of the GPs have two or more villages. Each gram panchayat has an average of 6.6 habitations.

Gram panchayat water data

The Government of India Ministry of Drinking Water and Sanitation compiles data on gram panchayat drinking water systems, including their demographics, physical characteristics, performance, and financial disbursements in an enormous IMIS database (Wescoat *et al.* 2016). The IMIS database contains 166 data formats (i.e., spreadsheets). Many of the spreadsheets compile data at the gram panchayat level. Gram panchayats are the smallest official level of government in India. However, IMIS data cannot be mapped at the gram panchayat scale due to the lack of geocoded shapefiles at that level. They can be analyzed statistically to determine frequencies, associations, and variability and used to assess GP water services, but they cannot be mapped statewide with current GIS resources.

Village water data in the Census of India

As noted above, gram panchayats may have more than one village (*gaon*) (Figure 2). Revenue villages have served historically as the primary level of local Census data aggregation for purposes of revenue assessment, socioeconomic surveillance, and some types of planning (e.g., for drought management). The first synchronous population census was undertaken in 1881, and it has continued on a decadal interval up through 2011 (Government of India, Census of India 2018). Early censuses concentrated on demographic and socioeconomic variables such as population, gender, occupation, language, literacy, and caste. Some early censuses also listed village houses and their amenities. Houselisting variables were included in 1901 and were significantly expanded to record housing materials, conditions, and water-related appurtenances in 1981. The 2011 Census included 13 drinking water and sanitation variables. These village water and sanitation data are far less detailed than those of the IMIS database, but they are used in research and planning reports to assess patterns in water supply and sanitation (e.g. Jaiswal & Joon 2017).

The Government of India, Census of India (2011) aggregates household water data first to the village level and then to the block and district levels. It does not disaggregate data

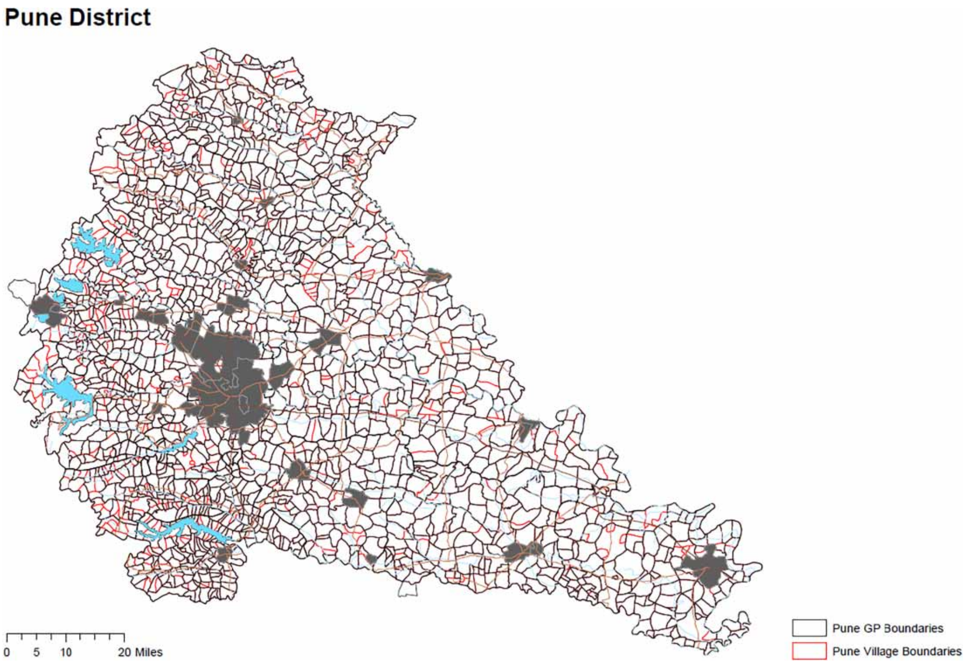

Figure 2 | Overlay map of gram panchayat and census village boundaries (MIT Geoweb).

to the habitation level or aggregate them to the gram panchayat level. Each village has a unique Census ID that is linked with GIS shapefiles. We have mapped Census water and sanitation data for Pune district to identify periurban and rurban water service patterns (Hui & Wescoat 2018). For example, Figure 3 displays data on the percentage of villages that have 'no drainage.' In 2011, almost half of the villages in Pune district reported having *no* drainage in 81–100% of the village. These underserved villages are concentrated in small remote hilly areas of the Western Ghats and in rural areas between block towns. Mapping and statistical analysis showed that better drainage conditions pertained in some periurban villages, which is not generally expected in planning practice.

Census villages have nationwide shapefiles that enable local GIS mapping of water and sanitation data. This data infrastructure is valuable for visualization and planning at the block, district, and state government levels. Some state agencies have developed their own spatial databases on a GIS platform. For example, the Groundwater Surveys and Development Agency (GSDA) has groundwater prospect maps and cadastral maps of village recharge priority areas that are used for project planning purposes (Government of Maharashtra, GSDA 2018).

Habitation water management

Habitations are the smallest level of village settlement that commonly have 10s–100s of households. As noted above, each gram panchayat has an average of 6.6 habitations. Habitations are arguably the most important level of water planning, as they have relatively spatially compact homogeneous needs. Habitations are the level at which drinking water schemes and detailed project reports are commonly prepared. Habitations also have had an enormous amount of water data compiled in the IMIS database since 2015. It is therefore unfortunate that this local level of water management and planning does not have statewide or nationwide GIS shapefiles. Additionally, each IMIS data query must proceed through a strictly hierarchical sequence, which makes it tedious to analyze multiple habitations in a gram panchayat, let alone a large sample of habitations at the block or district scales.

Changes in settlement structure and classification over time

The final challenge posed by multiple levels of local water management involves changes in the number and types of

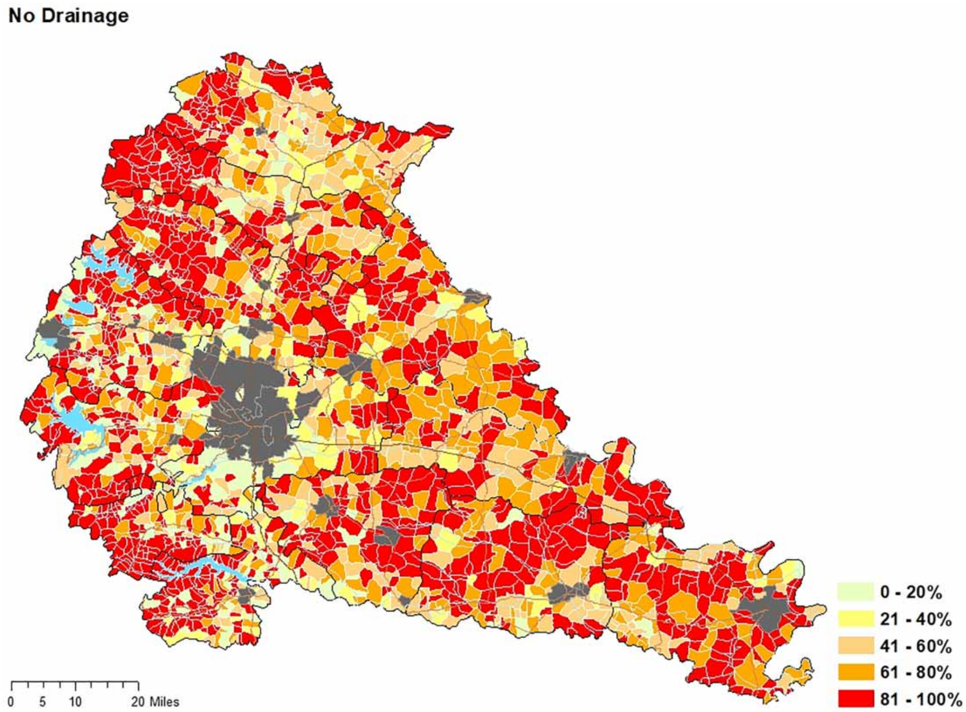

Figure 3 | Percentage of villages that have no drainage (Government of India, Census of India 2011).

settlements over time. Comparing the 2011 Census and the 2018 IMIS database indicates that India had an increase in districts, blocks, GPs, villages, and habitations. Maharashtra, by comparison, remained relatively stable in administrative terms, with a slight decrease in GPs and villages and a slight increase in habitations. Pune district likewise reported a decrease in local GPs, villages, and habitations (Table 2). While all levels of government can aggregate or divide into new units, the number of changes at the local level far exceeds those at the district and state levels. The key point for planning purposes is that processes of aggregation and subdivision pose challenges for assessing baseline conditions and trends.

It must be acknowledged that 2018 population data are estimates of uneven quality that do not include the so-called floating population of seasonal and long-term migrants. District drinking water planners report that village population forecasting is one of the greatest scientific and practical issues they face, because they are not able to determine accurately the baseline populations, seasonal labor fluctuations, and trends necessary for estimating water demand and service requirements. Instead, planning guidelines specify several linear and geometric population projection techniques from the 2011 Census, which is both outdated

Table 2 | Change in rural settlements over time (India, Maharashtra, and Pune district)

Level	2011 (Census)	2018 (IMIS)
States in India	31	31
Districts in India	636	697
Blocks in India	6,434	6,859
Gram Panchayats India	245,877	258,169
Villages in India	594,097	606,041
Habitations in India	1,664,068	1,719,284
Districts in Maharashtra	35	36
Blocks Maharashtra	351	351
GPs Maharashtra	27,960	27,838
Villages Maharashtra	41,302	40,605
Habitations Maharashtra	98,842	99,533
Blocks in Pune district	13	14
GPs in Pune district	1,402	1,401
Villages in Pune district	1,873	1,877
Habitations Pune district	9,262	9,207
Rural population, Pune district	3,678,226	3,762,547

and not related to the gram panchayat and habitation contexts of water planning.

This combination of spatial data analysis, mapping, and change over time poses significant challenges for water planners at all levels. There are few digitized habitation or gram panchayat maps, and few district planners have GIS capability for census data mapping. Thus, the abundance of local water data available is not organized in ways that facilitate rural drinking water planning. Nevertheless, when we assemble all of the available datasets, a number of practical strategies can be identified for coordinated analysis and mapping, particularly for district Annual Action Planning.

Before proceeding to those conclusions, however, it is important also to note that village settlements of all types depend upon larger watershed and aquifer systems. Rural drinking water schemes in Maharashtra rely in particular upon groundwater sources. The Maharashtra GSDA monitors watershed conditions with a range of tools that include observation wells, groundwater prospect maps, recharge priority maps, and aquifer delineation maps. At present, however, village drinking water databases are not well integrated with these watershed and aquifer tools, except episodically when new schemes and programs are developed. However, these can also be incorporated into practical strategies for local drinking water planning.

STRATEGIES FOR BRIDGING GAPS IN LOCAL DRINKING WATER MAPS AND DATA

This paper has assessed the complicated levels of Panchayati Raj water governance in India. We have shown that the gram panchayat level itself has three levels, which have distinct data resources, mapping capabilities, and planning roles. On the one hand, India has more detailed rural drinking water data than any other country in the world today (Wescoat *et al.* 2016). On the other hand, it does not yet have the GIS shapefiles needed to map those gram panchayat and habitation data. It seems unlikely that habitation data will be aggregated to the revenue village level, or that gram panchayat data will be disaggregated to the revenue village level to facilitate GIS mapping. To address this situation, we have identified six practical strategies for planning purposes:

1. *Sequence GIS and IMIS analysis.* One approach begins with GIS analysis of 2011 Census data at the revenue village scale to establish a planning baseline. The planner then undertakes a statistical analysis of up-to-date IMIS data at the habitation level. The advantage of this strategy is its ease of implementation and logical use of available information, while a deficiency is its lack of data integration. The only administrative and funding requirements would be for districts to hire one or more career GIS analysts, which should be standard capabilities in any event.
2. *Update 2011 Census village data with current field data.* This approach starts with 2011 Census data and maps and returns to each village to update population and water service data (e.g., to 2019). The new data can be charted and mapped to describe patterns and trends. The strengths of this strategy are its combination of time series analysis from 2011 to 2018 and GIS mapping to visualize patterns. Drawbacks include the limited number of common water and sanitation variables in the Census and IMIS and field data collection costs. However, the practicality of these methods has been demonstrated with mobile apps and data collection by *gram sevaks* in Pune district.
3. *Aggregate IMIS habitation data to the village scale.* This approach would assign unique spatial id numbers to habitations and prepare shapefiles to map those data. This can be done by hand for single and even multivillage studies at the *mandal* scale of 5–10 villages and possibly at the block level of roughly 100 villages. New GSDA cadastral maps for assessing recharge potential could enable aggregation and disaggregation of IMIS and Census data, but this strategy would require more technical and financial resources.
4. *Conduct a proportional analysis of gram panchayat, village, and habitation data.* Data in the three local planning contexts are not strictly comparable, but there are ways to draw qualified comparisons. For example, in blocks where most GPs have one village, those two levels can be treated as equivalent. In cases where the number of villages per GP varies, the analyst can compute percentages or other normalized data to compare results across databases. The advantages of this approach are its computational simplicity, low cost, and use of all available data. Its limitations include uncertainties associated with comparing data collected with different

methods and aims. Again, the only institutional and funding requirements would involve basic statistical and GIS training for district officers.

5. *Develop new data mining and machine learning techniques for integrating Census and IMIS data analysis.* The IMIS database, GIS mapping software, and mobile app survey methods were unimaginable a generation ago. We anticipate technological changes that will further transform the current situation, e.g., machine learning algorithms that use remote sensing imagery to estimate water use patterns and processes, and spatial autocorrelation analysis to identify potential multivillage schemes. National and state remote sensing agencies (e.g., Maharashtra Remote Sensing Application Centre (MRSAC)) have the capability to work on this with the National Informatics Centre, but it would require substantial coordination and budgeting.
6. *Link local drinking water data with watershed and aquifer data.* For any of the strategies above, a high priority will be to link drinking water data with watershed and aquifer maps to improve groundwater planning in hydrologically connected habitations. In the case study area, these types of efforts are underway by both the Groundwater Surveys and Development Agency and the Jal Yukt Shivar watershed conservation program.

These six strategies can also be employed jointly in rural drinking water planning in the years ahead. At some point, it is likely that geocoding will be completed at all three levels of the gram panchayat, village, and habitation – if not by the Census of India then by state agencies like the MRSAC – which would contribute to water resources data integration. Going forward, it will be important to have mapping capabilities at the GP level, with spatial disaggregation to the habitation level, as coordinated responsibility for operations, maintenance, and service delivery will rest mainly with these levels of local settlement. While improving mapping and data integration would require some financial resources, initially the long-term benefits include: (1) identifying the neediest habitations, villages, and GPs for investment; (2) strengthening district Annual Action Plans; (3) monitoring drinking water services at all levels; (4) evaluating operations and maintenance practices that affect sustainability; and (5) adapting datasets and maps as the boundaries of PRI units continue to evolve over time.

CONCLUSION

This paper systematically describes the challenges facing rural drinking water planners at the local level in India with a case study of Pune district in the State of Maharashtra. The historical analysis showed that experiments in devolution to the local level are at least 150 years old. However, we found that less attention has been devoted to village-level planning and governance than to districts. The case study of villages in Pune district identified gaps between drinking water responsibilities, data resources, and mapping capabilities at the gram panchayat, revenue village, and habitation levels. Even so, we identified six practical strategies for combining data analysis with GIS mapping to support local and district drinking water planning in India.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest in this study.

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