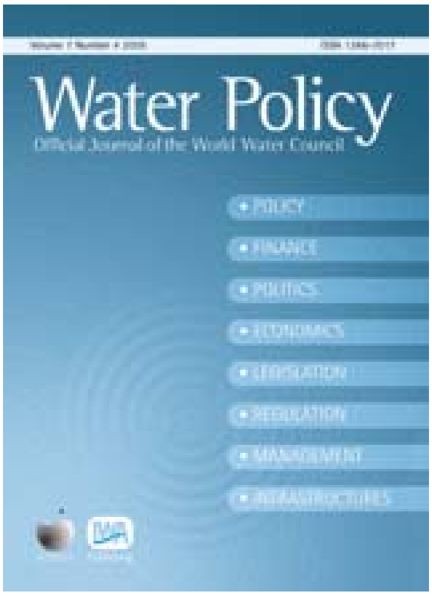
Water Policy
Official Journal of the World Water Council
POLICY
FINANCE
POLITICS
ECONOMICS
LEGISLATION
REGULATION
MANAGEMENT
INFRASTRUCTURES

Water Policy 16 (2014) 557–577

Analyzing the potential of community water systems: the case of AguaClara

Marcela González Rivas[a], Karim Beers[b], Mildred E. Warner[c] and Monroe Weber-Shirk[d]

[a]*Corresponding author. University of Pittsburgh, Pittsburgh, PA USA. E-mail: mag231@pitt.edu*
[b]*Cornell Cooperative Extension Association of Tompkins County, 615 Willow Ave. Ithaca, NY 14850, USA*
[c]*City and Regional Planning, W. Sibley Hall, Cornell University, Ithaca, NY 14853, USA*
[d]*Civil and Environmental Engineering, Hollister Hall 265, Cornell University, Ithaca, NY 14853, USA*

Abstract

Successful maintenance of water provision has as much to do with the ongoing governance of these systems as the technology that goes into building them. This governance generally occurs at the community level. Most water systems are small and located in areas where there is generally not the profitability necessary to entice private investment. Understanding how community management can improve is therefore essential to solving water provision problems around the world. This paper develops a three part framework for analyzing water projects through a focus on technology, management and governance. The framework draws on research on collective action and various forms of capital as they relate to technology (natural and physical capital), management (financial and human capital) and governance (social and political capital). We demonstrate the usefulness of the framework by studying AguaClara, a program that has helped seven Honduran communities build eight water treatment plants and set up functioning systems of governance.

Keywords: Community capitals framework; Community water management; Water infrastructure; Water systems governance

Introduction

In 2010, the world met the United Nations' Millennium Development Goal (MDG) for drinking water, which was to halve the proportion of people living without sustainable access to safe drinking water between 1990 and 2015 (WHO/UNICEF, 2012)[1]. This means that since 1990, more than two

[1] Target 7c.

doi: 10.2166/wp.2014.127

billion people have gained access to improved drinking water sources. This is significant progress and it has been especially rapid in some regions, such as East Asia (largely dominated by progress made in India and China). For Latin America, a region with a relatively good baseline in 1990 – with 85% of people having access to an improved water source – the change from 1990–2010 was nine percentage points and thus the region as a whole has met the target[2].

However, these achievements should not be overestimated, for two reasons. First, the overall rates of progress on MDGs mask great inequalities within countries, for example between rural and urban areas. In Asia and Latin America, about one in five rural inhabitants do not have access to an improved water source and the ratio rises to one in every two in Africa (United Nations, 2010)[3]. Second, the MDG definition of sustainable water access is a minimal standard that does not ensure access to safe drinking water (Godfrey *et al*., 2011; IDB, 2011; Zawahri *et al*., 2011; Clasen, 2012). In fact, the WHO/UNICEF Joint Monitoring program recognizes the need to monitor water quality as one of the key current challenges in the water and sanitation sector worldwide. In Latin America, an estimated 36.8 million people lack access to safe sources of drinking water (Akhmouch, 2012).

Therefore, despite the progress on the MDG's water target mentioned above, finding new solutions to the challenge of water provision remains an urgent task and new solutions will have to account for the following three main related challenges:

- *Challenge of technology/infrastructure*. Water system designs are usually too complex, costly and difficult to manage for many communities (Howe & Dixon, 1993; Hokanson *et al*., 2007). Communities need cost-effective, transparent and intelligible systems (Adelman *et al*., 2012).
- *Challenge of management*. The places and people without water access do not usually have sufficient resources to improve water access on their own and water systems are often too expensive for local users (McDonald & Ruiters, 2012). In fact, World Bank studies of rural water supply and sanitation in Latin America have found that although drinking water services in rural areas cover operation and maintenance (O&M) costs, they are not financially sustainable in the medium term and require additional capital to replace the current infrastructure or expand coverage (Water and Sanitation Program, 2011: 7).
- *Challenge of governance*. Small rural communities or communities distant from the municipal center fall outside the interest of the usual water providers, as they are attractive neither to governments aiming to reach large populations nor to international private providers owing to their lack of profitability (WHO/UNICEF, 2012). As a result, some studies have called for alternative ways of developing water systems, such as through cooperatives, non-profit organizations and community-based management (Akhmouch, 2012). However, community-based systems often do not work, owing to the technology challenges described above.

In recent decades, as a response to these challenges, new ways of providing water service have emerged (Tropp, 2007), known as 'community-driven improvements' (Satterthwaite *et al*., 2005; Padawangi, 2010) or 'innovative local financing' (Spencer, 2007) and these have been shown to work in both rural and

[2] In 2010 the coverage rate was 94%. Figure 6 (WHO/UNICEF, 2012: 8).

[3] Furthermore, only 29% of rural residents around the world have access to piped water in the household (the higher standard of water access), compared with 80% of urban residents (WHO/UNICEF, 2012: 12).

peri-urban settings (Spencer *et al*., 2008). These alternative systems often lie outside of formal State-run systems and corporate public-private partnerships (e.g. Amis *et al*., 2001; Jaglin, 2002; Nickson & Franceys, 2003; Moretto, 2006) and represent important methods of service provision in peri-urban areas, as well as in low-income rural towns, which have traditionally been ignored by service providers.

Given the continued need to improve water access in the developing world, understanding the potential opportunities and challenges of these alternative systems is critical. In this paper, we propose one way that organizations trying to develop successful water projects can evaluate these opportunities and challenges, using the community capitals framework that up until now has been mainly used for examining the ability of communities to foster development projects (Emery & Flora, 2006; Masinde *et al.,* 2009). This framework arose in response to work, mainly by Ostrom (1994), demonstrating that physical capital was only one kind of capital that determined the success of projects. Other kinds of capital could be equally important, including social, human and political capital.

Our goal is to take this perspective and demonstrate how it is useful not only for communities, but also for organizations trying to develop successful water projects in the developing world. This framework seems particularly useful in light of calls for more attention to the social and governance aspects of water projects, as these projects have focused primarily on the physical capital of water systems (Tropp, 2007; Water and Sanitation Program, 2011).

To demonstrate the utility of this kind of approach, this paper assesses an alternative water system known as AguaClara. AguaClara is a collaboration between Cornell University and Agua Para El Pueblo (APP), a Honduran non-governmental organization (NGO) focused on providing clean, piped water to low income communities across Honduras. AguaClara aims to address the three challenges mentioned above with a community-managed water system that uses a simple technology that is affordable by the communities. AguaClara has implemented eight community-managed plants in Honduras. More details about the organization are provided below.

Our methodological approach builds from the tradition of participatory action research (Reason, 1994). Rather than present an external evaluation, we partnered with the AguaClara project and involved its director, Monroe Weber-Shirk, as a co-author. While this risks losing objective distance, it facilitates better access to data on an ongoing basis and a more thorough review in a process of collective critical reflection. Research is based on field visits by two of the co-authors, interviews with staff and community members in Honduras, collective evaluator meetings both in Honduras and at Cornell and review of project documents. Theory-based evaluation schemes now recommend such engaged evaluations as a means to promote organizational learning (Greene, 1994; Patton, 2011).

The paper is organized as follows. In the next section, we discuss the community capitals framework and how it has been used to assess the capacity of communities to manage water and other development projects. We propose a simplified framework for assessing community-based water systems. In the third section, we give background on AguaClara and illustrate how our framework is useful for highlighting its potential and challenges. A final section provides a conclusion.

The community capitals framework

The community capitals framework grew out of the pioneering work of Ostrom (1994), who highlighted the important role that governance and institutions could play in the success of local development projects. Ostrom underscored the importance of social and human capital at a time when much attention was being given to technical aspects of development. '[A] major lesson we need to take forward into the next century is that it is a mistake to design irrigation and other development projects on the presumption that physical capital is the most important input factor in development' (Ostrom, 1994: 21). She saw human and social capital as 'necessary complementary inputs' in order for physical capital – the built infrastructure – to have a lasting impact (Ostrom, 1994: 20).

Her observation that communities have different kinds of capital, all of which are important for the success of development projects, has spurred work toward identifying helpful frameworks for assessing community potential, particularly with regard to water projects. Flora (2004), for example, identified six forms of capital that communities needed for sustainable development:

- *Natural* capital is the community's environment and natural resources.
- *Cultural* capital includes 'ways of knowing …, language, ways of acting and defining what is problematic' (Flora, 2004: 8) and it 'determines how we see the world, what we take for granted …, what we value … and what things we think possible to change' (Flora, 2004). Cultural capital has been shown to be important for water system management (Keating & Gasteyer, 2012).
- '*Human* capital is the native intelligence, skills, abilities, education and health of individuals within a community' (Flora, 2004).
- *Social* capital includes 'mutual trust, reciprocity, collective identity, cooperation and a sense of a shared future' (Flora, 2004).
- *Political* capital is 'the ability of a community to influence the distribution of resources and to determine which resources are made available' (Flora, 2004: 10). It includes political connections to access resources (Hardoy *et al*., 2001).
- *Financial/built* capital includes both sources of funding (debt, investment, savings, taxes, etc.) and the physical infrastructure that the funds are designed to construct.

Gasteyer & Taylor (2009) modified Flora's framework, separating financial and built capital into distinct categories and dividing social capital into 'bridging' and 'bonding' social capital. They used this framework to assess the strength and resilience of a community's governance structure related to its water system. Fabricius & Collins (2007) used the lens of community capitals to examine failures of what they called 'community-based natural resource management' (CBNRM). Drawing on work by Carney (1998) and others, they cited five categories of capital related to people's livelihoods: natural capital, social capital, human capital, physical capital and financial capital (Fabricius & Collins, 2007: 84). This is known as the 'sustainable livelihoods framework'. The authors suggest that while local communities may count on plentiful natural and social capital, the short supply of human, physical and financial capital make CBNRM initiatives extremely vulnerable. According to the authors, the five types of capital act as buffers that can absorb shocks and surprises and buttress CBNRM initiatives. They suggest focused efforts on strengthening the 'harder' types of capital – human, financial and physical – which they consider to be in short supply, without neglecting the social and natural capital already present and which are less mutable over time.

The different kinds of capital highlighted in these frameworks contain significant overlaps and have divisions that at times seem arbitrary. Nevertheless, the overall message is the same: development success is likely to result from strength in all of these related capitals. Focusing on technical capital at the expense of social, human and political capital will result in a weaker development project, as experience shows (Water and Sanitation Program, 2011).

To adapt this framework for organizations trying to develop successful water projects in the developing world, we focus on the three interconnected areas identified in the introduction as the main challenges for water systems: technology, management and governance. Each of these areas encompasses two of the capitals discussed previously. 'Technology' refers to aspects of natural capital (such as surface water, land for the plant construction, etc.) and physical capital (mainly referring to the treatment plant, the piped distribution system, etc.). The 'management' area includes financial capital (referring mainly to funds for the system's O&M and construction) and human capital (technicians, knowledge about how to operate the plant, etc.). Finally, 'governance' includes aspects that are related to social capital and political capital, such as community ownership, trust and the policy environment. Figure 1 illustrates the interconnected nature of these domains.

Application of our framework to AguaClara is based on data collected from project and consultancy reports, interviews with program managers in the USA and Honduras and interviews with the APP circuit rider. In addition, during a field visit to Honduras in January 2012, we visited a wide range of water plants, from traditional high-technology city-run plants, to the low-technology community-run

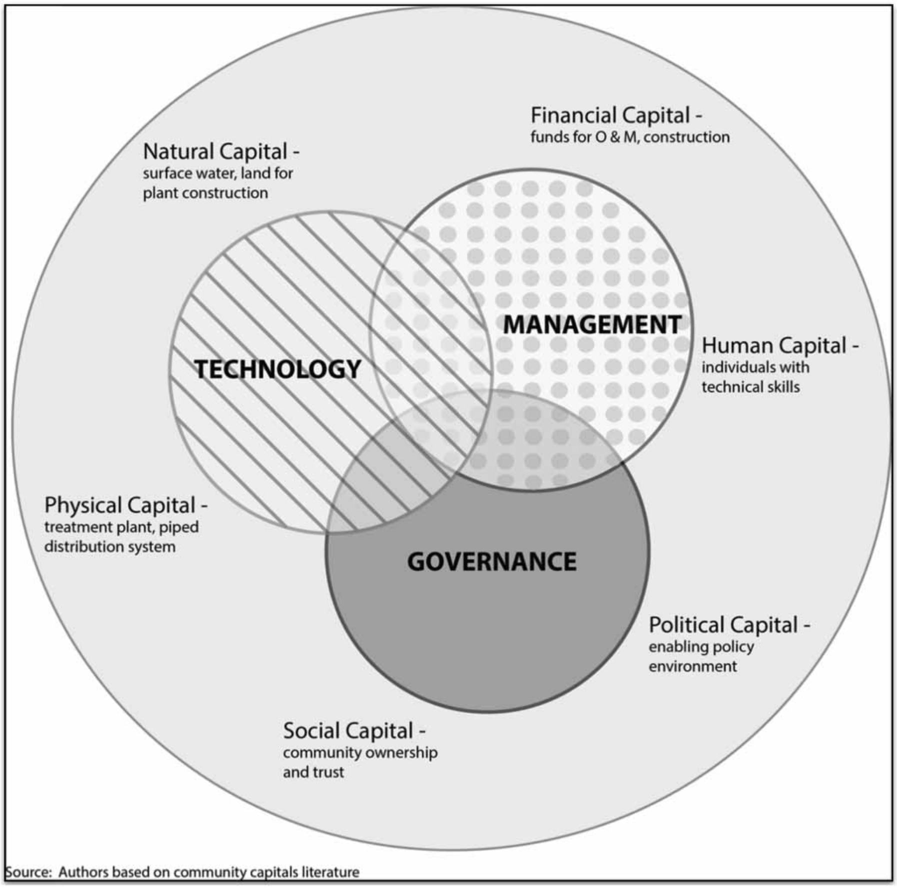

Fig. 1. Framework for analysis – community capitals.

AguaClara plants, to communities lacking treatment systems. We stayed in communities with families and visited municipal officials and health officers. During this time we conducted over 30 interviews with Honduran local government and health officials, water system operators, community water board members and community members. This field research gave us many different perspectives on the challenges and opportunities in community water system management. In developing our framework for evaluation, we worked closely with the AguaClara system designers in a process of collective critical reflection. This utilizes new innovations in evaluation research that seek to involve program designers and operators in an ongoing collective critique of program design (Greene, 1994). We believe this is a strength of our approach.

The framework applied: the case of AguaClara

The AguaClara program began in 2005 as a collaboration between Cornell University and APP, a Honduran NGO focused on providing piped water to poor communities across the country. Honduras is still recovering from the massive damage that Hurricane Mitch caused the country in 1998, which caused US$2 billion in damage (CIA factbook, n.d.). It is the second poorest country in Latin America, with about 65% of its population living in poverty (CIA factbook, n.d.). Of the whole population, 87% has access to 'improved' water sources (WHO/UNICEF, 2012: 45) and one recent study found that it was on track to reach the MDG targets for rural water supply (Lockwood & Smits, 2011). This, however, does not take into account infrastructure failure rates and, as noted before, it does not mean that most people are receiving water that is safe to drink. A study of 43 rural potable water systems in Honduras found that in 88% of the systems, the water was not being treated and in 70% of the systems the water had excessive coliform counts (Zamorano, 2004).

AguaClara was started by its current director Monroe Weber-Shirk, senior lecturer at Cornell's School of Civil and Environmental Engineering, who is the director of the program. The principal goal is to develop and implement innovative water treatment technology that both provides sufficient drinking water to meet national standards and does so at an affordable price for low-income communities. Since its founding, eight AguaClara plants have been built in seven small rural communities around Honduras, shown in the map in Figure 2 (see Table 1 for details about the plants). The eight plants are located in low- to moderate-income rural communities ranging from 20 km from Tegucigalpa to more remote locations that are a few kilometers from the Nicaraguan border. Coverage ranges from 98 to 100% in most communities.

How might the community capitals framework be applied to the workings of an organization like AguaClara? Essentially the question that organizations should ask themselves is, 'What do I need in terms of this particular capital in order for the project to be successful?' We focus on the capitals under the three domains of technology, management and governance, in order to demonstrate the usefulness of the model. In Table 2, we provide a list of the community capitals emphasized above, along with the question we have chosen to investigate with regard to AguaClara[4].

[4] In the context of the space constraints of this paper, we have focused on one question for each of the kinds of capital, in order to demonstrate the usefulness of the model.

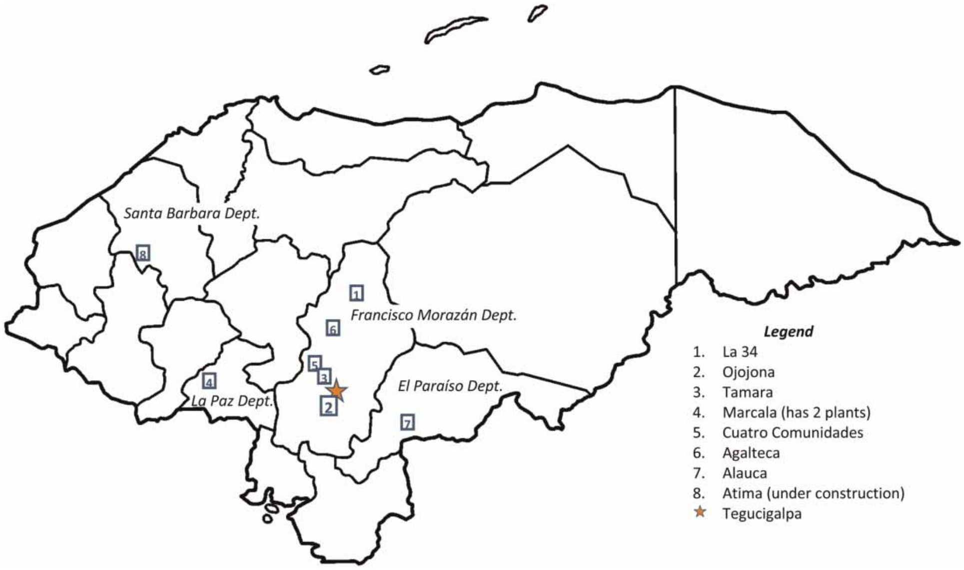

Fig. 2. AguaClara plants in Honduras. *Source:* http://mapsof.net/map/honduras-departments-blank; AguaClara website (n.d.).

Technology

Natural capital is an area of strength for AguaClara. Most communities in Honduras use surface water and, given the hilly terrain, gravity-fed systems are common. AguaClara works with communities that have adequate surface running water – for example rivers and streams – but need a plant for treatment. Honduras has a long history of piped surface water that communities control.

Unfortunately, most of Honduras's surface water sources have problems of turbidity that have been exacerbated by deforestation and increased agricultural activity. High turbidity makes the traditional treatment method of chlorination ineffective, because chlorine reacts quickly with the organics in highly turbid water and does not kill the pathogens that make people sick (Ordóñez *et al*., 2009). Turbidity is at its worst during the rainy season (May–November in the interior of the country, where the treatment plants are located), when torrential downpours wash tonnes of sediment into the rivers. Turbidity can reach thousands of nephelometric turbidity units (NTU) during high runoff events. Untreated river water, which is the norm in most rural villages, is brown during these months.

Because of these problems, physical capital is arguably AguaClara's greatest strength, because it has developed a technology particularly suited to local conditions in Honduras. Its technology treats surface water with turbidity over 500 NTU[5]. AguaClara plants are designed to reduce turbidity to less than 5 NTU through a process of flocculation and sedimentation, illustrated in Figure 3[6]. To get particles to clump, operators add aluminum sulfate or polyaluminum chloride and make the water zigzag through compartments to get the particles to bump into each other and grow in size. The flocculated water then

[5] NTU is a measure of turbidity or light scattering by particles in water. High turbidity water has high concentrations of inorganic and organic solids and may include pathogens and thus is not suitable for human consumption.
[6] Flocculation is the clumping of particles together, which then settle faster for efficient removal by sedimentation.

Table 1. AguaClara plants in Honduras.

Community	Year built	Financed by	Implementation partner	Population served	Capital cost (US$)	Flow rate (L/s)	Tariff (US$) (household (HH)/month)	Other
Ojojona	2006/7	Fundación Sanjuan, VWB[1], Cornell, ESW and municipality	APP, IRWA, Engineers for a Sustainable World (ESW)	2,100	68,028	6	2.83	VWB members do not change; some problems with corruption
Támara	2008	Rotary International, Cornell, VWB	APP	3,500	61,594	12	2.65	VWB approached APP and requested plant. APP took lead role and high degree of community participation
Marcala	2008	IRWA, municipality	IRWA, Agua y Desarrollo Comunitario (ADEC), APP	9,000	64,000	30	3.18	IRWA supervised construction of a retrofit to a failed filtration plant; APP's role was limited; municipal government manages plant; ADEC provides ongoing technical assistance
Cuatro Comunidades	2009	CESAL, Alliance for Water Progress, private donors, VWBs	APP	1,500	49,063	6	3.18	Single plant serving four small villages, each with a water board. VWB made up of members from all four community boards
Agalteca	2010	Five Star Mining, municipality, others	APP	2,160	58,279		2.65	First plant built using the AguaClara Online design tool
Marcala Expansion (El Chiflador)	2011	ACRA (Italian NGO)	APP	6,000	83,382	22	3.18	Enabled town to abandon a second untreated source of water
Alauca	2011	CARE International, COSUDE (Swiss Agency for Development)	APP	3,000	82,375	12	2.88	Built as part of a CARE project in the community
Atima	2012	Rotary International	APP	3,300	76,530 (includes AguaClara staff cost)	16	2.62–10.48	Cross-subsidized tariff scheme not approved yet

[1]VWB. *Sources:* Elvir, personal interview (10/24/11) and personal communication (2/8/12); AguaClara website (n.d.); Smith (2010); Presupuesto El Chiflador, 8/31/10; PresupuestoSocial.

Table 2. Examples of questions raised by the community capitals framework.

Domains/capitals	Question
Technology	
Natural	Does the community have access to a water source that can meet its needs for water supply?
Physical	Is the plant and distribution system suited to local conditions?
Management	
Human	Are operators able to run and maintain the infrastructure?
Financial	Does the system have access to funds to cover engineering costs, capital expenses and operations and maintenance?
Governance	
Social	Do communities feel like the systems belong to them and are they willing to self-manage them?
Political	Do governance institutions at the local, regional and national levels provide sufficient incentives for the success of the project?

passes to a sedimentation tank where the flocs settle at the bottom and the clear water rises to the top. Chlorine is added to the clean water to kill bacteria and other organisms. Currently, one of the AguaClara facilities has an additional treatment process of filtration, using 'stacked rapid sand filters' (Adelman *et al*., 2012) to reduce turbidity further to levels under 1 NTU.

Key innovations of the AguaClara technology include: (1) it does not require any electricity (the plants operate off grid), as the water flows by gravity; (2) all materials used for construction and treatment are locally available; and (3) the technology is transparent and understandable to local operators. Materials used for construction are stone, gravel, sand, cement, bricks, rebar, PVC pipe and accessories and transparent plastic sheets. Plant design is done automatically with the AguaClara web-based design tool (AguaClara, n.d.), in response to the required flow rate and the dimensions of the materials that will be used in construction. The automated design provides a fully detailed three dimensional model of the plant that can be used to generate construction documents. Designs are currently available for flows between 6 and 70 L s^{-1}. The automated design does not include the structural design of the plant building, which is done by the implementation partner[7].

The water supply system using an AguaClara plant for water treatment provides consistent amounts of water that meet Honduran and WHO standards. Indeed, the plants provide quality water far above the UN's definition of an 'improved' source; it is potable. The plants offer almost continuous service and provide an amount of water per person per day that exceeds numerous standards[8]. Furthermore, the plants meet many requirements of sustainable, pro-poor technologies: they are made and operated with inputs that are available locally, they do not rely on electricity and they can be run by local people. They also cost less than conventional mechanized water treatments (rapid mix, flocculation, sedimentation and rapid sand filtration), at a relatively low total cost of US$2–4 per household per month. The chlorine costs approximately US$4 per million liters. The coagulant costs approximately US$10 per million liters. For small facilities, the highest operating cost is the salary of the plant operator.

[7] The web-design tool can be found in the following link: http://aguaclara.cornell.edu/design/

[8] Lockwood & Smits (2011), for example, recommend a standard of 60 liters/day/person and the plants supply well over 100 liters/person/day.

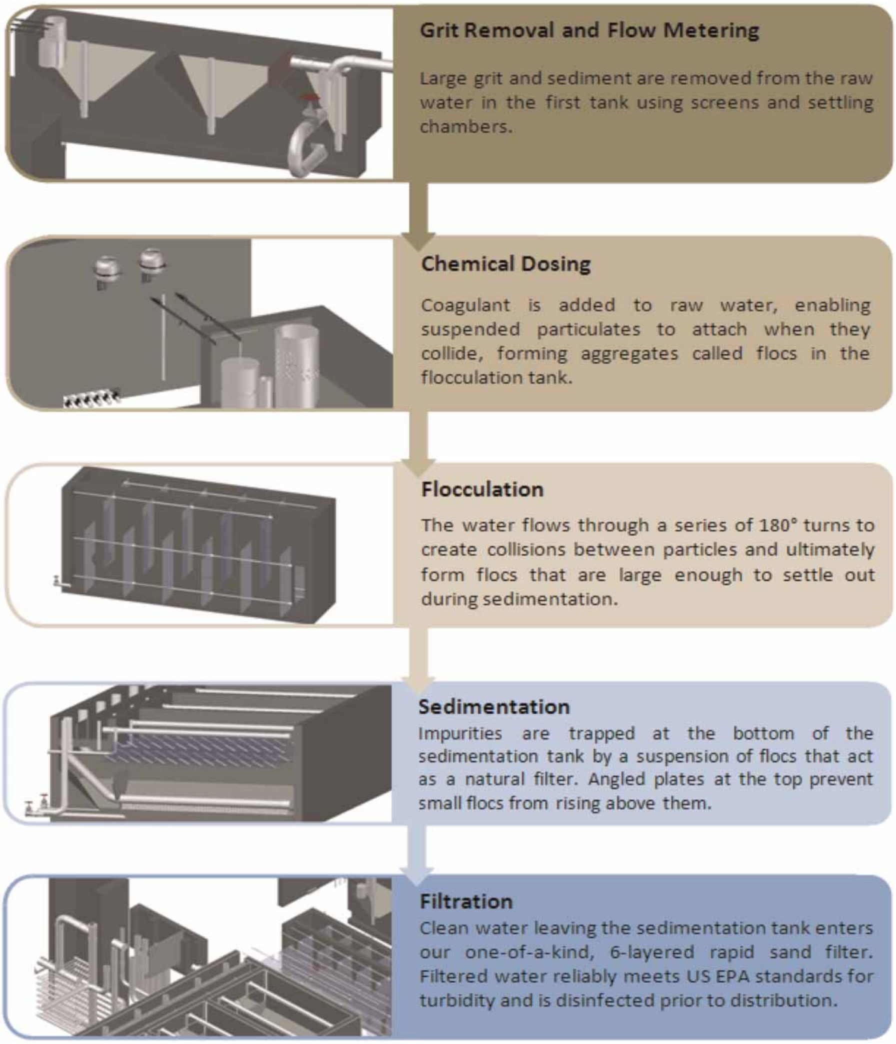

Fig. 3. Schematic of AguaClara plant design showing major unit processes of flocculation, sedimentation, and filtration. Used with permission, http://aguaclara.cornell.edu/technology/.

However, beyond the innovations of the water treatment plant, there are two issues of concern. The first has to do with infrastructure not related to the plant, such as the distribution system. In the communities where AguaClara has worked, this infrastructure existed prior to AguaClara's interventions and may be of variable quality. Water pipes that are of poor quality, poorly designed and poorly maintained can lead to water leaks, which in turn lead to reduced water pressure and decreased water availability for some households. Faulty pipes can also lead to the contamination of the water after it has been treated (Lee & Schwab, 2005), although the high pressure in gravity-fed systems makes this an unlikely problem in AguaClara's systems. However, in one AguaClara community, leaky pipes raised demand for water above levels that the plant was able to treat effectively, leading to sub-optimal water service (Smith, 2010).

Just as there can be problems after the water is treated, there can be problems beforehand. In AguaClara's plant in the community of Agalteca, the *obra de toma* – the pipe that brings in water from the river to the plant – is in poor condition. This has led to numerous breakdowns and it is estimated that the plant is only functioning for 60% of the time during the rainy season. If AguaClara is to be guided by its vision of providing sufficient, clean, reliable water to low-income people, then it has to look beyond the plant and think about these broader issues. One mechanism to do this is in the governance structure, where one of the standing committees focuses on environmental issues and coordination with municipal government to ensure continued access to the water source.

Management

One of the biggest challenges with small community water systems is financial and staff management to ensure the systems continue to function once installed. Lockwood & Smits (2011) estimate that between 30–40% of built water systems are dysfunctional at any given time, suggesting that the maintenance of the systems is just as important as the construction. The keys to good management lie in human and financial capital.

Human capital. No water system is foolproof and AguaClara's technology is sensitive to the skill level of its operators. In contrast to many modern systems, which use electro-mechanical control systems and an isolated control room that effectively prevents the operator from being able to control the plant while monitoring its performance, AguaClara is designed to be controlled by a plant operator who can observe the processes and adjust them at the same time. In this sense, the plants are designed to reduce the need for high levels of human capital. No expertise is needed in electricity, electronics, pneumatics, mechanized valves, or computer software and hardware. Thus a single operator can understand and maintain all aspects of the plant. In conventional mechanized water treatment plants, a team of highly specialized technicians is required to maintain the layers of systems required to automate control of the facility. In an AguaClara facility, all processes are in open tanks that can easily be observed and monitored by the operator.

A report by a Fulbright ambassador in Honduras highlighted the importance of the simple presence of the operator. According to the report, 'the presence of the operator [at the plant] was the most important factor for producing good quality water' (Smith, 2010: 3, our translation). The author had found that when operators were not around, the plants did not work well. The reasons for the operators leaving were varied: sometimes the workers were being pushed beyond human limits, assigned to work over 80 hours a week; at other times the absences were due to negligence or personal emergencies (Smith, 2010). In Támara, when the operator left the plant under someone else's care for 2 or 3 days, the Village Water Board punished him by withholding pay for a week and the operator chose to quit[9].

Nevertheless, the tasks of measuring turbidity, selecting the appropriate dose of chemicals and observing the flocculation process all require training for the operator (which requires primary school education). The same report indicated that some water quality problems resulted from operators'

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[9] A primary incentive for operators to do their work well is their salary. They receive a minimum wage (about US$250 a month), which is seen as good pay in rural areas where stable work is scarce.

incomplete understanding of how to work the plant (Smith, 2010: 51). The operator also records observations, sends performance data (raw water turbidity, treated water turbidity, coagulant dose, chlorine dose and plant flow rate) via text messages every 12 hours to the online data system[10], keeps track of chemical inventory (coagulant and calcium hypochlorite) and does regular cleaning and maintenance of the plant.

The human capital skills needed for successful running of the AguaClara plants can be organized into three sets: those related to management, those that are technical and concern the O&M of the plant and those that are financial. AguaClara's local partner, APP, has a training program that attempts to address all three sets of skills. The first module is on organizational strength and includes short courses on organizational roles and the functions of the general assembly, village water boards (VWBs) and committees; leadership and community participation; teamwork; and basic accounting for treasurers. The second module is on water quality and covers the relationship of water to health, ways of measuring water quality and the Honduran legal framework for water quality. This is especially geared towards health workers, the mayor and other municipal administrators and the plant operators. The third module is on water treatment and includes information on both AguaClara technology and other types of treatment systems. It is primarily for VWB members and plant operators. The fourth module is on basic math skills and is intended especially to help the operators learn to measure well and carry out the necessary arithmetic for setting the coagulant and chlorine doses. The last model is on operating and maintaining the plant and it includes information on calculating appropriate tariff levels. Each module takes 2 or 3 full days of training and the classes are later complemented by on-the-job training, especially for operators.

Aside from the modules mentioned above, APP budgets 3 days a week for 3 months for a circuit rider to accompany the operators with the tasks of the plant, including proper dosing, cleaning and bookkeeping (APP, 'Cronograma Social Alauca', n.d.). After 3 months, engineers still visit each plant every few weeks to check on the equipment and test the water. APP visits regularly and transcribes the notes and measurements of the operators to electronic format for APP's analysis (more recently the operators feed this information to an online data system).

There is still progress to be made, of course. In the community of Támara, for example, despite the months of training, the operator still made mistakes when applying chemicals, which affected the water's quality (Smith, 2010: 173). The operator continued receiving training and visits once a week, but he kept making mistakes when applying the chemicals. The operator was replaced.

Currently, the direct human capital support communities receive comes from APP. However, the bulk of this support lasts some 3 months after the construction of the plant. Afterwards, although APP staff visit occasionally to check on the plants, communities basically fend for themselves. The administration of the plants receives little attention after the initial round of training. APP's attention turns to focus on new plants, because 'that is where our salaries come from and there isn't enough funding to attend to the old plants' (interview, 10/24/11). APP laments this situation, as it is aware of several problems currently facing the plants and it is working to build an Association of Community Water Systems that could collectively finance an ongoing circuit rider for technical support[11].

[10] Found at: http://monitor.wash4all.org/.

[11] APP estimates adding another 5 lempira (US$0.25) to the household monthly tariff would allow participating communities to self-finance the circuit rider.

Financial capital. To assess AguaClara's ability to access and leverage financial capital, we look at the different areas of expenditure incurred over a plant's lifetime. These fall into three categories: engineering studies, O&M and capital costs (including initial construction and subsequent major repairs or expansions)[12].

Having an open-access design tool and a continuous group of engineering students working on AguaClara projects reduces the costs of engineering studies significantly. This is a significant strength of the project, as engineering design is often a significant barrier for small communities. Typically AguaClara finds grant funds to cover design costs, but since 2012 a number of Honduran towns have paid APP to provide designs for AguaClara plants, with the goal of using the detailed designs to obtain funding for construction.

O&M costs are well accounted for in AguaClara's model. Numerous scholars have written about the imperative of total cost recovery for at least the O&M costs (see e.g. Carter *et al*., 1999), which in AguaClara's case include salaries of the operators, purchase of chemicals and some administrative costs. AguaClara has achieved total costs recovery of O&M costs. There are at least three factors behind this success. First, the treatment technology produces abundant and clean water at a relatively low cost. The average tariff is approximately US$2.90 a month per household (this figure is calculated based on estimates of salaries for operators, chemicals, office supplies, etc.). While some communities have differential rates based on household usage, most AguaClara communities employ a single tariff structure with an equal charge for all households. Systems are not metered and thus a flat fee structure is used. Average household size is 5–6 people, so this works out to be around US$0.50 per month per person. Carter *et al*. (1999) suggested providing the service at £2/year, which in today's terms is around US$4.50. While the AguaClara plants fall short of this, considering that the minimum salary in Honduras is US$250/month and that the going rate for a farmhand is US$5/day (Carter *et al*., 1999), this rate does not seem inordinate. It represents between 1–3% of these salaries, assuming the farmhand works 20 days a month (Elvir, personal interview, 10/24/11)[13].

A second reason AguaClara has been able to cover O&M costs is that people are both willing to pay and do pay their water bills. This is strong evidence demonstrating that rural water users value safe water highly, as the communities have voted for water tariff increases and voluntarily pay up to twice the amount they formerly paid for the same amount of unsafe water in their homes[14]. As discussed further below, AguaClara's local partner demonstrates the treatment process to communities, showing the water quality before and after and this has helped convince people to support the construction of the plant and approve increases in tariffs. Some wealthier members of the community, who would otherwise be buying bottled water, save money by using the much less expensive tap water.

The third category of costs is capital costs. The capital costs listed in Table 1 are the costs incurred by APP in the design and construction of the facilities. However, they may not include all in-kind community contributions (land, labor and materials) or additional design costs contributed by AguaClara. If these costs were all fully monetized, system costs would be much higher. This component of financial capital may be one of the biggest impediments to the widespread diffusion of the AguaClara system. So far AguaClara

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[12] This is a simplification. There are other activities such as training that are an integral part of the AguaClara model; however, so far they have not required a significant outlay of funds.

[13] It is sometimes challenging to get communities to accept even this tariff level, however.

[14] While research has shown low income residents have multiple demand curves and are willing to pay different rates for different qualities of water (Spencer *et al.*, 2008), AguaClara presents a simpler one-system approach that benefits from economy of distribution of low cost, high quality water.

has depended on third party funding, from international NGOs such as CARE, Rotary International and the International Rural Water Association (IRWA) and from the Swiss Agency for Development and Cooperation. AguaClara has been looking into the possibilities of amortizing community payment into the user fee also to cover plant construction. This would enable more rapid expansion of AguaClara plants throughout Honduras and analysis shows it would be affordable to middle income communities[15].

Capital financing is also needed to support major repairs or expansions to water systems. The plants are designed to last 20 years and raising resources for capital improvements or repairs is a crucial component of ensuring system sustainability (World Bank, 2011). AguaClara's first plant in Ojojona needs an infusion of capital to bring it up to par, yet capital is not forthcoming. The plant in Agalteca also needs financing to fix its water source pipe. It is AguaClara's intention to turn over the plants completely to local control (in order, in part, to dedicate its efforts towards working with new communities and plants). If this occurs, most local communities currently do not have the capacity to access large amounts of capital for repairs or expansions that entail a significant outlay of funds.

Finally, there is a category of capital costs external to the plant *per se*, but which have to do with questions of equity and access. Connecting the poor and marginalized in a community is a concern for AguaClara and money is needed to connect those households currently not benefitting from the water system. This may require subsidizing the water tariff for some, or putting in pipes to connect them to the network. In fact, the community in Atima is currently exploring the possibility of implementing tariff rates with cross subsidies.

There are at least three factors that can help mitigate the challenge of capital financing for these costs. First, capital costs for AguaClara plants are generally lower than for other comparable technologies (Adelman *et al.*, 2011). Second, communities can contribute significantly through in-kind contributions. It is estimated that communities offer 30–40% of the total cost through in-kind contributions of materials and labor.

Third, AguaClara understands the need to forge relationships with external sources of capital. Some communities may be able to pay for these repairs and expansion through debt financing and AguaClara is currently exploring a model for this (this model may also be used for construction of new plants). In addition, as part of the national decentralization in Honduras, municipalities supposedly have central government funds to support water and sanitation work in their respective towns and villages[16]. These funds are inconsistently accessible, but they provided part of the support for the plant in El Alauca. Municipal support can enable communities to access these funds and provide another solution to the dearth of capital financing.

Governance

Local governance capacity is essential for sustaining community-based water systems. While technological choice and managerial capacity are necessary for creating systems that provide sufficient, safe

[15] Capital costs of US$140,000 debt at 5% interest for 10 years would require US$1.50/month (30 lempira) per household if divided over 1,000 households. Current monthly payments range from 60–90 lempira for O&M. The additional 30 lempira for debt servicing is still within range of what many households could pay.

[16] The government has some funds for water projects and an institution to channel these, the *Fondo Hondureño de Inversión Social* (FHIS). A 2010 report states that Honduras is receiving between 50–75% of financing needed to meet the MDG goals regarding water and sanitation (WHO, 2010). Also, the Honduran government passes 6% of its national budget on to municipalities, which could be used to cover water and sanitation expenses.

and regular drinking water, the governance of a water project – the 'capacity … to coherently organise the sustainable development of water resources' (Peña & Solanes, 2003: 3) – is often neglected at great cost to the impact and sustainability of the project (González Rivas, 2014, in press).

AguaClara's relationship with the communities in which it works has changed quite a bit since it began. The prototype for AguaClara was a small-scale gravity-powered plant built in 2004 for a town known as 'La 34'. This was not technically an AguaClara plant, as the program had not yet started, but the experience informed AguaClara about what happens when capitals aside from the physical are neglected. The plant was funded by IRWA and did not involve community participation in the construction. The plant is not used much, apparently being run only when someone from AguaClara pays the community a visit.

When AguaClara formally began to build plants, they enlisted the help of APP, a Honduran NGO with decades of experience in the water treatment sector, to provide technical assistance to local water boards. Under APP's direction, the community is substantially involved before construction begins. In particular, APP establishes relations with the community's Junta Administradora de Agua, or 'VWB' (Kayser, 2011). These are nationally mandated bodies and according to national legislation, are elected every 2 years by all water users of that community (interview Elvir, 10/24/11). Generally, the VWB has a president, vice-president, secretary, treasurer, 'fiscal' and two other voting members, all of whom work on a voluntary basis (APP, 'Estructura JAA y sus Estatutos', n.d.). They are supposed to serve a maximum of two 2-year terms, although this is not always practiced or enforced.

In fact, it was the VWB in Támara that approached APP to request a plant be built. A technician from APP then went to the community to explain the AguaClara technology at a community-wide water user meeting. APP also approached local health centers to learn more about waterborne diseases in the town and shared this information at the meetings. Water samples of untreated and treated water were displayed to show the difference between them and the results of laboratory tests with information on fecal coliform counts and other contaminants were shared. After these meetings, the water users were asked whether they wanted such a plant and if they were willing to pay an increased tariff (about double the previous one), which APP had calculated beforehand. A majority agreed. They also agreed to contribute 30–40% of the construction cost by providing materials (such as sand and bricks) and unskilled volunteer labor. Every water user had to volunteer for 1 or 2 days in order to receive treated water later. This was all formally detailed in a contract signed by the water users and APP.

Based on the success of these sorts of interactions, AguaClara has learned that creating the conditions for communities to take ownership of their water systems is fundamental, as community ownership ensures the system is cared for, paid for and protected from malfeasance. This is accomplished through VWBs, which are supported by a technical assistance circuit rider who conducts visits that involve community education, mobilization and training. VWBs coordinate various parts of the construction, oversee operations and maintenance of the plant after construction, hire and pay operators, set and collect tariffs, and resolve conflicts and problems at the local level. More broadly, communities participate in the 'Asemblea General', the assembly of water users which elects the VWB and makes major policy decisions. This assembly is engaged early on in the project and community members have to vote on whether they want AguaClara or not. Community participation is greatest in the smaller communities (as in Ostrom, 2010) and it is estimated that 70–90% of water users attend these meetings. However, after the initial period of education and accepting the AguaClara plant, it is estimated that the assemblies meet generally only once a year. In addition, since the assemblies comprise paying water customers, those who are not connected to the water system do not have a voice there. This is an obstacle towards addressing the concerns of the poorest and marginalized on a local policy level.

The success of an AguaClara project depends a great deal on the effectiveness of the VWB. This dependence is both the key to success in community governance but also can create problems when VWB members have conflicting incentives and obligations. One example is the difficulty faced by AguaClara in getting the VWB to change the water tariff in Ojojona. APP had calculated that in order to pay for the minimum O&M costs – including paying the salaries of the technicians and the chemicals needed for treatment – the tariff would have to double from around 25 lempiras to about 53 lempiras per household per month, approximately from US$1.25–2.50. APP had to visit the community several times to convince them that the increase was necessary. The trouble seems to have been that several members of the VWB had political aspirations and this is likely to have made them reluctant to raise the tariff (Kite, 2008).

The national framework states that VWB members must be volunteers. VWB members are elected by the body of water users, but some small rural communities lack a sufficient supply of local leaders willing to play this volunteer role. For example, in Ojojona, in spite of national regulations that stipulate that members can serve a maximum of two consecutive 2-year terms, the VWB members have not changed since the plant was built in 2006. VWB members sacrifice personal time and resources (lost labor) to serve their communities. This reflects a problem in community management systems based on generalized reciprocity, where individual leaders incur a direct cost but only indirect benefit (Bourdieu, 1986; Warner, 1999). As one water board leader from El Alauca stated, 'My family is sometimes hungry because of the time I have to spend on the water board.' APP is aware of this problem and is exploring solutions.

Conflict within communities is another important challenge that VWBs face. It is axiomatic that if the community does not take responsibility for the system, it will fall into disrepair. An example of this challenge occurred in Atima, where the members of the town were not all convinced that it was worth paying the new higher tariff. A second (shadow) water board declared itself and began reconnecting households that had failed to pay the new tariff. The second water board then charged the old rates to these reconnected households. The official water board called a town meeting, where the case was discussed and the shadow water board was disbanded.

These challenges of governance all highlight the importance of a community's social capital in the successful workings of water projects, as Carter *et al*. (1999) have emphasized. Social capital, or norms of reciprocity, include both hierarchical (patron-client) and horizontal ties. While horizontal ties bind members of the community together and enhance collective action, bridging ties help them access resources outside the community (Putnam *et al*., 1993; Ostrom, 1994; Warner, 1999; Flora, 2004). The key to AguaClara's success is its focus on both bonding and bridging ties. While APP helps build bridging ties to access external technical expertise and financial resources, the participation of the community is based primarily on horizontal forms of social capital. A key to the construction and success of social capital are the extent of relevant linkages in a community, as these are what facilitate information exchange and successfully 'embed' organizations in a community. One concern, which Agua Clara takes seriously, is whether all members of the community are included in the relevant social capital networks of their communities.

In particular, AguaClara acknowledges the need to increase women's participation in the management of their water systems, not only on the basis of equity but also because access to safe water affects women in a particular way. Women are generally the ones whose lives are most affected by the quality of the water system, since they are generally in charge of water collection and purification for cooking and cleaning. Giving women a voice in assemblies is crucial therefore to ensure the system is designed in a way that meets the consumers' needs[17]. Women's participation in VWBs is one good indicator of community participation. In AguaClara, women constitute 23% of VWB membership in the five AguaClara communities with water boards[18]. Clearly there is considerable distance to go. One of the reasons for lower participation of women in VWBs is that they work both inside and outside the home and view the additional (unpaid) leadership role on the VWB as an additional burden. One woman from El Alauca, for example, admitted that she only attended the first meeting and sent her husband to all subsequent meetings because she was too busy (as quoted in Hill, 2013).

Finally, there is political capital, an important aspect of which involves bridges to national level resources. In Honduras, Servicio Autonomo Nacional de Acueductos y Alcantarillados, which used to be in charge of all water provision, is in the process of devolving this responsibility to municipalities and water boards. The first 'basic policy' of CONASA (Consejo Nacional de Agua y Saneamiento) is to 'support the decentralization process with citizen participation and strengthening of local government' (CONASA website). There is a nationally-sponsored *Plataforma del Agua de Honduras* as well as associations of VWBs on national and regional levels, which may potentially contribute to an environment that is conducive for water projects, with accessible materials, shared knowledge, technical and financial support and legal resources. However, weaknesses in these forms of political capital are an important challenge faced by AguaClara communities – a challenge somewhat beyond their control to address (Beers, 2012).

Monitoring and oversight are also important components of political capital for a successful governance model. APP provides some of this for the technical aspects of the plant's functioning, with the APP circuit rider accompanying the operator for much of the first 3 months of operation. VWBs are also checked on to see that they are meeting regularly and have their books in order. VWBs are required by law to have yearly audits of their accounts, which provide another level of monitoring. However, this is an internal audit, done by the 'fiscal' member of the board. Another level of oversight comes from the Ministry of Health, which periodically tests water quality and lets APP, and presumably the VWB, know when it is deficient (interview Elvir, 10/24/11). Donors also monitor APP, especially keeping tabs on spending.

Conclusion

Success in building environmentally and financially sustainable community water systems rests on three pillars: technology that is resilient, affordable and reliable; management that is within the reach of the human and financial resources of the community; and a governance system that is trusted and supported by the community and by higher levels of government. Our analysis using the community capitals framework has demonstrated that AguaClara is building sustainable water systems by giving

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[17] The United Nations Economic and Social Council recommends gender mainstreaming as 'a strategy for making women's as well as men's concerns and experiences an integral dimension of the design, implementation, monitoring and evaluation of policies and programmes in all political, economic and societal spheres so that women and men benefit equally and inequality is not perpetuated' (as quoted in Tiessen, 2007: 12).

[18] The sixth system, Marcala, is run by the municipality (although the director of water services there is a woman).

attention to capacity building in the three critical arenas: technology (natural and physical capital), management (human and financial capital) and governance (social and political capital). Too many water projects focus only on the technical side, but as the case study of AguaClara demonstrates, looking at management and governance of water systems is equally critical.

The process of building up the various forms of capital takes a long time and careful stewardship. Governance, as we have shown, includes both the formal decision-making structures and more informal social networks, as well as the relationships of trust that sustain them. Governance (political and social capital) is responsible for caring for, building and marshaling all the other forms of capital. Our analysis shows that AguaClara engages in a form of 'cooperative governance' where engineers and local communities share information and develop innovative solutions. In this framework, each actor plays a key role. Local communities build the support, trust and willingness to invest that keeps a water system operational over time. The role of engineers and technical assistance from AguaClara and APP is to provide engineering and training support.

One area of weakness in the community-focused model is how to facilitate more effective communication and resource flows between communities and higher levels of government. Ultimately, more government support is needed to ensure long-term stewardship and to reinforce the legitimacy and accountability of the community-based system (Spencer & Guzinsky, 2010). But the AguaClara model provides an important example of the critical role of technology, management and governance in ensuring the long-term success of community-based water systems management. While external support for capital construction and engineering is needed to expand access to safe drinking water for the two billion people in the world that are currently underserved, AguaClara has shown that community-based models are an important part of the solution. The fact that all of the plants continue to provide safe drinking water years after their construction and continue to self-finance O&M, is proof of the sustainability of the AguaClara model.

Future research should explore the intersections between these three domains: technology, management and governance. There are strong synergies between the domains and strength in one can help bolster another. For example, we have shown that AguaClara's emphasis on simple, sustainable technology helps make the managerial and governance domains work better. However, the managerial and governance domains also require careful, ongoing attention. While the AguaClara program builds positive synergy between technology, management and governance, we know that community water systems around the world suffer from managerial and governance failure – often exacerbated by inappropriate technology. By giving equal emphasis to all three domains, we have demonstrated how sustainable community water systems can be built and sustained over time.

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Received 26 July 2013; accepted in revised form 18 November 2013. Available online 17 February 2014