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Reevaluating onsite wastewater systems: expert recommendations and municipal decision-making

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Abstract

Onsite wastewater treatment systems (OWTS) serve 20–25% of the households in the USA, and large parts of rural Canada, Australia, and Europe. Urbanization and newer environmental standards are leading many communities that currently rely on OWTS to think of alternatives. We study this decision-making in 19 municipalities across the USA through the unique lens of feasibility reports commissioned by the respective municipalities and authored by engineering/design consulting firms. The reports omitted certain essential information relevant to the decision-making process, and were not of high quality due to a lack of specificity on various parameters. However, the reports evaluated a balanced mix of decentralized and centralized treatment options, and the final recommendations were not biased in any particular direction. Most municipalities failed to take any follow-up action on the report recommendations, calling into question the motive behind commissioning these reports. Although not representative of the entire USA, the small sample of feasibility reports evaluated here is indicative in nature and provided significant insights about the inputs that help municipalities make decisions on complex issues.

Keywords: Decentralized; Decision-making; Feasibility reports; Onsite systems; Wastewater management

1. Introduction

Approximately 20–25% of households in the United States are served by onsite wastewater treatment systems (OWTS) (USEPA, 2008; 2014). Typically, these households are located in rural and suburban areas where centralized sewer systems are economically infeasible. OWTS are suited for locations with low density and large lot sizes. Wastewater treatment by OWTS is not restricted to the USA. Large parts of rural Canada, Australia, and Europe rely on them to varying degrees. The proportion of the population using OWTS is as high as one-third in the case of Ireland, but more commonly 10–15% as observed in Australia and Greece (Massoud *et al.*, 2009; Libralato, 2013). In a report to the United States Congress,

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the USEPA (1997) stated that 'adequately managed decentralized wastewater systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas'. The use of a simple paradigm in which urban households will be connected to a centralized wastewater treatment plant (WWTP) through a network of sewers, and rural households will rely on OWTS, is underlain by the assumption that rural and urban areas can be clearly distinguished temporally and spatially. In reality, rural areas become urban in character through increased in-migration, business development, smaller lot sizes, and densification. This transition creates micro-urban areas in rural counties, and exurban development around urban areas (Theobald, 2001). How do these rural and suburban areas that are experiencing densification deal with wastewater management? What is the impact of new water quality regulations or soil constraints on these growing towns? Whose expertise do the towns rely on in making such decisions? We explore decision-making in small towns[1] in the USA in the context of wastewater management through the information presented in wastewater feasibility reports that are commissioned by municipalities and authored by engineering/design consulting firms.

2. Onsite systems: failure and management

The Federal Water Pollution Control Act of 1972, better known as the Clean Water Act (CWA), was a landmark piece of legislation that combined a command-control policy with a permit system that was pegged to the 'best practicable' technology to eliminate pollution from the nation's drinkable and navigable waters. The CWA, however, only applied to point source discharges and excluded non-point sources such as agriculture, stormwater, and OWTS such as septic systems. Over time, the implementation of the various provisions of the CWA, such as 303(d) impaired waters listing, and other regional, state and local regulations have resulted in greater scrutiny of non-point sources of pollution (Boyd, 2000).

Despite the many forms of OWTS, the septic system – the most basic version involving a septic tank and a soil leach field – is the most commonly found OWTS system and is, in many instances, used synonymously with OWTS. Septic systems have often been debated as the cause of water quality decline in surface and groundwater. One of the more recent and high-profile reminders came from Maryland Governor Martin O'Malley in his State of the State address in January 2011. Acknowledging that the state has had some success in curbing pollution from farms and wastewater treatment plants, he stated that

> *'there is one area of reducing pollution where so far we have totally failed, and in fact it has gotten much worse ... and that is pollution from the proliferation of new septic systems – systems which by their very design are intended to leak sewage into our bay and water tables'* (Wheeler, 2011).

The allegation that septic systems result in water pollution is not totally unfounded. Poorly maintained septic systems, especially their density, are associated with endemic diarrheal diseases and water quality issues (Borchardt *et al.*, 2003; Hatt *et al.*, 2004). Although failure rates in septic systems are hard to assess on a large scale, recent observations from US states show failure rates of 18% in Delaware

[1] The use of the term 'town' here is meant to signify a small municipality. Administratively, they can include any form of government such as a village, town, township, city, borough or even county.

(EFC, 2008), 20–24% in Pennsylvania (Day *et al*., 2008) and 30% in Ohio (Vedachalam *et al*., 2012). Part of the difficulty in assessing failure rates is the inconsistency across state regulations on what constitutes failure.

Since the impacts of poorly maintained OWTS are spatially and temporally separated from the system in question, the rational decision for the OWTS owner is to undertake minimal to no maintenance, even though such a practice conducted on a large scale by various owners will eventually result in sub-optimal water quality in the community's common waters. Several communities have successfully navigated this 'tragedy of the commons' trap associated with OWTS, and demonstrated the use of these systems to meet their wastewater challenges. Mancl (2002) presented narratives from four such communities in California, Colorado and Iowa. Communities around Keuka Lake, Otsego Lake, and Skaneateles Lake and several others in upstate New York have employed a mix of advanced technology, a management program and homeowner cooperation to maintain OWTS and preserve the local water quality (Allee *et al*., 2001; Blanco *et al*., 2010). Others such as Cuyler, NY, several years ago embraced cluster systems, which are a hybrid of OWTS and centralized treatment (Feuss *et al*., 1994). More recently, the United States Environmental Protection Agency (USEPA) has proposed five levels of management to address septic systems maintenance and highlighted one or more communities that follow each of those management programs (USEPA, 2012).

3. Choosing the better option: sewer or onsite?

There has been limited but growing research on the question of which of the two options – centralized or decentralized – is better for any particular community. Researchers have tried to answer the question with representative models, or comparisons between different communities using the two options. Engin & Demir (2006) studied 22 villages in the district of Gebze near Istanbul, Turkey, and compared cost estimates for three options – a classic sewer system, a cluster system, and a package treatment system. Their results suggested that cluster systems were more economical for the first 9 years, but sewer systems and package plants were economical in the long run. Further, cluster systems were economical in the long run for small communities that were located 7 km or less from the sewer interceptor line. Prihandrijanti *et al*. (2008) conducted a similar analysis for a sub-district in Surabaya, Indonesia's second-largest city. The authors conducted a cost-benefit analysis of three options and reported that decentralized domestic wastewater treatment combined with an ecological sanitation system had the lowest cost-benefit ratio and highest net present value. The ecological sanitation system described in Prihandrijanti *et al*. (2008) requires the separation of black, gray and yellow (urine) water, and aims to recover nutrients present in each of the waste streams.

Maurer *et al*. (2005) investigated the competitiveness of decentralized systems by evaluating national-level data from the USA and a few European countries. The authors estimated the total annual cost of centralized wastewater treatment, including capital financing, depreciation and operation and maintenance (O&M), to be $142 (2002 value) per capita for a large country such as the USA. They further argued that the most basic decentralized system should cost no more than $142 per capita per year to be competitive with the centralized option. Pinkham *et al*. (2004) evaluated the decision-making process for a hypothetical growing community in the USA. They concluded that if the mode of financing is ignored, the capital and O&M costs are the same for centralized and decentralized options on a present value basis over a 60-year period. However, when the mode of financing is considered, the centralized system owned by the township is most expensive over the same 60-year period. Resident-owned OWTS are somewhat less expensive than township-owned OWTS, since O&M costs are borne by the residents. Therefore, decentralized systems can be competitive against a centralized treatment option in a hypothetical scenario. Libralato *et al*. (2012) sum it up well in their overview of recent trends in wastewater management. They suggest the coexistence of various levels of centralized and decentralized treatment, given advances in treatment technologies, new regulations and acceptance of reuse. The cost involved in upgrading and replacing aging treatment plants also plays in favor of decentralized options that are easy to install and expand (Libralato *et al*., 2012).

Despite the competitiveness of decentralized systems, they are not the preferred choice of some residents, environmental groups and government monitoring agencies, who view these systems as outdated, inferior in technology, prone to failure and difficult to monitor. One of the key reasons these groups have not been able to phase-out OWTS entirely is cost – centralized systems are extremely expensive. It is a challenge to convince residents to pay higher costs for a service that many of them did not seek voluntarily. In some cases, the suggestion to centralize wastewater treatment is viewed as an act of government interference in daily lives.

This article aims to add to the growing literature on the process of decision-making with regard to wastewater management in rural areas and small towns. However, our work differs from previous efforts due to the novel approach we take in understanding this process. From time to time, municipalities in the USA (either at the level of city, town, village or county) commission studies to evaluate their existing infrastructure (water, transportation, housing, etc.) and propose improvements, while factoring in demographic, technological, and regulatory changes. Municipalities that rely on OWTS face challenges related to the failure of individual systems resulting in a decline in water quality, or arising from new regulatory standards, and increases in population or business potential. Typically, they identify an engineering/design consulting firm to conduct a review of the existing wastewater treatment infrastructure and suggest suitable replacement options. Such a study is then presented to the town board or a similar decision-making authority for approval and further action. We review a sampling of these study reports to understand the process by which US municipalities make decisions about replacement of onsite systems.

4. Methods

Since municipal infrastructure studies are not indexed or stored in a single repository, we conducted a web search on Google (www.google.com) using the phrases '''Town [or Village] of [state name]'' & "septic system" & "study''' or '''Town [or Village] of [state name]'' & "wastewater management" & "study [or feasibility report]'''. The search was conducted during the month of June 2013. In search results that yielded summary documents but not the entire report, the respective municipality and/or the consulting firm that prepared the report were contacted to obtain the full report. Through such interactions, names of other municipalities in the state that had gone through a similar process were obtained. The search process was repeated, but with the names of specific municipalities. Thirty reports were identified using the web search process. For inclusion in our study, the reports had to meet the following criteria:

(a) dated between 2004 and 2013;

(b) solely focused on wastewater management (and not general planning documents);
(c) the current wastewater system is an OWTS;
(d) more than one alternative is discussed;
(e) cost of the alternatives is presented; and
(f) available in their final form, as they were submitted to the respective municipality.

Only 16 of the 30 reports met the inclusion criteria. The authors were in possession of an additional three reports, all from New York, before the beginning of this search process. These 19 reports were analyzed to identify patterns in decision-making at the municipal level (see the Supplementary Information for a list of the reports, available in the online version of this paper). Since several reports used the word 'feasibility' in the title or in the executive summary, we refer to these reports as 'feasibility reports' at various points in this manuscript. The studies have a distinct bias toward Northeastern and Pacific coastal states (see Figure S1 in the Supplementary Information, available online). This could be partly attributed to the strong environmental laws and public awareness in some of those states. These states are also home to a large number of lakes, whose water quality could be affected by inputs from OWTS. In addition, proximity to the ocean, especially sensitive bay regions, can heighten the concern about poorly functioning OWTS.

5. Results

An overview of the wastewater characteristics of the municipalities included in the study is presented in Table 1. More than half the study areas currently rely solely on basic OWTS, primarily septic systems. The rest use a combination of OWTS and other techniques such as cluster systems, advanced OWTS such as sand filters, and a centralized sewer system. Nearly all reports mention the current average wastewater flow (in gallons per day (gpd); 1 US gallon = 3.785 liters), which ranges from 5,640 gpd in Marin County, CA (1) to more than a million gpd in Easton, MA. Less than half the reports provide information on planned future wastewater flow. Of those, two reports projected average wastewater flow. The reports also provide justifications for conducting the feasibility study. The majority of the reports present reasons based on water quality and poorly maintained septic systems. A significant number of the reports also present justifications related to expected growth in population, encouraging expansion in business and new regulations that prohibit the use of existing systems.

The municipalities' geographical and socio-economic details are presented in the Supplementary Information (Table S1, available in the online version of this paper). A clear governance pattern is seen in the type of municipality that commissioned the study. All the studies conducted in the eastern USA are by smaller units of government such as towns or town-equivalents due to strong home-rule governance in those states. However, except for Abilene, TX, all the studies from states west of the Mississippi River are conducted by the respective county governments, who are able to make joint planning decisions for multiple jurisdictions, as observed in the column 'study area'. The size of the study area, as measured by the residents or households affected by the feasibility studies, varies widely. The household median income ranges from $32,574 to $105,880. However, only three reports contain data on household median income of the municipality. The rest of the median income data was obtained from the US Census Bureau for either the municipality or the county in which the study area was located.

The authors of the study reports and a summary of previous efforts are provided in the Supplementary Information (Table S2, available online). Two of the firms appear twice in the list. Most of the reports

Table 1. Wastewater characteristics of the municipalities.

Municipality	Current WW system[a]	Average wastewater flow (gpd)		Compliance issues[b]
		Existing	Planned	
Abilene, TX	1	131,400		4
Blooming Grove, NY	1	255,200		2
Bristol, RI	1, 4			3
Califon, NJ	1			1, 3
Clallam, WA	1, 4	62,370	79,110	1, 2, 3, 4
Colerain, PA	1, 4	341,725	614,914	4
Easton, MA	1, 4	1,193,000		3, 4
Georgia, VT	1, 2	36,700	169,000[c]	1
Inlet, NY	1	16,690		2, 4
Koochiching, MN	1	25,250	59,725	1, 2,3
Lansing, NY	1	66,293	77,411	2, 3, 4
Lysander, NY	1	16,800	94,000[c]	3
Marin, CA (1)	1	5,640		1, 2, 3
Marin, CA (2)	1	31,000–34,650		2, 3
Mason, WA	2	175,155		2, 4
Mina, NY	1	170,000		2, 3, 4
Paradise, CA	1	534,000		3, 4
Routt, CO	1	19,735	27,535	1
Warren, RI	1, 3			2

[a]Current WW system: (1) basic OWTS, (2) cluster OWTS, (3) advanced OWTS, (4) WWTP and sewer system.
[b]Compliance issues (figures in parentheses denote number of municipalities stating that reason in the report): (1) new regulations such as lot size for septic systems are not met, soil conditions are degrading (6); (2) contamination of nearby water bodies (i.e. groundwater, watersheds), water quality issues, public health concern due to current subpar wastewater systems (10); (3) present systems are failing, or cannot handle existing flows, they may be too old to perform well (11); (4) expected population growth, encourage business growth, preserve environment/nature (9).
[c]Projected wastewater flow.

build on similar studies conducted in the past. This gives us preliminary evidence that these feasibility reports are not the last word on this issue and local governments do not take immediate action following the issuance of these reports. Paradise, CA, is a case in point, whose feasibility report cites five previous efforts beginning in 1969. The list of previous efforts does not include general planning documents such as the town's comprehensive plan which is not specific to wastewater.

5.1. Alternatives and recommendations

Each report discusses multiple alternatives to replace the existing OWTS. Broadly, the alternatives fall into the following categories:

(a) Maintain status quo.
(b) Implement an onsite management program: such a program involves regular inspection and annual maintenance by either the municipality or a management entity created for this task. The treatment unit is typically owned by the resident, although municipal- or management-ownership of the unit is possible.

(c) Lagoon treatment: this is a variant of decentralized management where wastewater from a small number of households is aerobically treated in a shallow lagoon. Depending on the number of households, one or more lagoons may be employed for treatment purposes.
(d) Build a cluster system: a cluster system involves the use of individual septic tanks in each household that collect the solid waste. The liquid waste is then transported via small diameter pipes to be treated at a small-scale centralized treatment facility. Depending on the use of gravity or pumps to transport the liquid, they are also known as septic tank effluent gravity/pump (STEG/STEP).
(e) Connect to an existing treatment plant in a nearby municipality.
(f) Build a new centralized treatment facility with a sewer collection system.

The first four options use decentralized treatment, while the remaining two involve centralized treatment. Cluster systems, described in (d), incorporate principles of decentralized (the use of individual septic tanks) and centralized treatment (large volume treatment at a single location) systems, but since they are typically smaller in size, such treatment is generally categorized as a decentralized method. In their analysis of the various alternatives to the existing system, 10 of the 19 reports divided the study area into multiple regions and considered separate options for each region. The division of the study area into multiple regions was necessitated by differences in soil suitability, population, slope, and other constraints. Table 2 shows the various alternative options that were considered and finally

Table 2. Alternatives and recommendations.

Municipality	Separation of study area	Status quo	Management program	Lagoon	Cluster system	Connect to existing facilities nearby	Build treatment plant/sewer system	Alternatives considered (number)
Abilene, TX	√		**1**		**1**		**1**	3
Blooming Grove, NY	√		**1**		1		1	3
Bristol, RI			**1**		1	1		3
Califon, NJ			**1**					1
Clallam, WA	√		**1**		1	1		3
Colerain, PA	√		1	1	1	1	1	5
Easton, MA	√	**1**	**1**		1	**1**	1	5
Georgia, VT	√		1		1	1		3
Inlet, NY		1			1		**1**	3
Koochiching, MN	√	1	1		1	**1**	1	5
Lansing, NY				1	1		**1**	3
Lysander, NY	√		1		**1**	**1**		3
Marin, CA (1)		1	1		1	**1**		4
Marin, CA (2)		1	1		1	**1**		4
Mason, WA		1	1		1	1	1	4
Mina, NY	√		1		1		**1**	3
Paradise, CA				1	1	**1**	1	4
Routt, CO		1	1	1	**1**	1	1	6
Warren, RI	√		**1**		1		1	3

Note: the check mark in column two indicates the study area was separated into multiple regions and separate alternatives were evaluated and recommended. A '1' against a particular alternative (columns 3–8) indicates that the option was evaluated in the report. Gray shading of the cell indicates that the alternative was recommended.

recommended. Consideration of a particular option is indicated by a '1'. Gray shading of the cell indicates that the option was recommended for the town to implement. Reports that divided the study area into multiple regions also recommended different alternatives for each region, hence some rows have multiple shaded cells. The reports for Colerain, PA, Georgia, VT, and Mason County, WA, evaluated multiple alternatives, but none were explicitly recommended.

A summary of the results is presented in Table 3. Most of the case studies considered building a cluster system and instituting a management program. In a cluster system, the use of small diameter pipes to only carry the effluent without the sludge reduces overall cost and facilitates easier monitoring. Creating a management program for the existing OWTS is another attractive idea, since it is seen as a low-cost option that has been increasingly adopted by several communities across the country. A little more than half the reports considered either connecting to an existing treatment facility in a neighboring municipality or building a new treatment plant with a sewer system.

Of the alternatives considered, management programs and connection to an existing facility were recommended most often. Construction of a new treatment plant was recommended in only a third of the cases where such an alternative was considered. One of the reasons for not recommending this option included the large construction cost, and disruption of the municipalities' day-to-day activities in the short run. Many of the study areas attract tourists, and, as such, were not amenable to the decline in visual attractiveness and business revenue typically experienced during a long construction period. Maintenance of the status quo was considered in less than 40% of the reports. Except one, none of the seven reports recommended that option since the municipality would fail to meet either new regulations, health standards or water quality concerns. The one report that did recommend the status quo option had divided its study area into multiple regions, and one of the regions did not require immediate action. None of the reports recommended the use of lagoons as a treatment option, even though four reports had considered it in their analysis.

5.2. *Quality of reports*

Table 4 lists a few characteristics of the reports that could potentially influence the quality of those reports. Five companies, who authored six reports in the sample, appear in the Engineering News-Record's (ENR) list of the top 500 design firms in the USA. Entry in the list is based on the company's revenue earned through design services, and is thus indicative of the staff size and resources available to execute projects such as the ones being analyzed in this study. Municipalities sought companies that were located nearby, typically in-state, to execute their feasibility analysis[2]. The median distance

Table 3. Alternatives and recommendations – summary.

	Status quo	Management program	Lagoon	Cluster system	Connect to existing facilities nearby	Build treatment plant/sewer system
Evaluated	7 (37%)	16 (84%)	4 (21%)	18 (95%)	12 (63%)	12 (63%)
Recommended	1 (14%)	7 (44%)	0	3 (17%)	6 (50%)	4 (33%)

[2] In our sample, all but one municipality chose a consulting firm located in the same state. The only exception was the case of Mina, NY, which chose a company from the neighboring state of Pennsylvania, but one that was only 11 miles away.

Table 4. Quality of reports.

Municipality	Consulting firm ENR rank 2014	Distance (miles)	Pages in report	QR score
Abilene, TX		240	26	0.44
Blooming Grove, NY	250	50	52	0.74
Bristol, RI	450	40	97	0.53
Califon, NJ		40	384	0.50
Clallam, WA	208	101	83	0.79
Colerain, PA		96	64	0.65
Easton, MA	23	48	231	0.82
Georgia, VT		86	57	0.50
Inlet, NY		128	70	0.65
Koochiching, MN		171	32	0.53
Lansing, NY		62	73	0.65
Lysander, NY	366	16	77	0.56
Marin, CA (1)		70	173	0.85
Marin, CA (2)		32	254	0.82
Mason, WA		90	543	0.88
Mina, NY		18	96	0.82
Paradise, CA		24	28	0.62
Routt, CO		56	49	0.56
Warren, RI	250	27	36	0.71

between the study area and the company's office (headquarters or branch office, whichever was nearest) was 35 miles (56 km). The length of the reports varied considerably, ranging from 26 pages in the case of Abilene, TX, to a voluminous 543 pages in the case of Mason County, WA. The median report length was 73 pages.

To counter the heterogeneity in the report composition, we constructed a rating scale to evaluate the quality of reports. The ratings included 17 parameters, classified under three broad categories – background information, alternatives, and recommendation and follow-up. *Background information* included details on the number of users, their socio-economic conditions, existing wastewater systems, information on soils and topography, regulatory requirements and history of planning efforts in the municipality. *Alternatives* included the total number of alternatives considered, extent of details provided for each of them, cost data on each of the alternatives, breakup of capital and O&M costs, and the average cost per housing unit. *Recommendation and follow-up* included recommendation of one or more options and its justification, information on grants and other funding options, and an appendix with additional information. A rating rubric was designed with each parameter worth 1 point (see Supplementary Information Table S3, available in the online version of this paper). Except in two parameters, reports meeting partial requirements on a certain parameter were awarded 0.5 points. The parameters were uniformly weighted, and each report could score a maximum of 17 points. The resulting score (quality of report score, QRS) was normalized by the maximum possible points (17) to result in a final score that ranged from 0 to 1. A higher score implied a better quality report.

The average QRS of all studies was 0.66. While the low number of reports prevented us from performing multivariate regression to isolate the effect of independent variables on QRS, we performed simple univariate regressions to find associations between QRS and other variables of interest (Table 5). A higher number of pages in a report was weakly associated with a high QRS. All other

Table 5. QRS: bivariate regression results.

Independent variable	Coefficient (S.E.)	*p*-value
Year	0.003 (0.012)	ns
ENR 500 rank	0.040 (0.070)	ns
Distance	−0.011 (0.008)	ns
Pages in report	0.043 (0.022)	0.07
Separation of study area	0.017 (0.066)	ns
Median income	0.060 (0.170)	ns

Note: dependent variable is QRS. Standard errors are reported in parentheses. ns = *p*-value not significant. The variables, 'ENR 500 rank' and 'separation of study area' are binary; rest of the variables are continuous.

tested variables were not significant. The most intriguing was the role of the engineering firm authoring the report. Inviting firms listed in the ENR 500 did not result in any quantifiable increase in the quality of the report. Similarly, division of the study area into multiple regions to propose unique solutions for each region was not associated with a better report.

5.3. Cost data

Data on cost were well presented across all reports. Some reports presented extensive data tables with breakdowns on treatment and collection for each option. As such, we will not attempt to summarize the cost data presented in each report. Nevertheless, the cost estimates had a wide range. The total costs ranged from a low of $1.2 million for a management program in Marin County, CA (1) to a high of $41 million for Paradise, CA, to connect to a nearby treatment plant. However, the per capita costs come out very different due to the different populations served by each of these options. The use of inconsistent measures to describe the population served prevented us from comparing the per capita costs across the municipalities. We present a schematic from one of the reports to show the complexity of arriving at the total cost for any particular option and then comparing it with other alternatives and with other similar studies. Figure 1 shows the cost for each of the alternatives considered in the case of Lansing, NY. The numbers in parentheses refer to the total annual costs, which is the sum of debt service on capital cost (calculated at 4.0% over 30 years) and O&M costs. The total cost is comprised of the cost of collection and treatment of wastewater. Three collection and four treatment alternatives were

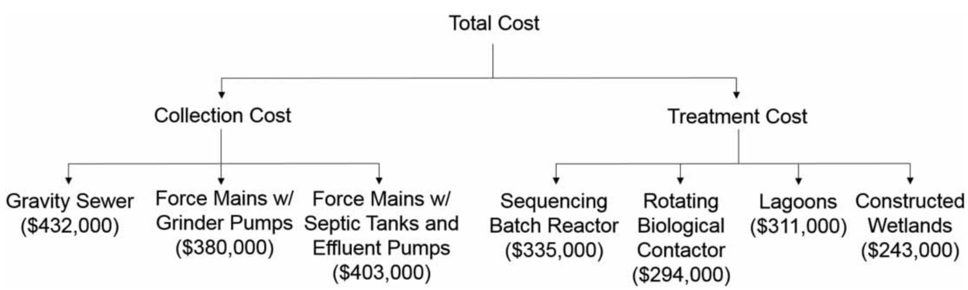

Fig. 1. The total annual cost of debt service and O&M for each of the options considered in the Lansing, NY report.

considered. The capital cost ranged from $4.6 million to $6.6 million for the collection system and $3.0 million to $4.4 million for the treatment system. Surprisingly, the consulting firm recommended the gravity sewer mains and the sequencing batch reactor system, even though they were the most expensive of the options considered.

6. Discussion

The range of populations currently using onsite treatment systems (Table S1, available online) and of wastewater flow generated (Table 1) in the municipalities studied raises the obvious question: is there a general rule for when neighborhoods transition from OWTS to a sewer network and what triggers that transition? The answer seems to be 'No', despite the localized models discussed in Section 3 that can provide an answer if relevant data are provided for the model. In the absence of a robust decision system, municipalities are left to decide which neighborhoods are best served by creating or extending sewer networks, and which are best left on OWTS. Though expensive, local governments prefer getting residents on the sewer network because it solves the 'moral hazard' problem associated with OWTS. Apart from the raw population numbers, density of those neighborhoods is likely another critical factor that determines the decision for or against sewer extension, although we have insufficient information from the 19 studies to conclude if higher housing density results in a recommendation for centralized treatment.

The median income of any town is a crude measure of its residents' financial status and signifies the ability to pay for the cost of a new project through rate increases. The USEPA suggests that wastewater (or water) rates are '*affordable*' if they are below 2% of the median household income (USEPA, 2002). Even if the system-wide rates are affordable, it is possible that, in any municipality, the rates are above the affordability limit for some low-income customers. Hence, it is quite surprising to see that only three reports provide median income data for the neighborhoods that were analyzed. More than half the reports do not provide information on planned future wastewater flows. We can assume that to be the case in municipalities that are not likely to grow and are only concerned about addressing current problems. However, half of the 12 reports that did not provide future wastewater flows cited expected population growth and encouraging business growth as reasons to undertake this study. There is large inconsistency even in the data on population affected by the feasibility studies. The reports use lots, parcels, housing units, equivalent-dwelling units and number of persons to describe the affected population without there being a universal conversion factor to go from one measure to another.

The majority of the reports cited previous efforts undertaken to assess the adequacy of the current wastewater system and the feasibility of alternatives, suggesting that often a single report may not be sufficient to necessitate action on the report recommendations. We observe a continuation of that pattern with the present set of reports (Table 6). Only a few of the municipalities have taken specific actions to implement report recommendations. In contrast, the report recommendations were explicitly rejected by the residents of Lansing, NY, who prevented a voter referendum on the construction of a new wastewater treatment plant over concerns about high costs.

On average, the reports presented between three and four alternatives for the municipal government to consider (Table 2). Except for the Borough of Califon, NJ, whose report had only one alternative discussed, all the reports had a minimum of three options. Routt County, CO, discussed all six possible alternatives, of which one was recommended. Contrary to our initial expectation that the consulting firms would not consider decentralized options (management program, lagoons, cluster system) and

Table 6. Updates and follow-up action.

Municipality	Year of report	Recommendation (s)	Follow-up action	Additional notes
Abilene, TX	2008	2, 4, 6	No action	
Blooming Grove, NY	2008	2	*	
Bristol, RI	2007	2	*	
Califon, NJ	2006	2	No action	
Clallam, WA	2013	2	No action	Funding constraints; lack of public and political support
Colerain, PA	2009		None	The study was a hypothetical exercise to examine feasibility of absorbing employes from an Army base that was planned for relocation from Maryland
Easton, MA	2004	1, 2, 5	*	
Georgia, VT	2005		*	
Inlet, NY	2006	6	New sewer district created; location for treatment plant identified	
Koochiching, MN	2008	5	*	
Lansing, NY	2012	6	Town board withdrew plans for a voter referendum	Public opposition over high capital costs led to the withdrawal. The town plans to fix some of the failing septic systems in the town's three school districts
Lysander, NY	2011	4, 5	*	
Marin, CA (1)	2011	5	Underwent CEQA review, awaiting project financing	
Marin, CA (2)	2011	5	Awaiting CEQA review	
Mason, WA	2006		No action	Lack of public support over high monthly rates
Mina, NY	2007	6	*	
Paradise, CA	2012	5	Town Council approved report recommendation	Discussions ongoing with City of Chico to extend sewer lines
Routt, CO	2013	4	No action	Consultation with residents in Summer 2013 yielded insufficient community support
Warren, RI	2009	2	*	

Note: the numbers in column 3 indicate the recommendation(s) made in the final report: (1) status quo; (2) management program; (3) lagoon; (4) cluster system; (5) connect to existing facilities nearby; (6) build treatment plant/sewer system.
*Indicates inability to reach the municipality; CEQA refers to the California Environmental Quality Act of 1970.
The updates were obtained in July 2014.

would recommend centralized options (connection to nearby facilities, constructing new treatment system) over decentralized methods, the reports had a balanced mix of alternatives. Further, the final recommendations were also well distributed across the two major categories.

The feasibility reports empower municipalities by providing context to the current situation, exploring alternatives and, at times, recommending a particular course of action to take. Therefore, it is extremely important for these reports to be as comprehensive as possible and to be written in a language that is accessible to all members of the community, including decision-makers and ordinary residents. The QRS was our attempt to compare the reports at the same scale. Since each report could score a maximum of 1 on the QRS scale, an average score of 0.66 does not reflect well on the overall quality of these reports. Even though we found no association between the QRS and the listing of the engineering firm in the ENR 500, the role of the 'author' in determining the quality of the report is significant. The QRS for reports written by the same author were similar (0.74 and 0.71 for Fuss & O'Neill, and 0.85 and 0.82 for Questa Engineering). Since municipalities often choose local firms to do the feasibility reports, it is important that they emphasize certain minimum standards regarding the content of the report in their contract with the engineering firms tasked with preparing the assessment and writing the report. States such as New York provide planning grants to municipalities (up to $50,000) to facilitate this process (NYSDEC, 2014).

Presentation of the cost data for various alternatives was the most complex part of any report. Some reports had extensive cost analyses, including regional breakdowns, projections over multiple years, various discount rates, and separation of capital and O&M costs. Further, it was difficult to compare costs across projects since some reports did not provide cost data for all the alternatives. Some alternatives were rejected after an initial screening, and cost projections were provided only for the remaining ones. In one instance, only the collection cost was provided for a cluster system; treatment costs were omitted. The difficulty in comparing costs across various options is echoed by Maurer *et al.* (2005), who state,

> *'Firstly, it is difficult to track the different sources of investment capital in the wastewater sector, where public funds play a major role. Secondly, due to different lifespan assumptions, the problematic distinction between investment and maintenance, the diverse approaches to interest rates, and the frequent lack of knowledge of the depreciation rate for the total assets, it is difficult to determine the total annual costs correctly.'*

In the absence of a robust decision-making model, communities in the USA and across the world will go through their own process of evaluating alternatives and selecting the 'best' option. The superiority of a certain alternative will depend on local conditions, availability of technology, and social and political factors. While acknowledging that each community will need a customized matrix of options and recommendation(s), consulting firms should streamline their assessment and evaluation process to enable each municipality to compare the costs of the various options with their peer municipalities. Using consistent reporting techniques and well-accepted accounting practices will result in a fair evaluation by the municipalities' local leaders and the public at large. We list a sample set of guidelines that consulting firms could follow to standardize the content in feasibility reports (Box 1).

Well-functioning OWTS are a low-cost option for suburban and rural communities, such as the ones discussed in this article. Even basic septic systems sited on appropriate soils bring additional benefits such as improvements in the valuation of the property (Vedachalam *et al.*, 2013). Although not widely popular, cluster systems are in use in many communities, offering a balance between keeping an onsite system and utilizing centralized treatment. On the other end of the spectrum are centralized treatment plants that are favored by administrators and health officials due to the ease of monitoring and localization of potential hazard sites. However, academic studies that present a comparison between OWTS and centralized treatment systems sometimes fail to capture the nuances of the debate. For

Box 1. Guidelines to aid consulting firms in preparing wastewater feasibility reports.

1. Assess the current population, average household wastewater flow and median income of the municipality.
2. Use a single metric to quantify the population.
3. Study the socio-economic and demographic trends to project future population, business potential and wastewater flow.
4. Document previous planning efforts and identify the factors that prevented implementation of those recommendations.
5. Work with the municipal government to obtain political and public support during the process to ensure report recommendations are aligned with community expectations.
6. Evaluate at least three alternatives with full cost analysis.
7. Present data from peer municipalities currently using any or all of the alternatives considered to provide richer context to the residents.
8. Standardize analysis criteria such as project lifespan, discount rate, and asset depreciation rate.
9. Provide capital and O&M cost per housing unit for the recommended, if not all, option(s).
10. Provide advantages and limitations of all alternatives, and justification for the recommended option. The cheaper option need not be the best one.
11. Include plans for maintenance and replacement, if any of the decentralized treatment methods are recommended.
12. Identify opportunities through grants and loan programs that could mitigate the project cost, in the event that report recommendation(s) are accepted by the municipality.

example, a recent study showed that energy use, greenhouse gas emissions and air pollution were higher in a community-scale cluster system when compared to centralized treatment system on a per capita basis (Shehabi *et al*., 2012), but it was criticized for its inappropriate comparison between a small cluster system (0.015 million gallons per day (MGD)) and a large central facility (67 MGD) (Vedachalam & Riha, 2013).

Size is an important consideration even among centralized treatment plants. A review of over 16,000 centralized wastewater treatment plants in the USA reported higher energy use per volume of wastewater treated in plants that are 0.1 MGD or smaller, as compared with those that are up to 1 and 5 MGD (Muga & Mihelcic, 2008). The effluent violation rates at smaller plants (0.01 MGD) are 10 times those observed in plants that are 100 MGD or larger (Weirich *et al*., 2011). Municipalities currently using OWTS that choose to build new centralized treatment plants would, in all likelihood, be building a small treatment plant (0.1 MGD or smaller) that would encounter some of these problems as well. Connecting to a nearby town with an existing treatment plant could be a reasonable solution, if the economics of wastewater conveyance worked out. Democratic decision-making about sustainable wastewater alternatives at the municipal level will require the active participation of residents, municipal leaders and local experts including engineering/design consulting firms. Researchers have an equally important role in facilitating this decision-making by providing objective analysis and recommendations. We hope that this article contributes to this spirited and ongoing debate about the suitability of options for each community.

7. Conclusions

Even as newer communities are installing OWTS, urbanization and changing environmental standards are prompting many existing communities currently relying on OWTS to revisit their wastewater management systems. Through the unique lens of wastewater feasibility reports prepared by engineering/design consulting firms for 19 municipalities, we studied the choices presented to these communities. Many reports had glaring omissions; relevant information such as median income and planned future wastewater flows were not mentioned in the reports. However, even though the reports varied in detail and presentation style, the use of the QRS allowed us to compare all the reports across the same scale. The overall quality of the reports was not high, and except for the length of the report, the QRS was uncorrelated with firm characteristics such as size and distance from the study area, year of the report and median income of the community. On average, between three and four alternatives were presented in these reports, and, in most instances, one or more were recommended to the municipal government. The alternatives and the final recommendations were well-balanced between the various forms of OWTS and centralized treatment. The reports presented extensive cost data, but differences in time horizon, detail and separation of capital and O&M costs prevented any meaningful comparison between the reports. In many instances, these reports were a continuation of previous efforts undertaken to address the issue of wastewater management, thereby indicating that these reports were not likely to be acted upon soon. Only two of the municipalities had implemented the recommendations of the feasibility report, calling into question the objectives behind commissioning such reports. Although not representative of the entire USA, the small sample of feasibility reports evaluated here is indicative in nature and provided significant insights about the inputs that help municipalities make decisions on complex issues. Municipalities could negotiate a better contract with consulting firms to ensure the final report includes all the necessary information, yet is accessible to the local leaders and laypersons alike. Further, political and community support should be sought alongside the feasibility study process to ensure the report recommendations are in line with community expectations and receive maximum support for faster implementation.

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