20-Year Life Cycle Analysis of an Effluent Sewer (STEP) System City of Lacey, Washington

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ABSTRACT

A well-balanced O&M program for municipal effluent sewer (STEP) systems results in customer satisfaction and low life cycle costs. Too little maintenance — a "reactive maintenance" approach — leads to premature equipment failure and dissatisfied customers. However, too much maintenance can increase costs unnecessarily. Having tried both approaches over the course of 24 years, the City of Lacey, Washington, worked with its STEP equipment manufacturer to develop an O&M protocol that provides customers with service that is both satisfactory and economical, even when compared with O&M costs of other wastewater collection systems, such as gravity sewers. With substantially lower up-front capital and repair/replacement costs, and with O&M costs that are virtually the same as those of gravity sewers, the life cycle costs of Lacey's STEP sewer are clearly lower than those of a typical gravity sewer.

KEYWORDS: life cycle analysis, STEP sewer, effluent sewer, gravity sewer, City of Lacey, operation and maintenance (O&M) costs, repair and replacement (R&R) costs, preventive maintenance, Full Service Maintenance (FSM), Bioxide Injection

INTRODUCTION — LACEY'S STEP HISTORY

The City of Lacey, Washington was an early adopter of a decentralized sewer technology known as STEP (Septic Tank Effluent Pump) sewers, in which raw sewage is captured in a watertight, underground tank at each property, and only filtered liquid effluent is pumped through shallowly buried, small-diameter collection lines to a treatment facility. Lacey has owned and operated STEP sewers since 1989. This 24-year period is long enough to provide empirical, real-world data for accurate life cycle cost analyses.

Lacey's STEP system currently has approximately 3,000 STEP connections and is designed to accommodate 6,000–7,000 in the future. The STEP pressure mains range from 50 to 400 mm (2 to 16 in.) in diameter and span about 88.5 km (55 miles).

Lacey owns and operates three different types of collection technologies comprising approximately 12,000 gravity sewer connections, 3,000 STEP connections, and 102 grinder pump connections. Lacey's STEP system intersects with its existing gravity sewer core infrastructure before being pumped through transmission mains to the regional treatment plant.

A regional growth boom in the 1980s spurred new development into areas with limited wastewater infrastructure. The immediate need for new infrastructure motivated the City of Lacey to seek less expensive alternatives to gravity sewers and, in 1989, Lacey piloted septic tank effluent gravity (STEG) sewers in a small development of 10 residential connections. After the pilot project was deemed a success, the City decided to expand the use of this relatively new effluent sewer technology. Initially, STEP was installed in new developments where wastewater infrastructure was not available. STEP systems were also installed in areas on the periphery of the city's wastewater service boundaries.

The City of Lacey, Washington, owns and operates three different types of wastewater collection systems: gravity, STEP, and grinder.

In the late 1980s, STEP technology was still in its infancy, and the benefits of proactive maintenance had not been fully documented. In fact, proactive maintenance and asset management were rarely a part of utility protocols, in general. Additionally, in these early STEP systems, pump screens and controls were problematic components. The situation in Lacey was no different. In the first eight years after its installation, Lacey's new STEP sewer received very little proactive maintenance, and the system experienced component-related problems, such as collapsing screens. By the late 1990s, operating costs began to escalate as reactive call-outs increased.

By 1998 the City of Lacey had 1,400 connections (see Figure 1) and was experiencing 365 call-outs annually, which represented 26 percent of total connections. STEP operating costs were beginning to impact other wastewater operation and maintenance (O&M) programs.

IMPLEMENTING AN AGGRESSIVE, FULL-SERVICE MAINTENANCE PROGRAM

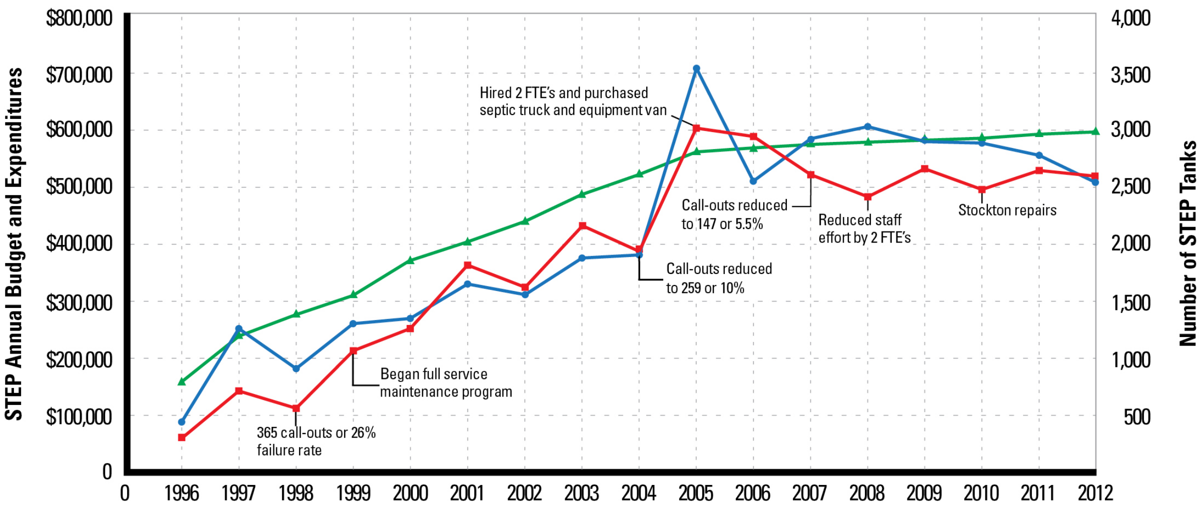
In 1998, to improve STEP system reliability, Lacey implemented a highly aggressive "Full Service Maintenance" program (FSM). The concept of FSM was untested, and, although reliability improvements were anticipated, the magnitude of the improvement could not be fully evaluated without implementation. Lacey's FSM included the following protocols:

1) STEP system start-up inspection: All new systems would be inspected after installation, before service began.
2) STEP system repairs: When responding to an alarm call, operators would perform both reactive and proactive work — including pumping the tank, replacing the floats, and cleaning the pump — each time they were called to the site.
3) Odor control: To eliminate all odor complaints, Bioxide® injection systems were installed upstream of locations where the STEP system discharged into the gravity sewer, and biweekly readings were to be taken at all injection points, along with quarterly maintenance. No odor complaint was considered acceptable, and odor complaints were treated as an emergency call-out.
4) STEP air release maintenance: All air release valves were to be removed and cleaned annually.

5) Community STEP tank maintenance: Lacey's system included several "community STEP tanks," which served subdivisions and multi-family dwellings. Tanks were to be pumped and cleaned on three-year cycles.
6) Five-year FSM overhaul: Every five years, every STEP site would receive a complete service overhaul, including tank pump-out, tank cleaning, pump servicing, power cord inspection, float switch check, and control box inspection.

As Figure 1 shows, by the end of 2004, Lacey had 2,654 active systems, and reactive call-outs had fallen to 259 per year, a 10 percent call-out rate. By the end of 2005, Lacey had 2,738 systems, and call-outs had fallen to 247 annually, a 9 percent rate. To keep up with the FSM program, the city added two additional staff members and purchased a pumper truck and an equipment van.

At the end of 2006, Lacey had 2,781 active systems and call-outs had fallen again, to 178 per year, a 6 percent rate. By 2007, Lacey had doubled the 1,400 STEP systems it had in 1998 while achieving a 20 percent reduction in its reactive call-outs.



Year (1996-2004)	1996	1997	1998	1999	2000	2001	2002	2003	2004
Budget	$82,199	$258,389	$182,944	$262,518	$268,896	$330,709	$314,226	$372,373	$388,275
Expenditures	$67,980	$146,927	$119,205	$216,984	$259,020	$363,635	$334,766	$439,449	$390,387
# of STEP Tanks	760	1,227	1,406	1,544	1,838	2,023	2,281	2,464	2,654

Year (2005-2012)	2005	2006	2007	2008	2009	2010	2011	2012
Budget	$711,981	$512,956	$589,684	$605,598	$574,021	$572,138	$553,011	$514,068
Expenditures	$609,738	$595,919	$527,754	$482,563	$533,759	$498,310	$538,576	$526,007
# of STEP Tanks	2,738	2,781	2,814	2,837	2,861	2,867	2,921	2,997

Figure 1: City of Lacey STEP System O&M Cost

THE EFFECTS OF A FULL-SERVICE MAINTENANCE PROGRAM

Lacey's proactive STEP maintenance program was, at that time, one of the most intensive known to Orenco Systems®, Inc., the manufacturer of Lacey's STEP equipment. Operationally, the results were exceptional. Reactive call-out rates were lower than any other STEP operation, odor complaints were reduced to zero, and customer complaints relative to the STEP system were minimal.

By 2005, however, Lacey was also spending more on O&M (per connection) than any other STEP community known to Orenco — $609,000 annually, or $223 per connection per year. Consequently, Lacey and Orenco staff started working together to identify a new O&M protocol for the community.

PERFORMING A STEP EVALUATION AND IDENTIFYING COSTS

In 2006, Lacey was still following the FSM protocol on its 2,781 systems, which called for pumping the tank every five years, as well as every time a customer summoned operators to a system in reaction to a problem. Lacey and Orenco staff started breaking down the costs.

STEP expenses per customer per year were $214, broken down as in Table 1:

Table 1: 2006 Costs: Full-Service Maintenance Protocol

Line Item	$/Customer/Year	Percent of Cost
Wages	$103	48%
Odor Control	$50	23%
Equipment Repair & Maint.	$25	12%
Equipment Rental Vehicles	$29	14%
Others	$6	3%
Total	**$214**	**100%**

As Table 1 shows, Lacey spent $103 in wages per customer per year. Although the protocol dictated that customers get an FSM every 5 years, the actual interval was closer to 3.8 years. Each FSM visit took 4.27 man-hours and cost $114 in wages; dividing that by 3.8 years shows that, of the $103 spent each year, $26, or 26 percent, was devoted to the FSM program (pumping the tank and replacing parts). The balance of the $103 was devoted to other activities.

Lacey's frustration continued and, to provide ongoing support services for all its STEP communities, including Lacey, Orenco created a new Asset Management Department. In 2007, this Asset Management Department took staff from Lacey's water and wastewater maintenance division on a tour of four cities with four different approaches to STEP sewer maintenance. Appendix 1 describes each city's maintenance protocol, but the differences are summarized in Table 2:

Table 2: STEP System Maintenance Protocols in Four Cities

City	Connections	Protocol	Annual Call-Out Rate	O&M Budget /per Connection
Port Charlotte, Florida	7,000	Reactive	>20%	$174
Missoula, Montana	1,300	Pump every 7 years	12.3 percent	$71
Camas, Washington	3,000	Perform proactive maintenance every 5-6 years	8.5 percent	$117
Yelm, Washington	1,625	Perform proactive maintenance every 3 years	10.4 percent	$134

Orenco also invited Lacey staff to an operator training forum at which 25 wastewater system operators discussed their maintenance protocols and had the opportunity to learn a great deal from each other. Systems ranged from those with fewer than 100 connections to Montesano, Washington, with 1,210. The operators agreed that more maintenance led to fewer reactive call-outs and that a pumpout interval of 7-10 years resulted in a reliable and manageable system. (For many households, even longer pump-out intervals can be achieved [Orenco Systems, Inc., 2013].)

REDUCING UNNECESSARY COSTS

In 2008, after careful consideration of various combinations and levels of proactive maintenance, Lacey adjusted its FSM program's guidelines as follows:

- 8-year tank pump-out
- 8-year system inspection and cleaning
- No component replacement unless warranted

In 2008, Lacey adjusted its STEP maintenance to reduce unnecessary costs, including changing tank pump-outs to an eight-year schedule.

This protocol was designed for an average of 2.5 man-hours per FSM for each system. With the number of connections at the time, about 350 FSMs would be completed annually, saving approximately 1,800 FTE hours annually. Lacey also adjusted its FSM protocol to anticipate longer life cycles for major STEP components, such as pumps and controls. Justification for extending these life cycles was based on a review of the records of other comparable STEP operators. This change reduced annual material and inventory expenditures by approximately $52,300, as follows:

- Office and operating supplies, $5,000
- Small tools and equipment, $2,300
- Equipment rental, $15,000
- Parts for repair and maintenance of STEP systems, $33,000

In addition to these revisions of the FSM program, FTE hours were reduced for the maintenance of air releases, annually saving about 112 FTE hours. Today, automatic air release valves are installed only on pipe segments that are known problems. All other air release valve locations have been either removed or fitted with manual air release valves. The manual valves are exercised only when there is a problem on that line segment.

Other changes were implemented:

- Changes in personnel — A number of two-person tasks were changed to one-person tasks: odor control monitoring and maintenance, Bioxide deliveries, STEP sampling, pressure monitoring, hybrid tank inspection, charcoal filter replacement, STEP start-ups, and grass-cutting.
- Changes in tankage — Subdivisions are now required to use one tank per home, rather than larger community tanks. Originally, it was anticipated that fewer pumps/tanks would equate to lower O&M costs. However this was not found to be the case. Now, tanks larger than 20,000 L (5,000 gal) are rarely used, with the exception of multi-family homes and apartments, which use larger tanks with tank size calculated on a per unit basis.
- Changes in equipment specifications — Standardization of equipment is important in keeping costs down. However, after the original design of the system, equipment specifications had eroded and service providers were finding an assortment of original and replacement components when making service calls. Lacey now requires the contractor to provide a "Certificate of Origin" (see Appendix 2) confirming the use of Orenco equipment packages during the final start-up inspection.

Lacey estimated that these changes would reduce annual FTE hours by 700 annually. Managers agreed to review operations periodically to make sure that converting some tasks to one-person jobs had no undesirable consequences.

Table 3 shows how the changes to Lacey's protocols reduced expenditures from $214 per customer per year to $173, while Table 4 shows that Lacey's total STEP expenditures dropped nearly $100,000 in that period, from $595,919 to $498,310 — a savings of 16.4 percent — even as the number of connections increased from 2,781 to 2,867.

Table 3: Expenses in 2006 vs. 2010

Line Item*	2006 $/Customer/Year	2010 $/Customer/Year	Change
Wages	$103	$78	($25)
Odor Control	$50	$60	$10
Equipment Repair & Maint.	$25	$16	($9)
Equipment Rental Vehicles	$29	$18	($11)
Others	$6	$2	($4)
Total	**$214**	**$173**	**($41)**

** Note: No proactive maintenance is budgeted for Lacey's STEP pressure mains because very little is done. Because of the very low solids content in the effluent, pigging has been unnecessary except on one occasion when Bioxide residue built up in a line.*

One of Lacey's managers, Roger Dickinson, attributes much of Lacey's success to a dedicated crew and the following factors:

Fast response time: Lacey has established very high expectations of keeping customer complaints at zero. When a STEP customer calls in, Lacey responds quickly and efficiently, which is received well by customers. If a customer reports an alarm, the on-call operator asks if there is wastewater on the ground. If so, operators respond immediately. If not, the customer is asked to push the red alarm light's "push-to-silence" button and call back in an hour. If the customer then reports that the alarm light has stayed off, operators know they can respond during normal working hours because Lacey's STEP tanks have an additional 757 liters (200 gallons) of emergency reserve above the high water alarm as a safety factor. If the customer reports that the alarm light has stayed on, an operator is dispatched to the site immediately (and arrives within 30 minutes), even if it is after hours.

Quality of work: Attention to detail is expected on each FSM because callbacks cost time and money. Lacey's crew is provided with clear expectations and the right tools for outstanding proactive maintenance, including a pumper truck and equipment van.

Lacey's maintenance crew is well-equipped with the right tools for O&M, including an equipment van and a pumper truck.

Trained operators: Lacey's operators are trained to troubleshoot STEP systems, and a two-man crew can execute a routine FSM in about 2.5 man-hours. Operators continually seek ways to improve performance by talking to other operators and providing feedback to the manufacturer.

Customer education: Lacey has invested in an intensive customer education program to reduce customer misuse, unwarranted calls, and costs. In addition, STEP operators interface with homeowners. When operators run across homeowners who dispose of baby wipes, diapers, and other garbage into their STEP systems, they counsel them against these practices.

Instead of accepting high maintenance costs as inevitable, Lacey's managers and staff developed a proactive maintenance program that was financially sustainable, yet maintained customer satisfaction. Today, the City of Lacey operates an effluent sewer with 2,997 connections at a cost per connection of under $15, which could drop to $11-$12 if odor control costs are equitably distributed between the STEP and gravity budgets, as anticipated. According to Dickinson, because FSM visits are running about 2.5 man-hours per system, his crews are capable of completing 6 per day. In addition, his crews are reporting a quicker FSM service on STEP systems installed after 2000, which use the newer Biotube Pump Package instead of a pump and a screen vault.

Lacey has a future capacity for more than double its current number of connections. Based on the city's 24 years of experience with STEP sewers, Lacey managers Roger Dickinson and Terry Cargil have determined that a two-person crew with appropriate equipment will be able to effectively handle up to 5,000 residential connections.

COMPARING LACEY'S STEP COSTS WITH ITS GRAVITY SEWER COSTS

Comparing Lacey's STEP costs with its gravity sewer costs requires an examination of how each is calculated.

A Closer Look at Lacey's STEP O&M Costs

Table 4 summarizes the budget and actual expenditures for Lacey's STEP system from 1996 to 2012. (Before 1996, STEP budget numbers were not broken out from the overall sewer budget, which includes gravity sewer.)

Table 4: Lacey's STEP Budget, 1996-2012

STEP Budget 1996-2004	1996	1997	1998	1999	2000	2001	2002	2003	2004
Salaries-Regular	28,364.31	30,163.89	43,943.47	93,179.99	81,584.69	113,049.72	107,920.39	128,553.78	109,243.42
Salaries-Overtime	6,087.32	9,851.91	8,513.03	14,329.55	8,701.77	7,041.47	11,023.97	10,197.98	10,246.96
Salaries-Part-Time		133.00	0.56	64.96	144.65	80.62	3,354.26	256.77	748.67
Employer Paid Benefits	9,860.59	11,807.71	16,005.10	32,747.73	26,426.64	33,513.22	30,019.21	37,132.22	35,116.28
Office & Operating Supply	963.37	769.19	1,935.00	19,652.20	3,678.07	5,032.45	6,248.97	4,733.88	4,160.79
Small Tools & Equipment	629.91	538.86	620.26	3,158.51	1,668.31	1,469.26	1,267.36	2,436.55	972.87
Supplies-Locks	546.74	974.85	1,450.24	1,209.21	832.06	140.60	705.11	1,304.10	1,062.38
Supplies-Odor Control	11,241.16	15,772.22	20,073.90	26,231.73	80,573.34	95,188.67	104,201.66	119,885.45	132,247.21
Prof. Svc-Others	2,997.50	30,452.00		594.00					
Wastewater Testing							204.00	670.39	
On Site Septic						291.47	496.80	10,377.86	
Equipment Rental	2,757.00	25,636.44	13,836.00	23,097.00	25,864.00	37,850.00	30,561.00	30,561.00	30,561.00
Rentals-Others		19.44						52.97	
Utility-Electric				252.71					
Rep & Maint-Equipment	3,573.69	2,711.56	10,152.11	623.81		893.29	632.25	1,191.62	81.64
Rep & Maint-Equip. Non Power	959.27	18,096.73	2,675.37	1,842.89	581.80	1,652.78	981.82	9,209.83	10,264.07
Rep & Equip.-STEP Systems					28,964.21	63,509.07	37,148.79	82,885.31	50,988.65
STEP Debris Tanks									4,693.08
Capital Outlays-Equipment						3,922.68			
Capitalized Assets									
Proposed	**82,199.00**	**258,389.00**	**182,944.00**	**262,518.00**	**268,896.00**	**330,709.00**	**314,226.00**	**372,373.00**	**388,275.00**
Total-Actual Spent	**67,980.26**	**146,927.80**	**119,205.04**	**216,984.29**	**259,019.54**	**363,635.30**	**334,765.59**	**439,449.41**	**390,387.02**

STEP Budget 2005-2012	2005	2006	2007	2008	2009	2010	2011	2012
Salaries-Regular	192,675.20	191,215.05	156,544.80	158,190.39	145,018.90	146,094.30	144,394.27	109,658.89
Salaries-Overtime	12,211.16	9,249.85	11,280.12	10,316.10	10,493.11	12,594.00	14,770.71	9,322.03
Salaries-Part-Time	5,372.27	123.00	-			13.05	1,760.13	10,770.48
Employer Paid Benefits	76,582.40	78,073.87	71,320.47	73,006.34	68,068.96	71,684.69	74,280.11	66,304.03
Office & Operating Supply	9,481.71	8,778.36	6,670.22	7,298.49	3,507.78	6,886.56	7,972.26	3,120.86
Small Tools & Equipment	5,097.32	3,353.55	4,546.95	3,085.32	2,452.66	3,818.90	5,270.86	1,170.16
Supplies-Locks	1,306.48	56.95	-	285.87	-	552.35	683.48	
Supplies-Odor Control	139,775.88	133,527.23	131,445.38	168,430.98	170,960.98	156,123.29	171,832.47	82,224.21
Prof. Svc-Others	704.60							
Wastewater Testing							1,854.00	
On Site Septic						110.00		
Equipment Rental	81,801.00	59,121.63	52,272.00	52,272.00	51,179.00	53,988.00	58,516.00	57,792.00
Rentals-Others					1,028.17	24.53	0	
Utility-Electric								
Rep & Maint-Equipment	1,042.17	443.97	985.79	322.49	553.15	507.84	-	760.33
Rep & Maint-Equip. Non Power	1,390.04	2,996.54	360.44	2,855.52	2,698.29	2,778.86	3,524.62	257.46
Rep & Equip.-STEP Systems	68,048.05	37,290.26	45,624.71	68,273.36	42,349.45	36,732.83	41,147.92	37,313.62
STEP Debris Tanks	430.44							
Capital Outlays-Equipment		3,523.54				46,666.44		
Capitalized Assets								
Proposed	**512,956.00**	**589,684.00**	**605,598.00**	**574,021.00**	**572,138.00**	**553,011.00**	**514,068.00**	**548,819.00**
Total-Actual Spent	**595,918.72**	**527,753.80**	**482,562.88**	**533,759.18**	**498,310.45**	**538,575.64**	**526,006.83**	**378,694.07**

STEP budget numbers include annual operation, maintenance and repair/replacement of the on-lot STEP tanks and the pressure mains in the right-of-way. Administration and treatment costs are not included.

Typically, two-thirds of STEP O&M costs are for tank pumping and for equipment repair and replacement (R&R), primarily for replacement of pumps. These are the costs that are most commonly overestimated by those who prepare life cycle cost analyses for wastewater customers. Lacey's STEP budget provides real world data.

Septic tank pump-outs: All costs for septic tank pump-outs are included in the "Salaries" lines items. Lacey pays no tipping fees because it is part of LOTT — a regional group of municipalities including Lacey, Olympia, Tumwater, and Thurston County, that cooperate on wastewater treatment. LOTT charges Lacey equally for treatment of gravity and STEP effluent.

Pump repair and replacement: Dickinson reports that in the past 17 years, Lacey has replaced fewer than 10 STEP pumps. All 3,000 STEP pumps are virtually identical Franklin pumps and fully interchangeable, with a rebuildable liquid end. These liquid ends can get clogged with grease and hair, causing a call-out. Operators carry spare pumps into the field and swap them out, which shortens the time-spent onsite. The malfunctioning pump is then cleaned and repaired in the shop and used in a future repair.

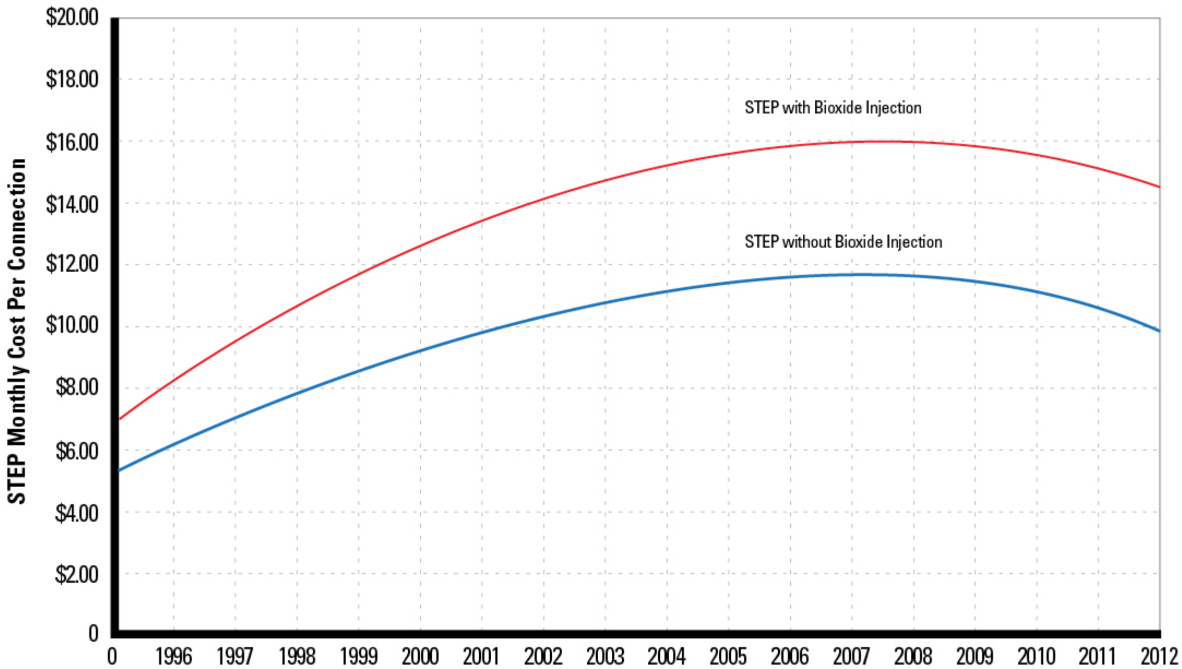
Orenco has put Franklin motors and liquid ends through severe tests to meet strict standards. The most severe test included turning the motor and liquid end on for 3 seconds and off for 6 seconds until the motor's rating of 1,000,000 cycles was surpassed. After this severe test, the pump's performance curve showed little degradation. For a STEP system that turns on three times a day, 1 million cycles equates to a life expectancy of 900 years.

Obviously, this is not the recommended life cycle, because the pump is not being tested under field conditions. But in Lacey (and in other STEP systems tracked by Orenco's Asset Management Department), after 24 years under real-world conditions, massive pump replacements are not occurring. (In fact, according to Dickinson, when older pumps are replaced, the motor is still working perfectly, but the splines on the liquid end have been worn down to the point that they will no longer engage.) Because of the pumps' resiliency, then, it is highly unlikely that large numbers will need to be replaced all at once. So Lacey can elect to spread out this cost — about $500 per pump — over several years.

Float replacement: Float switches are the weakest link in a STEP system. Float failure is the cause for the majority of STEP system call-outs. However, floats are relatively inexpensive, and re-splicing a new float into an existing system is relatively quick.

"Supplies — Odor Control" (Bioxide Injection): The line item for "Supplies — Odor Control" makes up as much as 30% of Lacey's annual O&M STEP budget and is assigned completely to STEP. This allocation is being reevaluated by the City because, before the STEP system was installed, Lacey's gravity sewer system also had odor and corrosion problems, and the original STEP system design was not optimized for intersection with a gravity sewer. Consequently, Lacey is currently considering splitting this line item between the gravity sewer and the STEP system, which would greatly reduce the cost per connection for Lacey's STEP system.

This will be discussed at greater length in the section titled "Comparing Lacey's O&M Costs for STEP and Gravity." Figure 2, however, shows the polynomial trend lines of Lacey's monthly STEP costs with and without Bioxide injection.



Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
STEP w/ Bioxide Injection	$7.45	$9.98	$7.07	$11.71	$11.74	$14.98	$12.23	$14.86	$12.26
STEP w/o Bioxide Injection	$6.00	$7.00	$5.88	$10.30	$8.09	$11.06	$8.42	$10.81	$8.11

Year	2005	2006	2007	2008	2009	2010	2011	2012
STEP w/ Bioxide Injection	$18.56	$17.86	$15.63	$14.17	$15.55	$14.48	$15.37	$14.63
STEP w/o Bioxide Injection	$14.58	$13.67	$11.66	$10.32	$10.65	$9.51	$10.91	$9.85

Figure 2: Lacey's O&M Costs Trends: With and Without Bioxide Injection

Lacey's O&M cost trends in Figure 2 show that its adjusted STEP cost-per-connection (without Bioxide injection) is currently running under $10/month, even with a "zero-tolerance" policy for customer complaints. This is well within the range of Orenco's experience with the operational costs of Orenco effluent sewers, as recorded in its published literature.*

** Note: Based on the documented performance of thousands of STEP households, Orenco has estimated that typical STEP systems using its equipment cost about $7.05 per month per equivalent dwelling unit (EDU) to maintain, with $2.04 of that total allocated to tank pumping and $2.81 allocated to equipment R&R, as shown in Table 5 (Orenco Systems, Inc., 2013).*

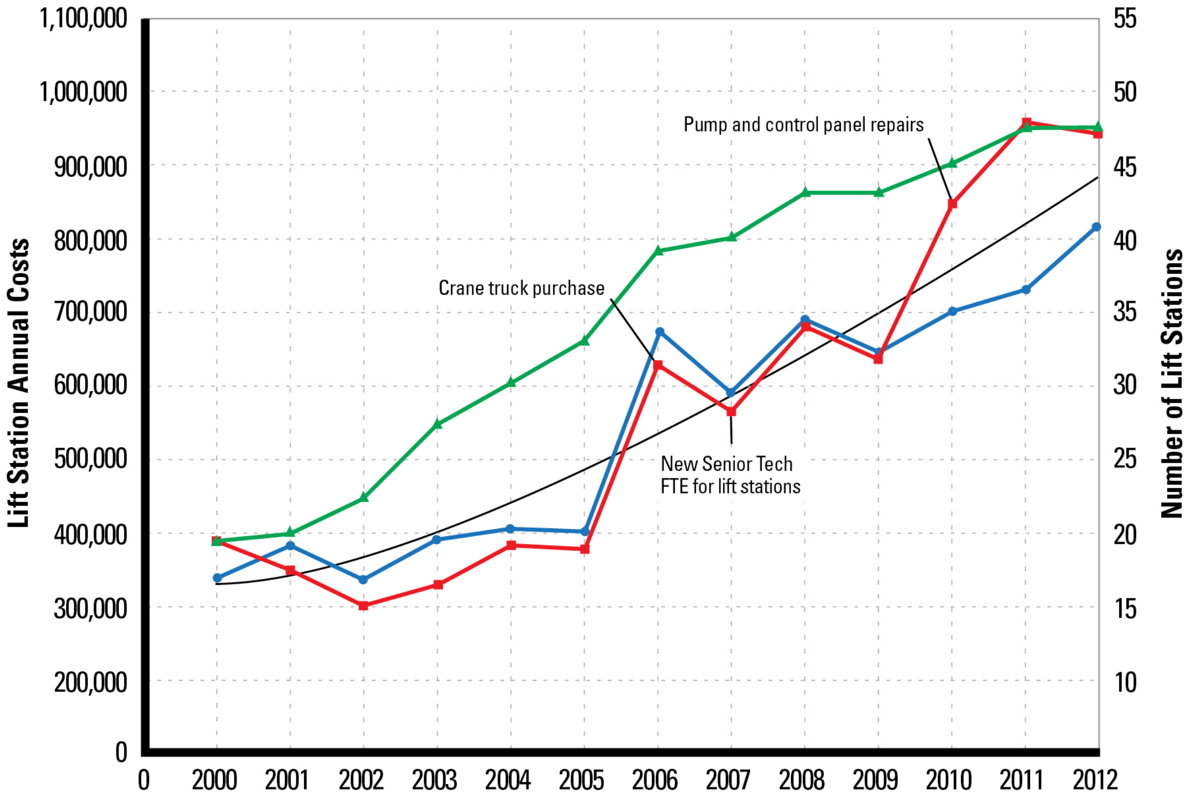
Table 5: Orenco Effluent Sewer O&M and R&R Costs (4% Interest Rate).

Item	*Cost per month per EDU*
Preventive maintenance	*$1.60*
Reactive maintenance	*$0.60*
Equipment repair and replacement	*$2.81*
Tank pumping	*$2.04*
Total	***$7.05***

A Closer Look at Lacey's Gravity Sewer O&M Costs

The City of Lacey also operates a gravity sewer that includes 47 lift stations and 245 km (152 miles) of mainlines. Consequently, Lacey can provide gravity sewer operational costs that allow for life cycle cost comparisons between the two technologies.

For example, the cost per connection for Lacey's lift station O&M from 2000 to 2012 is shown in Figure 3.



Year (2000-2006)	2000	2001	2002	2003	2004	2005	2006
Budget	$343,309	$381,925	$337,922	$377,408	$405,792	$400,972	$666,263
Expenditures	$390,211	$351,115	$301,473	$333,833	$382,648	$379,524	$633,194
# of Lift Stations	19	20	22	27	31	33	38

Year (2007-2012)	2007	2008	2009	2010	2011	2012
Budget	$594,877	$697,888	$643,205	$701,667	$672,270	$838,895
Expenditures	$560,872	$692,985	$642,276	$847,111	$958,491	$940,548
# of Lift Stations	41	43	43	45	47	47

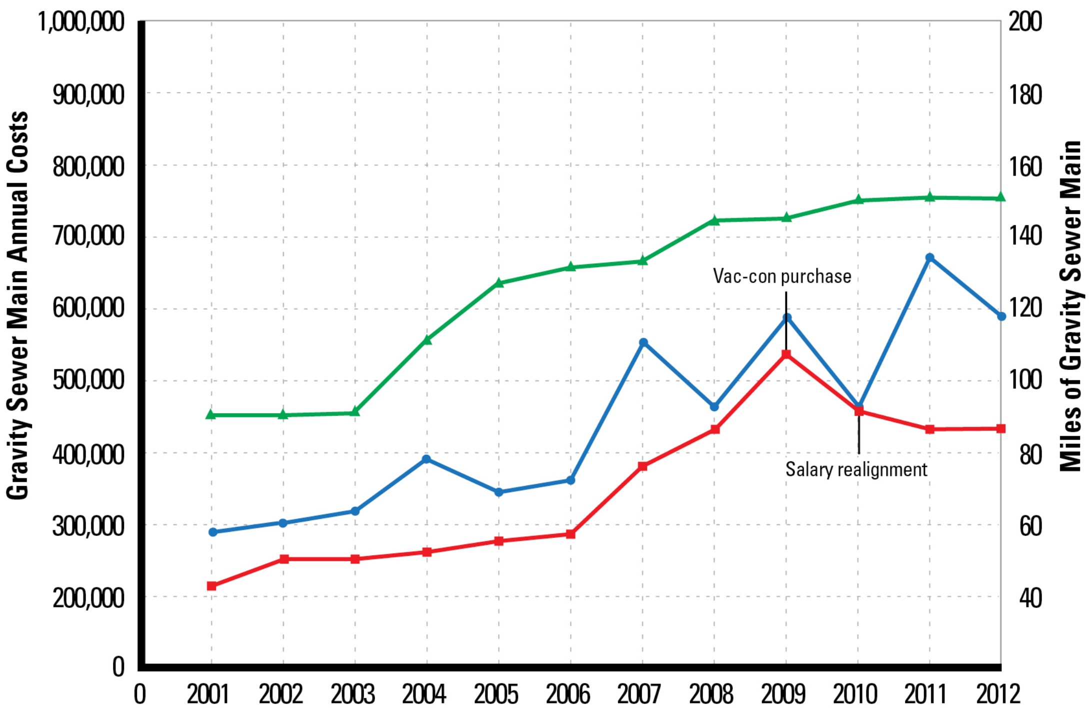
Figure 3: Lift Station O&M Costs: 2000-2012

In 2012, 22 of Lacey's 47 lift stations were less than 10 years old. One would expect operational costs per customer to flatten or fall when maintaining new equipment. Instead, the cost per customer of lift station maintenance has risen.

This increase is not unique to Lacey. To function, lift station pumps need the waste stream to stay above a certain liquid-to-solids ratio. But nationwide, several factors are combining to lower that ratio: the rise of water-saving devices and appliances in households, exfiltration of liquids out of leaking pipes, and the advent of "flushable" wipes. The result has been increased clogging of lift station pumps in many communities.

Extended power outages can also affect lift station O&M costs. During a recent extended power outage, for example, Lacey's crews worked around the clock the keep the lift stations running. There were no comparable costs allocated to the STEP system because the on-lot tanks in STEP systems provide for reserve storage.

In regards to O&M for mainlines, the cost per customer from 2001 to 2012 is shown in Figure 4.



Year (2001-2006)	2001	2002	2003	2004	2005	2006
Budget	$297,077	$310,678	$328,236	$385,098	$344,253	$368,413
Expenditures	$214,610	$228,757	$217,181	$234,924	$278,684	$289,837
Miles of Mains	92	92	94	113	125	132

Year (2007-2012)	2007	2008	2009	2010	2011	2012
Budget	$552,770	$469,390	$541,824	$466,198	$662,066	$577,324
Expenditures	$372,035	$430,806	$533,465	$455,202	$443,498	$431,721
Miles of Mains	136	145	147	151	152	152

Figure 4: O&M Costs for Gravity Sewer Mains

Lacey's proactive maintenance program for its gravity mains includes scheduled videoing, flushing, root removal, etc. As with the lift stations, water conservation and flushed wipes are causing blockages. Older gravity sewer pipes were designed using a standard of 322 L (85 gal) per day per capita at a 0.4 percent slope (for a 200-mm or 8" diameter main) to maintain flow. However some water conservation programs have set consumption targets as low as 189 L (50 gal) per capita per day — a 42 percent decrease in liquid available to transport solids.

A Comparison of Lacey's STEP and Gravity Sewer O&M Costs

The two figures in this section show how Lacey's STEP sewer O&M costs per connection compare with its gravity sewer O&M costs per connection.

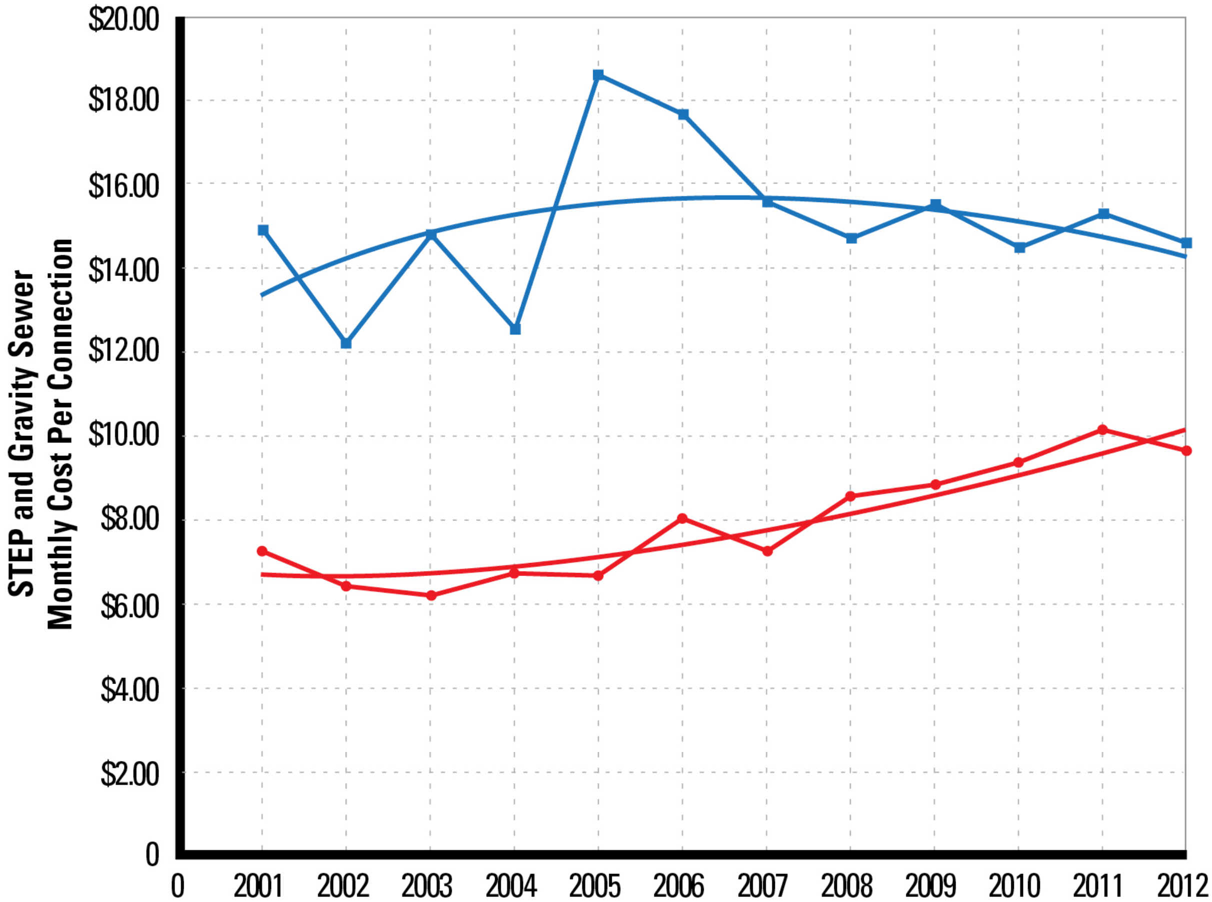
These numbers reflect Lacey's complete O&M budget for both technologies, including labor with overtime, materials, and equipment replacement over the period shown. Administration and treatment costs are not included. Note that this comparison offers two important constants: the same study period and the same operating entity, an operating entity that manages both collection systems with a strong commitment to proactive maintenance and customer satisfaction.

Figure 5a shows the cost comparison under the current accounting protocol, in which 100% of Bioxide injection costs are allocated to the STEP system's budget.

Figure 5b shows the costs under a revised accounting protocol, in which Bioxide injection costs are split with 80% of costs allocated to Lacey's gravity system (12,000 connections or 80% of the total) and 20% allocated to the STEP system (3,000 connections or 20% of the total).

Note that, in 5b, when odor injection is apportioned based on the population served by gravity and STEP, by 2012 the line that expresses "cost per month per user" for Lacey's STEP system begins to merge with the line expressing the "cost per month per user" for its gravity system. And Dickinson reports that the cost trend line for STEP is continuing to decline.

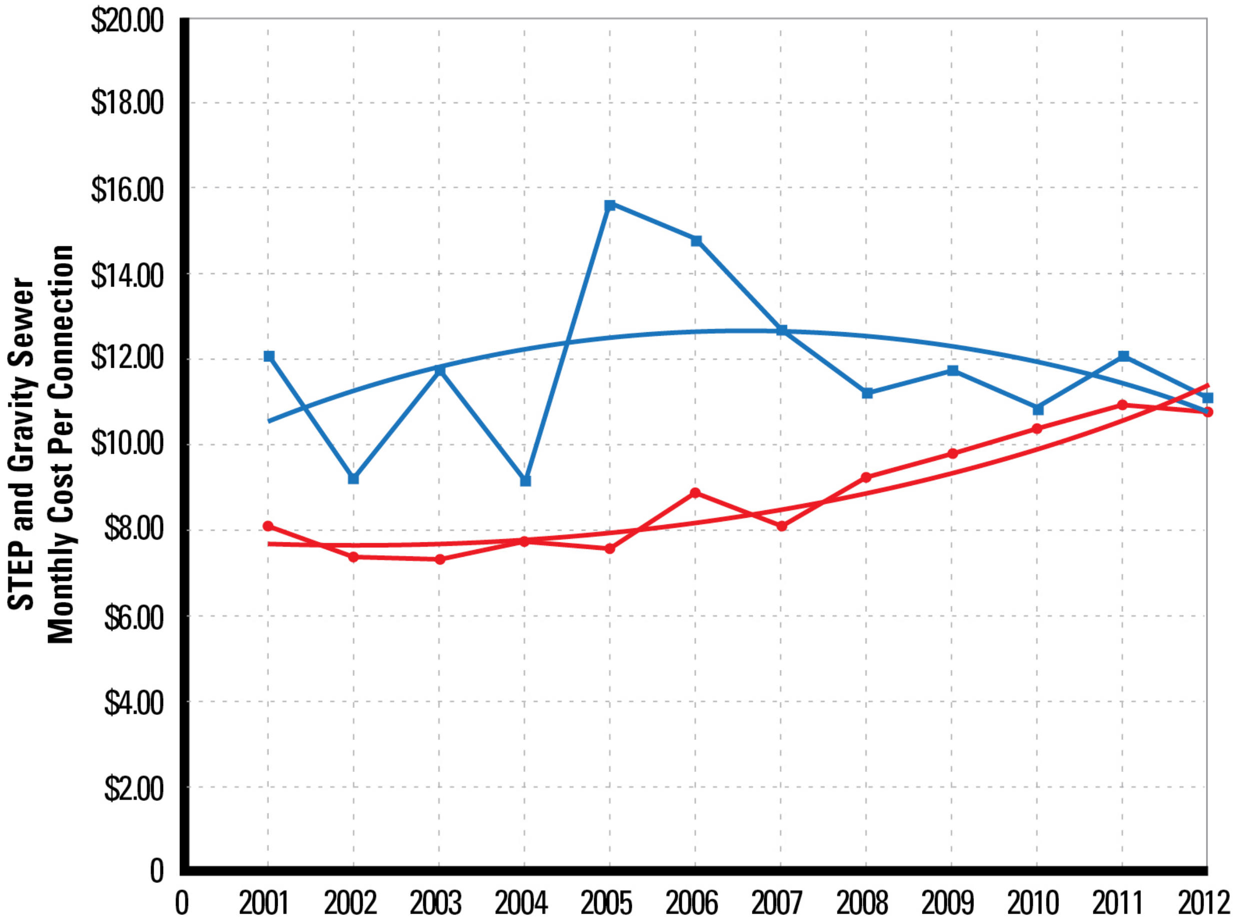
This is important because engineers and other specifiers who are not familiar with STEP sewers often assume or have the preconceived notion that O&M costs for STEP sewers are significantly higher than those for gravity sewers. This is clearly not the case with Lacey's nor with many of the STEP sewers that Orenco has tracked over time. Conversely, this real-world data demonstrate that labor, septage pumping, pump replacements, and other O&M costs for a STEP system are actually comparable with those of a gravity sewer.



Year (2001-2006)	2001	2002	2003	2004	2005	2006
STEP Sewer 100%	$14.98	$12.23	$14.86	$12.26	$18.56	$17.86
Gravity Sewer 0%	$7.25	$6.50	$6.38	$6.75	$6.60	$8.03

Year (2007-2012)	2007	2008	2009	2010	2011	2012
STEP Sewer 100%	$15.63	$14.17	$15.55	$14.48	$15.37	$14.63
Gravity Sewer 0%	$7.37	$8.47	$8.81	$9.46	$10.11	$9.81

Figure 5a: Lacey's STEP & Gravity O&M Cost-Per-Connection with 100% of Odor Control Cost Allocated to STEP



Year (2001-2006)	2001	2002	2003	2004	2005	2006
— STEP Sewer 80%	$11.84	$9.18	$11.62	$8.94	$15.37	$14.51
— Gravity Sewer 20%	$8.23	$7.52	$7.49	$7.90	$7.65	$9.00

Year (2007-2012)	2007	2008	2009	2010	2011	2012
— STEP Sewer 80%	$12.47	$11.09	$11.62	$10.51	$11.80	$10.80
— Gravity Sewer 20%	$8.21	$9.26	$9.82	$10.46	$11.01	$10.79

Figure 5b: Lacey's STEP & Gravity O&M Cost-Per-Connection with Odor Control Cost Split 80% to Gravity and 20% to STEP

UNDERSTANDING FULL LIFE CYCLE COSTS

When selecting a wastewater collection system, engineers and other specifiers need to evaluate the full life cycle cost of each technology being compared. Industry professionals often use 20 years as a life cycle study period when evaluating the cost and sustainability of competing technologies for an intended project, even though 20 years does not represent the true life cycle of any wastewater collection system. (Since a system is operated in perpetuity, the study period of the life cycle should reflect the number of years that all major components of the system are expected to last until replacement. For wastewater collection systems, the study period needed to cover a complete replacement could be as long as 50-100 years.) Accurate full life cycle costs, then, are the sum of all expenditures to own, operate, maintain, and repair/replace the wastewater collection system for a study period equal to the replacement time of all major components.

Before being totaled, all costs must be discounted to their present value in order to have a true comparison. The formula (Schultz, 2003) for computing the present-value life cycle cost of a project is:

$$PVLCC = \sum_{t=o}^{N} \frac{C_t}{(1+i)^t}$$

or

$$PVLCC = \frac{C_1}{(1+i)^1} + \frac{C_2}{(1+i)^2} + \frac{C_3}{(1+i)^3} \ldots\ldots\ldots \frac{C_N}{(1+i)^N}$$

where:

- PVLCC = Full Life Cycle Cost in present value dollars at the base date;

- t = the length of each time period (e.g., year);

- N = the number of time periods in the study period (e.g., 50);

- i = the nominal discount rate (which takes into account general inflation) in decimal form (i.e., 5% is entered as 0.05); and

- C_t = the total costs occurring in each time period.
  $C_t = C_t(CE)_a + C_t(O\&M)_a + C_t(R\&R)_a$, where:

  - $C_t(CE)_a$ = any annualized debt service on capital expenditures;*

  - $C_t(O\&M)_a$ = the annualized operation & maintenance costs; and

  - $C_t(R\&R)_a$ = the annualized repair & replacement costs.

** Note: Capital expenditures for all sewer collection systems can be financed. However, in Lacey, since developers contribute the majority of the sewer collection infrastructure as part of their construction costs, the majority of capital expenditures do not need to be financed by the City.*

Thus, the full life cycle cost of a wastewater collection system, as measured in present value dollars at the base date, is a function of the front-end capital expenditures, the O&M costs, and the back-end R&R costs over the life of the system. Engineers and other specifiers responsible for selecting a wastewater collection system often assume that although STEP systems clearly have lower front-end capital expenditures than gravity sewers, the annualized O&M and R&R costs of a STEP system are significantly higher. This incorrect assumption leads to a determination that gravity sewers have a lower full life cycle cost and are therefore the preferred wastewater collection technology from a fiscal perspective. While it is true that a gravity system with many connections and few lift stations can be cost-competitive with STEP systems, Lacey and a number of other systems tracked by Orenco provide evidence that in most other design settings, STEP sewers are significantly more economical than gravity sewers over the full life cycle of the system.

Within the PVLCC model, because of the time-value of money, the alternative with the lowest up-front capital expenditures starts with a significant advantage: A dollar saved today — because it can earn interest — is worth more than a dollar in the future. Virtually all industry professionals recognize that the capital expenditures for a STEP sewer are markedly lower than those for a gravity sewer. For example, in Woodland Creek Estates, a 137-home septic tank abatement project in Lacey's service area, both STEP sewers and gravity sewers were evaluated. In that evaluation, the capital expenditures for the STEP system were approximately 40 percent of those for the gravity sewer.

In addition, those lower capital expenditures are also reflected in lower future R&R costs. For example, the cost to repair or replace right-of-way pressure mains is much lower in a STEP sewer than the cost to repair or replace the main in a gravity sewer. STEP pressure mains can be easily replaced with directional boring through the existing pressure main, and additional capacity could be added just as easily. Moreover, directional boring for STEP sewers keeps restoration costs (such as pavement, driveways, etc.) relatively low compared with gravity sewer, which requires open trench construction in the middle of the right-of-way. The larger footprint of gravity sewer mains means higher R&R costs.

In comparing the fiscal advantages of gravity sewer against STEP sewer technologies, then, annualized O&M costs for a gravity sewer must be significantly lower than those for a STEP system to offset the remarkable difference in capital expenditures (bolstered by the added time-value of those front-end savings) and lower annualized R&R costs that give STEP sewers the advantage. However, as Lacey's 24 years of empirical evidence shows, a well-managed program for STEP O&M has annualized costs that run closely in line with typical annualized costs for gravity sewer O&M. Thus, when comparing the full life cycle cost of each technology in present value dollars, a STEP sewer with a well-managed O&M program is clearly more economical than a gravity sewer in many design settings.

ACKNOWLEDGMENTS

Special thanks are owed to Terry Cargil and Roger Dickinson for treating every dollar in Lacey's operating budget as if it were their own; to Mike Saunders (previously with Orenco and with Port Charlotte, Florida, the largest STEP system in the country) for his unrivaled understanding of utility operations, asset management, and engineering design; to Terry Bounds (Orenco Executive Vice-President) for his invaluable knowledge of STEP sewers and assistance with life cycle calculations; to Darren Paschke (Orenco Asset Manager) for the product and manufacturing knowledge that contributed to improving Lacey's operational efficiencies; and to Dave Norlin (Orenco Senior Technical Representative) for his extensive spreadsheet-number-crunching.

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APPENDIX 1: A TALE OF FOUR CITIES

In 2007, Orenco and Lacey personnel visited four cities with large STEP systems that embodied four different approaches to maintenance.

Port Charlotte, Florida

The first visit was to Charlotte County, Florida. Charlotte County Utilities owns and operates the largest and oldest STEP system in the country. At the time of the visit, the system had 7,000 connections and fronted approximately 14,000 properties designated for future STEP connections.

The utility operated on a reactive basis. Customer calls due to alarms or problems were running at 15 to 20 per day, with an overall budget expenditure of $1.22 million a year. Three staff members were permanently assigned to addressing these reactive calls.

The system used 3400-L (900-gal) baffled fiberglass tanks, cast iron effluent pumps, simple panels, and pump chambers with 10-mm (3/8-in.) screened inlets over four 100-mm (4-in.) holes. The system was not an Orenco installation and was assembled by the utility from various parts and pieces purchased through annual bids.

Since Charlotte County did not expend resources toward proactive maintenance, it was to be expected that the reactive call-out rate would be higher. In fact, the call-out rate was many times higher than Lacey's, due to Charlotte County's reactive maintenance program and substandard equipment.

The odor control program at the lift stations and outfalls in Port Charlotte used mechanical carbon scrubbing units. Odors were slight but noticeable. Although Port Charlotte viewed its odor control program as successful, the level of odors would not be acceptable in Lacey.

Charlotte County made little or no effort to monitor sludge and scum accumulation, nor did it pump tanks proactively. Tanks were pumped when a system failed because of sludge or scum accumulation. Despite the age of the system and the smaller tanks, the incidence of tank pump-outs was extremely low. The low pump-out rate, in most instances, could be attributed to a predominantly retired population, averaging 50 years and older with an average of 2.3 residents per household.

A final observation was made regarding automatic air release valves. Despite having an extremely large STEP system, Charlotte County did not utilize automatic air release valves. All air releases were manual and were comprised of a tapping sleeve, corporation stop, PVC extension, and lever-actuated ball valve. The ball valve was located in a meter box so that it was easy to locate and access. Manual air releases were only operated when excessive operating pressures are being noted within the system. The use of manual air releases avoided problematic odor releases as well as ongoing maintenance of the automatic air release assemblies. Additionally, a large capital cost was avoided. While the flat topography may minimize chances for air accumulation, the use of manual air release assemblies deserves serious consideration for mains with a low risk of air accumulation.

Charlotte County was visited with the intent of providing a benchmark for a reactive maintenance operating approach. Ultimately it was the opinion of both the City of Lacey and Orenco that a reactive maintenance program would not be in Lacey's interest, primarily because of its high call-out rate.

Missoula, Montana
Missoula, Montana was the second STEP system visited. At the time of the visit, Missoula had more than 1,300 STEP systems in place, with more being installed. In addition to individual on-site installations, Missoula operated 17 community-style STEP tanks. The bulk of the installations were part of a septic abatement program in the late 1980s and early 1990s, so Missoula's system was about the same age as Lacey's. It was also an Orenco installation, so it provided a very good comparison. Missoula has a committed and knowledgeable team managing its existing STEP system. The operators have an appreciation for STEP and have developed many innovative techniques.

At the time, Missoula scheduled pump-outs for 160 to 200 tanks per year. Pump-outs were typically scheduled during late spring into the early fall. This schedule avoided freezing ground conditions that could impede O&M activities during the winter months. In 1994, the call-out rate peaked at 298 call-outs. Call-outs have trended lower each year, with 160 in 2006. The reduction in call-outs is attributed to proactive maintenance and better inspection of new systems. Missoula has extensive yearly records regarding the types of system failures. The largest cause of failure has been attributed to floats. The lowest cause of call-outs, in every documented year, has been pump failure, with less than one percent of pumps failing annually. Proactive maintenance on pumps has been limited to inspection and cleaning with no effort toward pump replacement or refurbishment.

Historically, Missoula has never had an odor complaint, and it expends very little on odor control. In the Missoula STEP system, all force mains discharge directly to the sewer treatment plant. This design philosophy has mitigated all potential odor concerns with the exception of what is discharged from automatic air releases. Missoula effectively controls any odor problems from automatic air release assemblies through the use of a bio-filtering system installed into a pit with a vented lid.

Missoula reports that the community tanks have higher maintenance costs than single-family tanks. However, they do find benefits in reducing the number of on-site tanks that require O&M. Part of the higher maintenance cost can be attributed to an undersized debris tank.

Missoula has an outreach program to educate their STEP customers about the do's and don'ts of using a STEP wastewater collection system.

Camas, Washington
The third visit was to Camas, Washington. At the time of the visit, the city had 3,000 STEP systems, 3,000 gravity connections and 5 grinder systems that it owned and maintained. Like Missoula, Camas is an Orenco installation and is also very comparable to that of the City of Lacey.

As in the City of Lacey, Camas' STEP mains have outfall into the gravity sewer system. The outfalls caused odor issues similar to those that Lacey was experiencing. Also as in Lacey, Camas used Bioxide as the predominant method for odor abatement. Expenditures for Bioxide were $128,000 per year at the time of the visit.

In addition to Bioxide, Camas had utilized soil beds, with conflicting information regarding their effectiveness. The city was in the process of installing Ozone Oxidizer 2000 as part of its lift station packages to reduce or control odors. The Ozone Oxidizer 2000 would replace the soil bed filtering systems.

Camas maintains commercial STEP systems for domestic-strength waste but industrial systems — such as for Sharp Microelectronics, Heraeus Shin-Etsu, Linear Technology, and other manufacturers — are owned and maintained by the user.

As in Missoula, floats caused most of the failures in Camas. To reduce float failures, Camas, like Lacey, had removed the redundant OFF float from the system.

Camas had a proactive maintenance program and scheduled 500 to 600 proactive maintenance visits each year. The goal was to visit each on-lot system every 5-6 years. At the time of the STEP tour, Camas had assigned one person to maintain the STEP program, with the intent of adding one more person to address STEP maintenance and repairs the following year.

Camas contracted out pumping services and was charged $90 per tank or $47,500 per year with no charge to discharge at the treatment plant. In 2005, 233 call-outs were documented; in 2006, 257 were documented. The number of call-outs relative to the number of customers was almost exactly midway between those in Missoula and those in Lacey. The overall 2007 budget for Camas was $349,500. This was $240,184 less than Lacey's budget. The following line items accounted for the biggest budget differences: Labor, Odor Control, Office & Operating, and Equipment Rental & Repairs. Lacey's budget is significantly higher due to higher staffing and equipment rental rates.

As was the case in Lacey, Camas had removed or disabled all of the aerators that were in service. They neither maintained nor confirmed the operation of automatic air release valves within the system.

Camas provides customer education through flyers distributed annually as part of the consumer confidence report.

Yelm, Washington

The final visit was to Yelm, Washington, which had 1,625 STEP system connections. At full build-out, the city estimates it will have 10,000 total connections. At the time of the visit, the city was averaging one to two new STEP installations daily.

Yelm's system includes an 8-acre wetland park for wastewater reuse and aquifer discharge. As a result, its NPDES permit requires each on-lot system to be inspected every three years. Sludge and scum levels in the tank are measured and recorded, the pump is inspected, and the effluent screen is cleaned. Most residential units have 3,785-L (1,000-gal) tanks, which are pumped out every 6 years on average. As in Missoula and Camas, the most common failure was the redundant float. In the first few years after system installation, Orenco replaced all the floats for Yelm.

Yelm had no odor or corrosion issues. As in Missoula, all STEP force mains discharged directly to the treatment plant. Odor at the plant was treated with a carbon filter. All of the force main air releases had been turned off because they were an uncontrollable source of odors. Air releases were periodically activated manually when a line pressure increase was noted.

At the time of the visit, the STEP systems were being maintained by two employees, who were responsible for monitoring sludge, responding to alarms, and assisting a contracted tank pumping company. Yelm also had another staff member perform inspections on new installations.

In 2006, Yelm received 170 STEP system calls. The call-out rate was slightly better than Missoula's but was slightly below that of Camas.

Yelm, like Camas and Missoula, distributed educational material regarding STEP systems. Additionally, every new customer is given instructions on STEP system maintenance.

APPENDIX 2: LACEY'S "CERTIFICATE OF ORIGIN" FOR STEP EQUIPMENT

Certificate Number: Sample

Certificate of ORIGIN

CERTIFICATE OF ORIGIN

CITY OF LACEY
ENGINEERED WASTEWATER COLLECTION SYSTEM

SINGLE FAMILY RESIDENCE using 1500 or 1700 gallon tank

TWO FAMILY RESIDENCE (DUPLEX) using 3000 gallon Concrete Tank

The following Collection System On-Lot Package is certified to have been manufactured by Orenco Systems®, Inc., Sutherlin, Oregon. The On-Lot Package equipment listed below is covered by an extended factory warranty under the terms and conditions of Orenco Systems' Certificated Products Limited Warranty in effect at the time of sale.

On-Lot Package Code: PSA10-S1DS-LACEY-WA

- Adhesive: .... (3) ADH100
- Splice Box: .... (1) SBEX1-4, (3) SBHSY, (5) SBHSB
- Biotube® Pump Vault: .... (1) PVU57-1819-L
- Float Assembly: .... (1) MFAG-Y,G-27V-LACEY
- Discharge Assembly: .... (1) HV100BFCPR-80, (1) HVX100PR-80
- Check Valve: .... (1) PPSC-10
- Effluent Pump: .... (1) PF100511
- Control Panel: .... (1) S1DS-LACEY
- Homeowner's Manual: .... (1) PMHOMEMANUAL
- Installation Manual: .... (1) PMPSPPINST
- Certificate of Origin: .... (1) NCF-CO-LACEY-1

Additional Orenco Equipment Required for a Complete Installation:

- PVC Access Risers & Accessories: .... (1) RR30XX+SX, (1)RLA30, (1) G1, (1) RR24XX, (1) RLA,24
- Riser Adapters (Cast into Tank) .... (1) PRTA24, (1) PRTA30, (1) PRTA08
- Fiberglass Access Lids: .... (1) FL30G-4B, (1) FL24-4B-RLA, (1) FL8G
- Service Connection Valve Assembly .... (1) SC125-LACEY

For Customer Use:

Site address: ______________________

Lot number: ______________________

Development: ______________________

Installer: ______________________ Install Date: __________

Vendor: ______________________

City Inspector: ______________________

NCF-CO-LACEY-1
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