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10 March 2011

Johnson Family Trust
PO Box 13132
Tauranga

Attn: Jim Johnson

Dear Jim,

Thank you for sending us the plans for the proposed Peacocke Rd development.

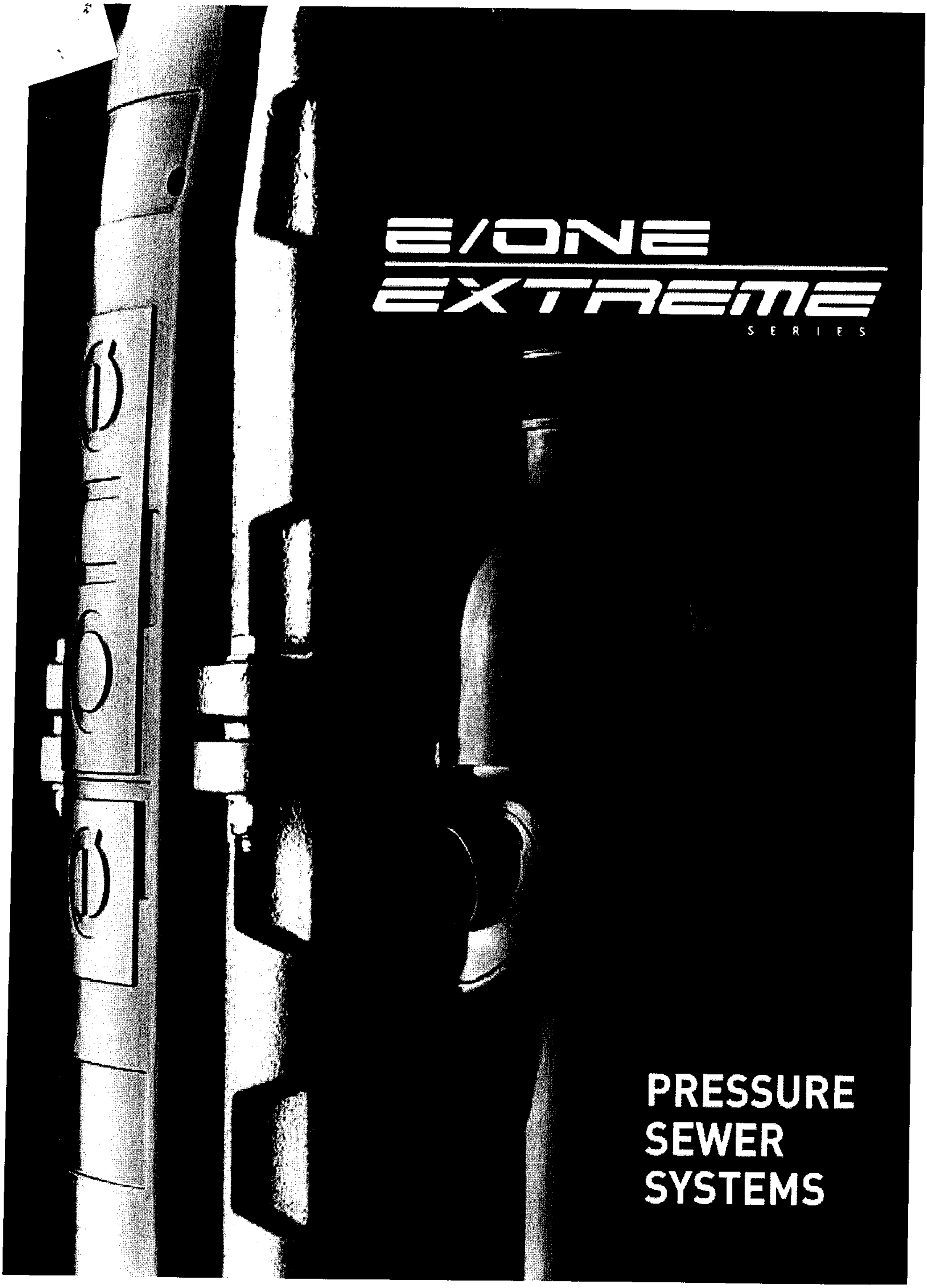
Aside from the ease and flexibility of installing a pressurized sewer system and huge capital cost savings gained, the major benefit with a development such as this from a design point of view is the allowance for stormwater infiltration into the network can be minimal. This has major benefits to council with much less flow to the treatment plant and much less cost of assets in terms of smaller diameter reticulation, transfer stations etc. In other words everything can be designed much smaller with less upgrade requirements of existing infrastructure

After looking at the plans we believe it may be possible for the E/One pressurized sewer system to pump all the way to the airport without the requirement of an intermediate pumping station. This means each E/One pump would have to accommodate the static of 9.7m between Peacocke & Airport plus losses through the pipe network which will fluctuate depending on how many pumps will be operating simultaneously. As a rough guide we have assumed 4500 properties connected to the system, out of those 4500 properties you can expect 141 properties to pump simultaneously at any given point in time. This is based on normal operation and pumping all household wastewater. From this we calculate the rising main to be around the 350mm outside diameter PE100 PN16 polyethylene pipe at the largest point from the Southern end of the development. The main line would get smaller as it heads north. There is the option of pumping blackwater only which would considerably reduce the flows effectively reduce the maximum number of simultaneous pump cycles hence further reducing pipe diameters. However further investigation may be needed for the effects of longer retention times and septicity of the blackwater.

Until we have a detailed plan of the quantity and layout of the lots we are unable to provide a preliminary design for the reticulation, however from initial observation it appears to be a practical solution to pump all the way to the airport without the requirement of a pumpstation.

Best regards,

Jon McGettigan
Project Manager

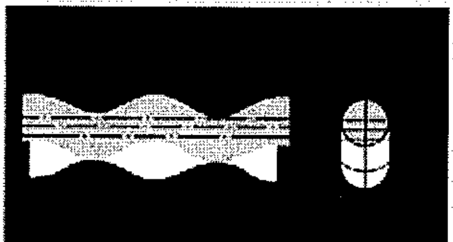

E/ONE
EXTREME
SERIES
PRESSURE
SEWER
SYSTEMS

ENGINEERED TO DO ONE JOB PERFECTLY.

At the heart of the E/One Sewer System is the toughest, hardest working pump in the industry. The new standard in excellence, durability, and longevity, the E/One Extreme Series Grinder Pump. Its evolution reflects everything we've learned in nearly 40 years as the originator and leader in the category of low pressure sewer systems.

The pump stations incorporate the grinder pump, motor controls and level sensing device integrated into a compact unit, easily removable for servicing when necessary.

And, the geometry of the pump not only produces a near-vertical pump curve, but allows passage of ground solids without clogging. Because of the low rpm and highest quality components, we experience the lowest service call rate in the industry. An average mean time of 10 years between service calls is typical.



The Moineau Principle

The progressing cavity pump itself is based on the Moineau principle. A rotor turns within a stator, creating a sequence of sealed chambers. The precision-cast and polished stainless steel rotor moves wastewater through these chambers at a nearly constant flow, over a wide range of conditions - from negative to abnormally high heads. Turning at just 1425 rpm, the 0.75kW motor can pump fluid through more than 4 km of small diameter piping or elevation changes of over 56 metres.

Rugged, Ready, and Reliable – To The Extreme

EXTREME DESIGN

- Enhanced pump controls: expanded diagnostics, protection, and communications capabilities
- "Core" concept with integral level and motor controls
- Radial O-ring seals on all joints
- Thermally welded discharge assembly for high-pressure performance
- Differential pressure switch level control in separate, removable assembly
- Equalizer compensates for fluctuations in atmospheric pressure while providing a sealed, water-tight level control system
- Integral check valve and anti-siphon valve assembly
- New, more resilient stator material enables higher pressure rating of 80 psi, using E/One proprietary stator chemistry
- All fasteners and hardware are 300 series stainless steel

EXTREME RELIABILITY

- Huge double O-rings used for casting joint seals
- Casting joints designed for corrosive environment
- Indestructible level sensor housing
- Ultrasonically welded check valve assembly
- Superior corrosion protection – wet-applied coating on Class 30 cast iron vs. industry-standard powder coating
- Weld-free stainless steel stand

EXTREME PERFORMANCE

- Design pressures to 80 psi (185 feet total dynamic head)
- Progressing cavity pump provides predictable flow over varying system pressure
- 0.75kW 1425 rpm, air-cooled motor provides low speed, high torque operation, eliminating jams
- Field-proven, large-diameter grinding mechanism provides low inlet velocity, eliminating pump blinding or clogging
- Integral check valve protects against system back pressure; anti-siphon valve facilitates downhill pumping applications

EXTREME SERVICEABILITY

- No preventive maintenance required
- Quick-release core latch on D-Series – no mounting bolts required
- Electrical quick disconnect (EQD) seals and connects without tools; uses single turn locking ring
- Detachable level sensor assembly; wireless design available using inductive coupling
- Discharge plumbing quickly disconnects from grade level
- Backward compatibility to all earlier generations/designs
- Air-filled motor more efficient than oil-filled motors and eliminates need to change and dispose of oil
- One pump for all series
- Backward-compatible EQD

ECOFLOW

WHY YOU SHOULD BUY THE BEST

Engineered Tank.
The robust tank has been designed for seismic and drag down loads. It also features a tapered base which increases turbulence for self cleaning. The tapered base also reduce the residual volume which reduces odours. Most importanntly it has been designed and manufactured to the AS/NZS1546.1 standards for under ground sewer tanks.

High Grinding Torque.
Our unique pump system, driven by a 0.75kW motor turning at 1425 rpm, produces greater grinding torque, eliminating jams.

Energy Efficient.
The pump is activated automatically and runs for short periods. Typically annual energy consumption is comparable to a 40 watt light bulb.

Low Maintenance Submersible Motor.
Low maintenance and long life are the hallmarks of our air filled motor. Permanently lubricated ball bearings and Class F insulation eliminates the need for periodic oil changes and oil disposal costs required by oil filled submersible motors.

Large Diameter Grinder Assembly.
Almost twice the diameter of most other types of grinder pumps, contributing to a dramatic reduction of inflow for less wear and no binding, clogging or jamming.

No Preventative Maintenance.
EOne are the only Pressure Sewer Manufacturer to be able to boast nearly 40 years experience. This experience has resulted in a mean time between service calls in excess of 10 years. Whilst other suppliers may claim this lenght of time between calls, they can not back it up with real operating systems.

Integrated Valves.
The integral check valve protects against system back pressure and the anti-siphon valve facilitates downhill pumping applications.

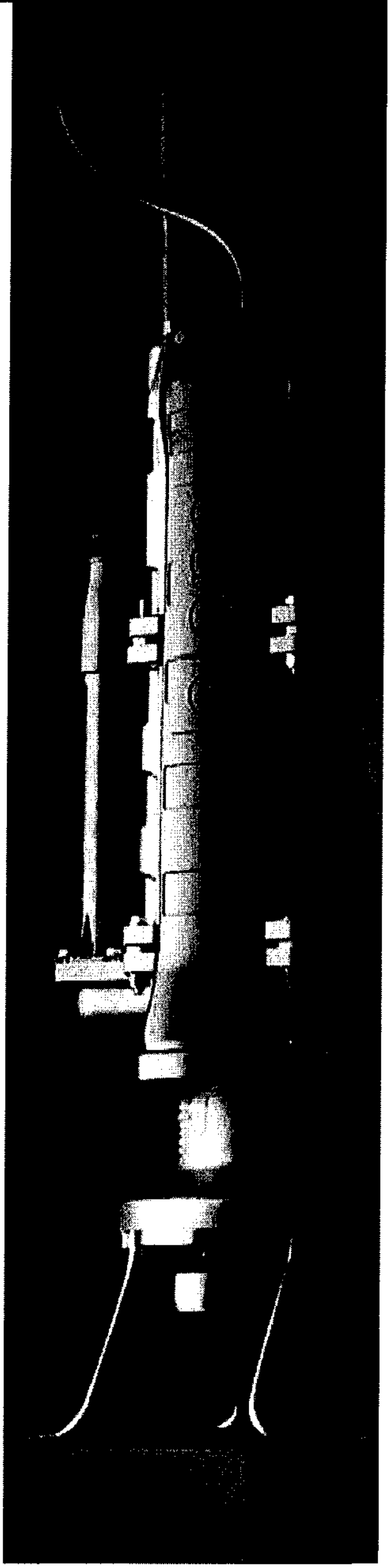
Corrosion Resistance.
E/One's stainless steel ball type discharge valve and piping won't corrode like copper or galvanised steel, and holds up years longer. No corrosion, no maintenance with casting joints that have been designed for corrosive environments, superior corrosion protection wet coatings , Class 30 cast iron and all fasteners of 300 stainless steel.

Submersible Grinder
Unlike other dry mounted units available, the EOne submersible grinder does not have issues with:

- solids build up in the tank and the requirement to periodically suck the solids out.
- The need to always have the rubber stator primed, and burning out of the stator if the prime is lost.
- Inability to work in frozen environments.

Pressure Switches.
EOne are the only unit on the market with a single joint in the pressure switch assembly. This greatly reduces the possibility of sensor failure and maintenance calls. Pressure switches require no maintenance, unlike floats which need to wash down periodically to remove fats and fibres.

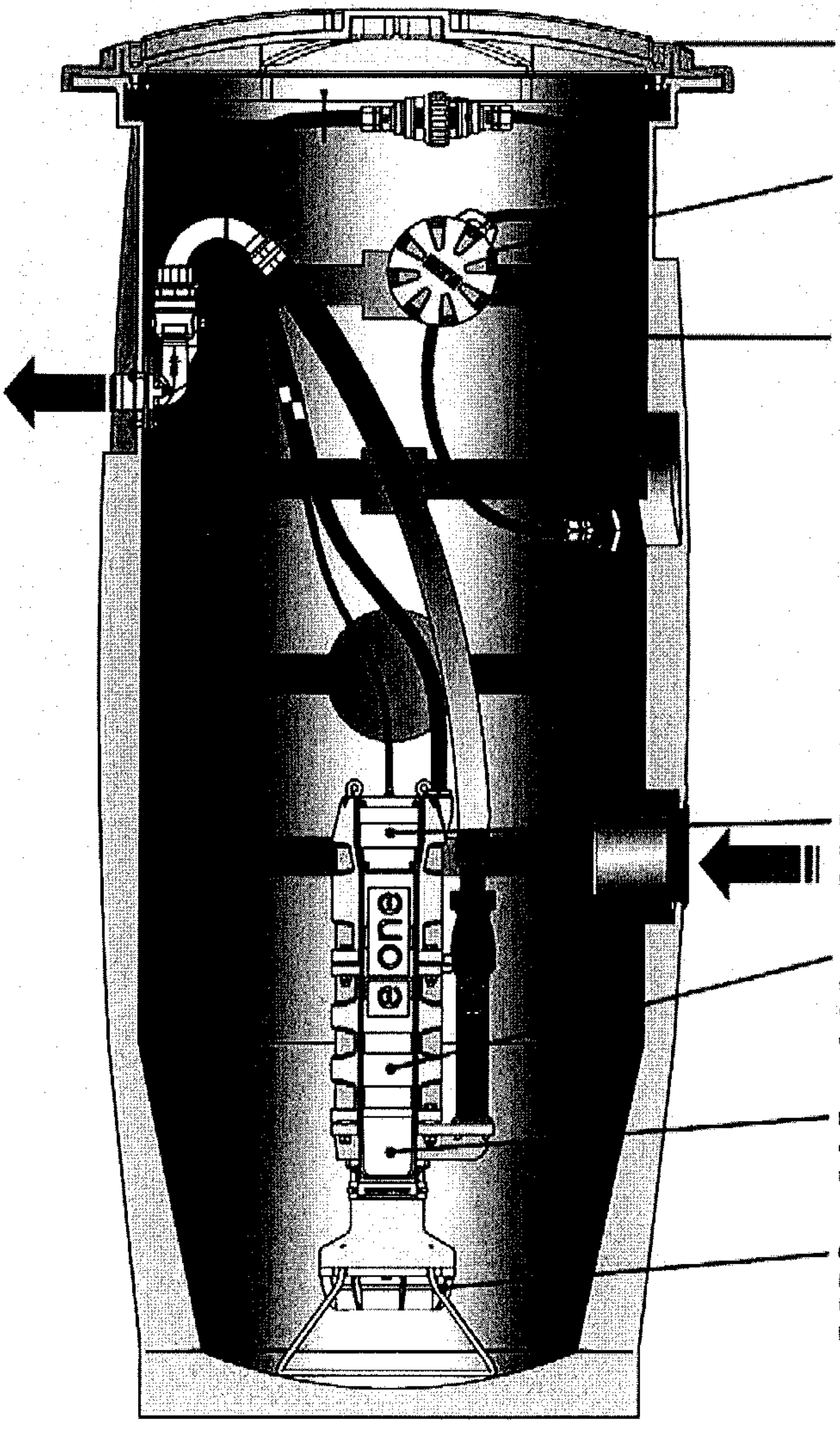
Serviceability.
Our unique design eliminates the need for in field trouble shooting and pump servicing. This means lower maintenance costs and minimum home owner inconvenience. The indestructible and removable level sensor housing allows forrapid change out of level sensors. Quick release core latch, no mounting bolts, electrical quick disconnect that requires no tools, allow for easy wash down / removal within the tank, on the rear occasion that maintenance needs to be performed And a one pump for all approach all adds up to the easiest unit to service on the market.



GRAVITY SEWERS ARE NO LONGER THE RULE FOR SOLVING WASTEWATER PROBLEMS.

At the heart of the systems is the E/One progressing cavity grinder pump – with high heads that can eliminate costly lift stations, and a robust, powerful design that translates into the industry's highest levels of reliability, availability and maintainability.

ENGINEERED PRESSURE SEWER SYSTEMS



LOW-PROFILE COVER: Aesthetically pleasing. Provides easy access for service while blending with surroundings.

E/ONE EQUALIZER: Compensates for fluctuations in atmospheric pressure to enable accurate level sensing while assuring the level sensing system is watertight.

PURPOSE-DESIGNED TANK: Constructed from polyethylene or FRP for rugged reliability. All vessels are designed with a tapered base to reduce the volume of retained wastewater.

STAINLESS STEEL HARDWARE (not shown): E/One's SS discharge ball valve won't corrode. No corrosion, no maintenance, no tools required.

DOUBLE O-RING SEALS (not shown): Make assemblies waterproof and novel joint geometry minimizes the effects of crevice corrosion.

UNIQUE CORE DESIGN: Eliminates the need for in-field troubleshooting and service. Modular controls simplify service.

PROGRESSING CAVITY PUMP: A deceptively simple design produces a nearly constant flow under a wide range of continuously varying conditions.

PRESSURE SWITCH LEVEL CONTROL: Self-cleaning level sensors require no preventive maintenance.

GRINDER WHEEL AND SHREDDER RING: Forged alloy cutter wheel with induction-hardened teeth. Proven cast shredder ring with offset tooth pattern.

NOBODY CAN TOUCH OUR CURVE.

In a low pressure system, constant, predictable pump output is the foundation for proper hydraulic design. It enables the engineer to minimize retention time, pump wear, and keep scouring action at effective levels.

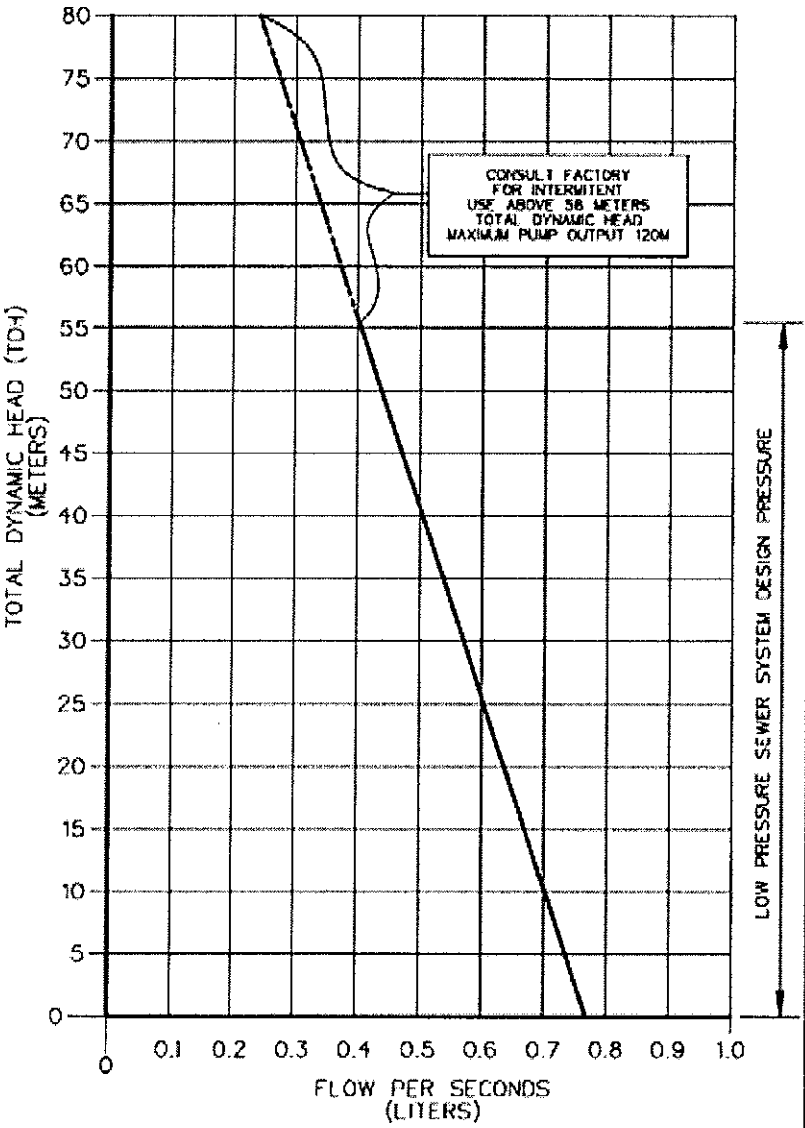
Environment One's semi-positive displacement, progressing cavity pump has a nearly vertical H-Q curve. Its is by far the most "forgiving" pump design - providing predictable flow over the full range of typical system pressures; strengths critical in a large-scale, low pressure sewer.

E/One's superior high head capability allows a system with few, if any, lift stations. And, it easily accommodates additional future connections without compromising system performance.

These E/One pump characteristics translate into:

- predictable hydraulic design
- lower collection system capital costs
- less maintenance
- lower operating costs

GRINDER PUMP PERFORMANCE CHARACTERISTICS



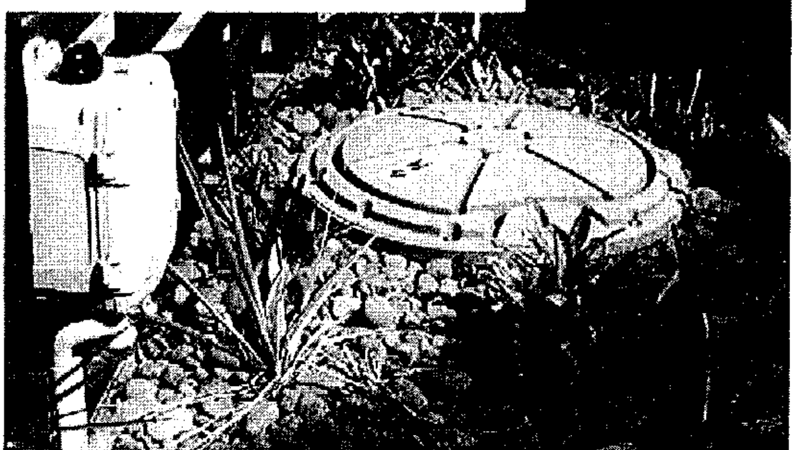
Sewer Anywhere and Save

E/One Sewer Systems give engineers, builders, developers, municipal sanitarians and land planners unprecedented new freedom in land usage and sewer rehabilitation.

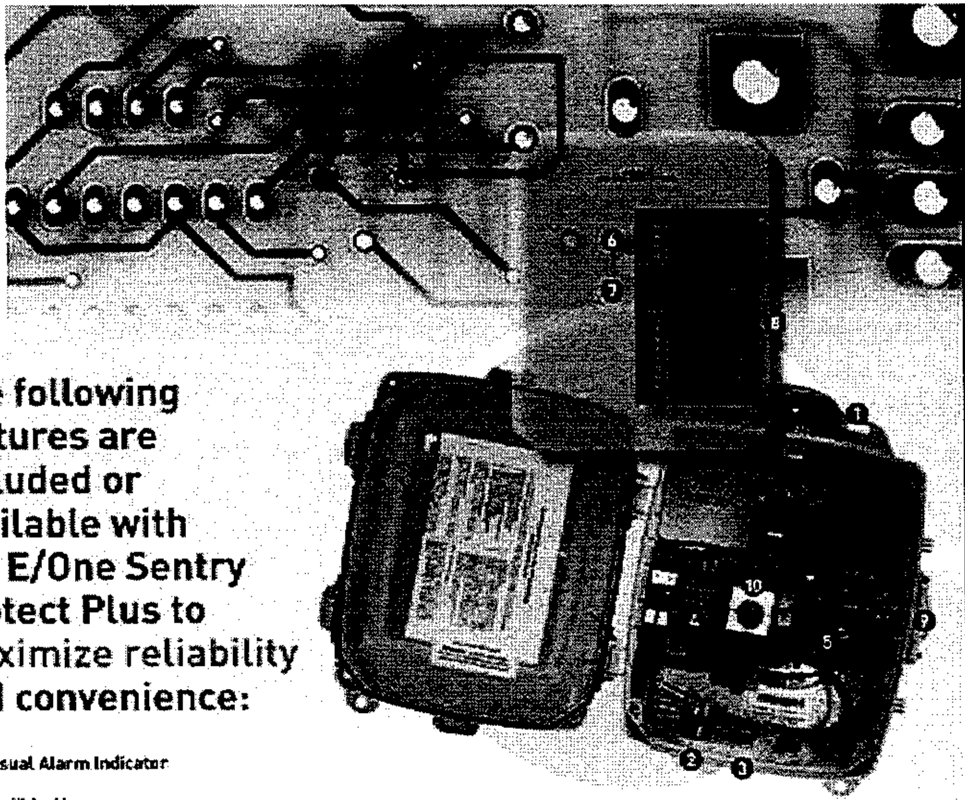
Easy to install. Easy to operate. And easy to maintain.

The sensible sewering solution that defies gravity and saves up to 50% - the E/One sewer system.

Environmentally sensitive. Economically sensible.



Sentry Maximizes Reliability and Convenience



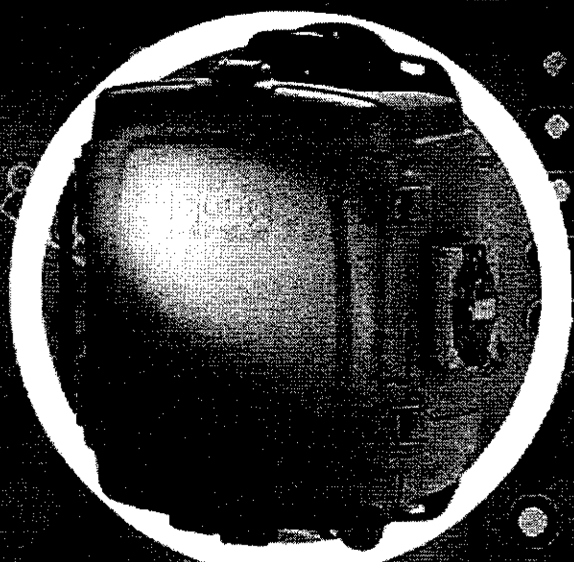
The following features are included or available with the E/One Sentry Protect Plus to maximize reliability and convenience:

1. **Visual Alarm Indicator**
2. **Audible Alarm**
3. **Alarm Silence Switch**
4. **Main Service Disconnect Breaker** (available option, not shown)
5. **Easy-Access Terminal Strips** Interface
6. **Display Panel Operating Indicators**
   - Ready (AC Power) Indicator
   - Pump Running Indicator
   - Trouble Indicator
   - High Level Alarm Indicator
7. **LCD Display**
   - Manual Run Switch/ Enter Switch
   - Scroll Switch
   - Trouble Indications:
     Brown-out Condition
     Run-dry Condition
     System Over-pressure Condition
     Voltage Problem
     Amperage Problem
     Run-time Limit Exceeded
8. **Diagnostic Mode Switch** (For system setup/service)
   - Diagnostic Mode Indicators
   - Pump Performance *provides access to performance statistics including:*
     Real-time Voltage
     Real-time Amperage
     Real-time Wattage
     Minimum Voltage
     Maximum Voltage
     Minimum Amperage
     Maximum Amperage
     Minimum Run-time
     Maximum Run-time
     Average Run-time
     Last Run-time
     Event Counter
     Hour Meter
   - Initialize System
   - Run Limit
   - Alarm Delay
   - Power Delay
9. **Generator Receptacle** (available option)
10. **Manual Transfer Switch** AC Mains to Portable Generator (available option)

e|one SEWER SYSTEMS

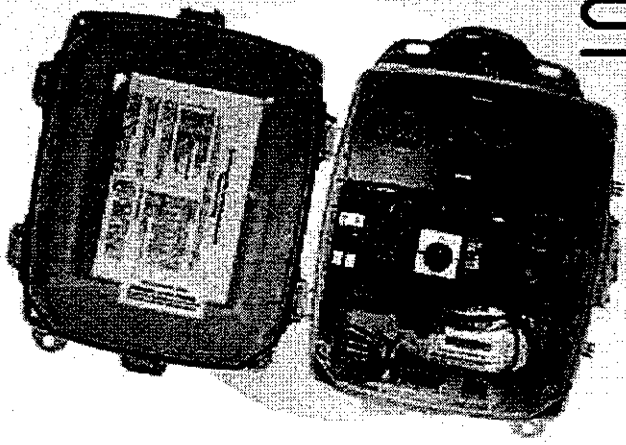
e/one sentry

Custom Alarm Panels for E/One Low Pressure Sewer Systems



The World's Best Low Pressure Sewer System Sets a New Standard in Reliability and Convenience

e one SEWER SYSTEMS



e/one sentry

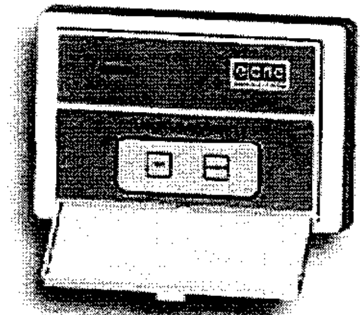
The Sentry line of alarm panels is custom designed for use with E/One grinder pump systems. **The E/One Sentry™ alarm panels provide the latest technology and the greatest flexibility** in customizing features to satisfy individual needs. The new alarm panels can be configured to provide functions ranging from basic alarm indication to advanced warning of pending service requirements. In between, **there are numerous features available** including an event counter; run-time meter; service disconnect capability; and remote alarm indication.

Like the E/One grinder pump station, all panels are ITACS listed and meet all applicable ASNZ 2000/3000 codes and standards. Furthermore, all E/One Sentry alarm panels are housed in IP 65 lockable enclosures, suitable for mounting on a wall or a post.

The basic E/One Sentry panel provides features essential to any installation:

A. Circuit breakers for pump power and alarm circuits
B. Audible high level alarm indication
C. Visual high level alarm indication
D. High level alarm silence switch
E. Manual Run switch
F. Redundant "Start" function with high level alarm
G. Run indicator to show when pump is operating

THE E/ONE REMOTE SENTRY DISPLAY MODULE provides visual and audible indication when the water level inside the grinder pump tank reaches a predetermined "high" level during normal operation, or in the event of a power outage (with hard-wired version of *Extreme* core and optional contacts in panel). It is ideally suited for installations where the outdoor alarm panel location is obstructed from view.



The Remote Sentry includes:

- A low profile attractive case (137mmW x 93mmH x 32mmD)
- Lithium battery
- Audible alarm (70dB)
- Push-to-silence audible alarm switch
- Push-to-test visual and audible alarm

Now Available in Two Upgrades

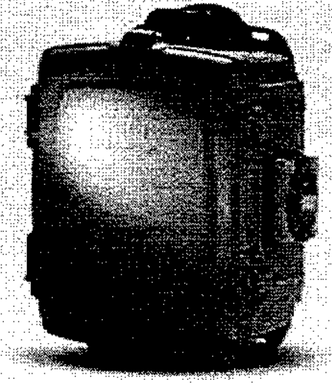
E/ONE SENTRY PROTECT

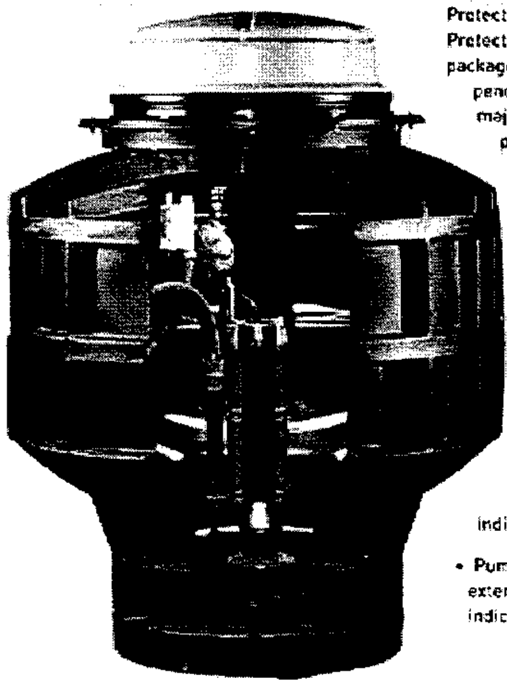
The E/One Sentry Protect panel provides important protection from external conditions that could otherwise prove damaging to the E/One grinder pump station.

Adding the Protect option to the E/One Sentry panel provides a Trouble indication and shuts down the pump/core temporarily in the event of an unacceptable operating condition.

The pump/core will automatically return to Normal operation when the condition is resolved. The Protect feature provides monitor-ing of:

- Brownout conditions with the electrical power supply
- System over-pressure condition such as with a closed valve
- Run-dry operation of the pump/core





E/ONE SENTRY PROTECT PLUS

Taking it to the next level, the E/One Sentry Protect Plus includes the benefits of the Protect option as well as a diagnostics package that provides advance warning of pending service needs by monitoring major operating conditions and providing a Trouble indication when these conditions fall outside of normal ranges. Depending upon the severity of the abnormal condition, the grinder pump station may continue to operate. The Protect Plus feature provides monitoring of:

- AC input voltage – if input voltage falls below 88% or above 112% of normal line voltage a Trouble indication is provided
- Amperage – if amperage exceeds preset limits a Trouble indication is provided
- Pump run-time – if the pump operates for extended periods (adjustable) a Trouble indication is provided

The E/One Sewer System. What it is. How it works. Why it's better.

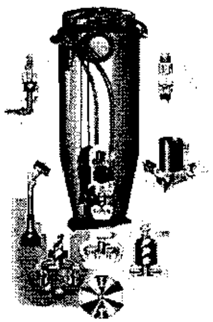
In the world of sewer system technology, less is more. The E/One Sewer System requires only a shallow trench and small 50 mm to 125 mm diameter piping. So, unlike conventional gravity central sewers, which use a 225 mm pipe and require deep excavation, the E/One Sewer System is not destructive to the landscape's natural or built features.

It also costs significantly less to install and operate than a gravity system. It requires less maintenance. But it guarantees big results.

Here's the idea behind the E/One Sewer System: Both the gravity sewer system and the E/One Sewer System are known as central sewer systems. (Septic systems fall into a whole other category of waste disposal—see "The High Cost of Septic Systems" on the following page.) Most cities and many villages use central sewering, which simply means that waste is transferred, usually by a pipe or main, to a central treatment plant.

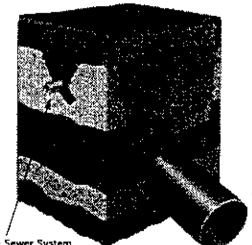
Gravity sewers are the "original" central sewers, with origins in the Roman aqueducts. Unfortunately, the technology behind gravity sewers is also centuries-old: they're bulky systems using a large main and can require major excavation to install. They must be accurately placed and bedded along a continuous downward grade. Plus they're expensive and not entirely efficient in transporting waste because they can tend to leak.

The more advanced E/One Sewer System employs highly sophisticated technology and has become known for its reliability, minimal maintenance, low upfront costs, reduced operating expenses, and ability to be installed at any site, regardless of the challenges of topography. And only the E/One Sewer System with its GP 2000i grinder pump overcomes the challenges of low-pressure systems, performing dependably day in and day out.



Small Is Beautiful.

Conventional gravity sewers use a 225 mm large-diameter pipe, or main, which requires major excavation and severely disrupts the landscape and any built structures such as lawns, driveways, and plantings. The E/One Sewer System uses an unobtrusive small-diameter 50 mm to 125 mm main installed at a minimum depth below the ground, following the natural topography of the land.



engineered
to do one job
perfectly.™

The GP 2000i grinder pump, the heart of the E/One Sewer System, provides wastewater storage, grinding, and pumping in a single unit. Translation: it lowers operating costs, the cost of waste collection, and reduces maintenance.

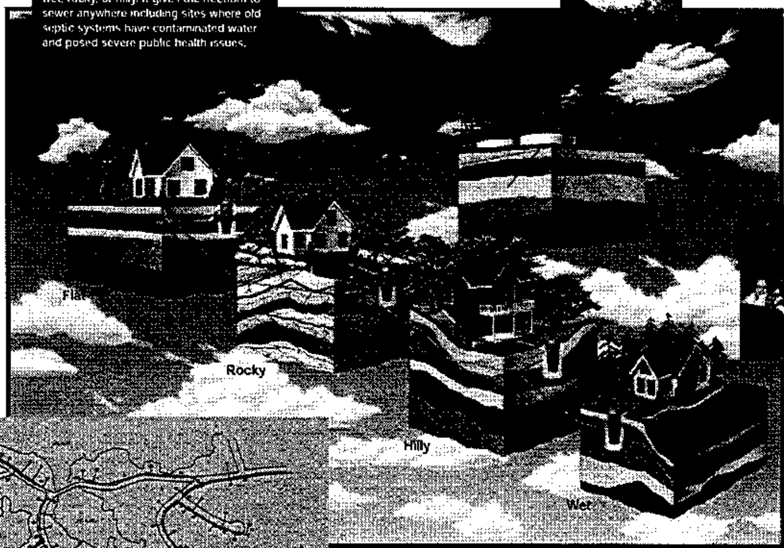
The E/One Sewer System grinder pump is engineered to do one thing perfectly and in the process will help communities control their growth and maintain quality of life.

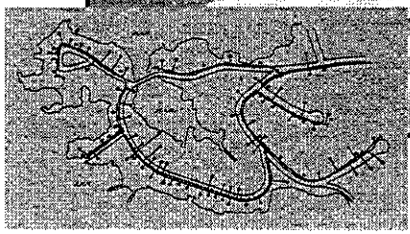
Defy Gravity with E/One.

The beauty of the E/One sewer system is that, unlike conventional central sewers, it defies gravity. Because installation follows the natural contour of the land, it is ideal for all terrain, including land that is flat, wet, rocky, or hilly. It gives the freedom to sewer anywhere including sites where old septic systems have contaminated water and posed severe public health issues.

How Does It Look From Where You Are?

Aesthetics are a major consideration for homeowners. The E/One Sewer System is virtually out of sight—the only visible part is a low-profile cover that blends seamlessly into the environment but provides easy access for servicing operations.



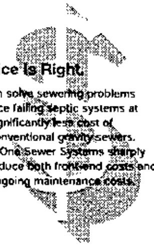


A Sense of Site.

Multi-branch E/One Sewer Systems serve the entire community and give engineers, developers, community planners, and homeowners the freedom to sewer anywhere, on any kind of site.

The Price Is Right.

E/One can solve sewering problems and replace failing septic systems at significantly less cost of conventional gravity sewers. E/One Sewer Systems sharply reduce both front-end costs and ongoing maintenance costs.



The Advantages of the E/One Sewer System.

Homeowners
- Safe—protects water quality and enhances quality of life
- Reduces costs of housing—both initial and ongoing
- Visually benign—only evidence is a low-profile cover that is easily camouflaged
- Does not disrupt the beauty of the landscape or damage built structures
- No maintenance or upkeep required of homeowner
- Central sewer increases value of home

Municipalities/Developers
- Permits freedom to sewer anywhere in any kind of terrain
- Low initial costs make central sewers economically feasible
- Low initial costs make development economically feasible
- Central sewer increases value of development units
- High reliability—maintenance is minimal
- Reduces operating costs
- Protective of public health
- Permits regulatory compliance

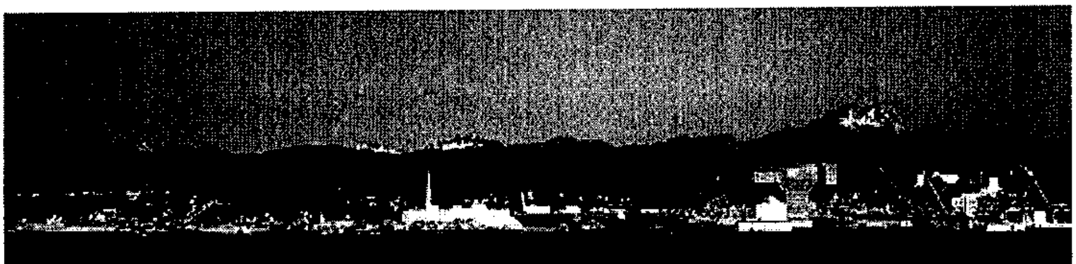
Engineers/Operators
- Proven engineering and design
- Ideal for every terrain and building environment
- Cost-effective central sewering solution for new construction or retrofits
- Engineering and technical support during design, construction, installation, and operation
- Reliable performance means reduced O&M costs
- When needed, E/One pumps are easy and safe to access and service
- Designed to keep maintenance to absolute minimum

Contractors/Construction Managers
- Installation follows contour of the land—does not require major excavation
- Needs only shallow trenches—increases ease and safety of installation procedures
- Labor and material costs are much less than gravity sewer systems

The High Cost of Septic Systems.

While septic systems may be a common way of disposing of residential sanitary waste, they are, at best, a temporary solution and come at a high cost to public health. All over the world, septic systems have degraded ground and recreational water, creating serious safety problems. Because of failing septic systems, water is not safe to drink. Children are not free to play near contaminated lakes and streams. Outbreaks of waterborne disease become common. Quality of life is eroded. In addition, failing septic systems decrease real estate values. E/One Sewer Systems can go wherever septic systems were initially used, eclaiming water quality and quality of life while providing an efficient, solution to wastewater disposal and treatment. In fact, communities retrofitting with E/One Sewer Systems have reported dramatic improvements in coliform levels in as little as 30 days after installation.

Relevant Articles



Engineering Low Pressure/ Grinder Pump Sewer Systems

Chuck Mayhew, Richard Fitzwater

The Beach Drive area, located directly across Sinclair Inlet from the Bremerton Naval Shipyard, is an area of magnificent water and mountain views.

Project Background

The science of civil engineering involves identifying problems, evaluating alternatives, and providing solutions that effectively meet the needs of those involved. Civil engineers are particularly interested in solving problems to improve the way people live and work and protect the integrity of the environment.

Kennedy/Jenks Consultants was recently asked to solve a common waterfront problem - failing septic systems. The Puget Sound region of western Washington includes hundreds of miles of private saltwater and lakefront property. In 1993, the Bremerton-Kitsap County Health District (Health District) began sanitary survey tests along a 5-mile stretch of coastline known as Beach Drive. The results of the testing revealed failing septic systems in 21 percent of the existing 215 homes. In some cases, a septic tank or drain field did not even exist, and the homeowner's sewage discharged directly to the bay. The Health District estimates a typical failure rate of 5 percent in areas served by septic systems; the 21% failure rate constituted a public health emergency.

The high percentage of failing septic systems was attributed to a number of factors:

1. The average age of the septic systems along Beach Drive was approximately 50 years. Some systems had been rehabilitated, and newer homes typically possessed more elaborate, pumped systems, but most of the systems had never been improved.

2. The geographic and topographic conditions along Beach Drive are not conducive to adequate treatment by traditional septic systems. Although the soil conditions along Beach Drive range from clay to solid rock, clay is the predominant soil type on private property. The homes with failing systems were located along the beach against a very steep hillside that contributed copious runoff.

3. The average annual precipitation in the Bremerton-Port Orchard area is 51 inches per year, resulting in saturated soil conditions many months of the year.

4. Many homeowners had not maintained their septic tanks and drainfields.

The combination of these factors resulted in the unusually high failure rate.

The Health District subsequently declared a public health hazard and mandated that homeowners with failing systems either make the necessary repairs to their existing system or connect to the public sewer system. The homeowners with failed systems faced repair bills of $15,000 to $18,000 to replace the septic tanks and drainfields according to local codes or to install new high-tech filtration units. Many homeowners recognized that connection to the public sewer was an affordable alternative that would provide a long-term health benefit to the area. Fortunately, the jointly owned Port Orchard-Kitsap County Sewer District No. 5 secondary treatment facility was located at one end of the Health District's test area.

Formation of Utility Local Improvement District

A handful of proactive homeowners assembled to form the Beach Drive Sewer Committee. The Committee's goal was to rally the community in an effort to build a public sewer to serve the properties along the waterfront. With the treatment plant located adjacent to Beach Drive and in sight of many homes, the Committee anticipated a quick, relatively inexpensive sewer project. However, when the Committee approached the Kitsap County Sewer District No. 5 (District) about connecting to the public sewer, they encountered a number of significant hurdles:

1. The Washington State Growth Management Act (GMA) prohibits the extension of urban services (including sewer collection systems) into designated rural areas such as Beach Drive. This statute prohibited various state and local agencies from approving design and construction of the sewer system along Beach Drive.

2. Because the entire area proposed for sewer service was located outside the current District boundary, the entire area would have to undergo a lengthy annexation.

3. Substantial capital costs were required to plan, design and build the system.

The Sewer District cooperated with the community and was willing to provide sewer service to the Beach Drive area if the problems could be solved. The District recommended that the Committee work closely with the District Engineer, Kennedy/Jenks Consultants, to resolve the problems confronting the project. Kennedy/Jenks Consultants helped the Committee obtain a GMA statutory exemption for a declared health hazard.

The Engineer also assisted the citizen's Committee with the petition process for annexing and creating a utility local improvement district (ULID) to finance the sewer project's capital costs. Washington State statute provides legislation enabling formation of a ULID to allow capital facilities to be built. The ULID statute requires the landowners within the ULID to assess themselves the costs of planning, designing, and building the improvements. The ULID is enclosed within a specified boundary, and creation of the ULID (by the petition method) requires the signatures of at least 51 percent of the area landowners. The petition requesting creation of the Beach Drive ULID was signed by 71 percent of the landowners.

Analysis of Sewer System Alternatives

Prior to creation of the ULID, the Committee asked Kennedy/Jenks Consultants to examine the various sewer system alternatives available for use in the Beach Drive area. Because the homeowners were assessing themselves for the capital costs of the project, the primary reason for the alternative analysis was to find the alternative with the least expensive construction cost. However, as the District Engineer, Kennedy/Jenks Consultants' responsibility was to find the alternative with the lowest life cycle costs [construction plus operation and maintenance (O&M)] for the District. The District had committed its resources to the sewer project early in the process and was responsible for preserving the community's public health. At the same time, the homeowners were under a mandate from the Health District to correct their failing systems or face court-ordered fines and condemnation.

The Engineer evaluated four systems for the Beach Drive area: 1) gravity sewer system that required three pump stations, 2) septic tank and effluent pumping (STEP) system, 3) vacuum system, and 4) low pressure/grinder pump system. Each system could be reasonably designed and constructed and they were each evaluated based on the District's needs (minimizing capital and long-term O&M costs) and the homeowners' needs (minimizing capital costs). Minimizing capital costs was critical to the District as well, because the properties within the ULID could not be assessed capital costs in excess of the sewer connection's assessed benefit to the property. In other words, if the capital cost assessment for a particular property was $15,000, but its appraised value increased by only $10,000, the District would be legally required to assume the $5,000 difference.

Construction cost estimates for each alternative were as follows:

System Alternative	Estimated Construction Cost	Estimated Annual O&M Cost
Gravity Sewer System (including three pump stations)	$8,420,000	$25,000
STEP System	$2,336,000	$12,600
Vacuum System	$2,222,000	$14,700
Grinder Pump System	$1,912,000	$10,710

The Engineer recommended the grinder pump system because it offered the lowest capital cost to the homeowner, minimized O&M costs, and reduced the risk of assumption of capital cost in excess of assessments to the District.

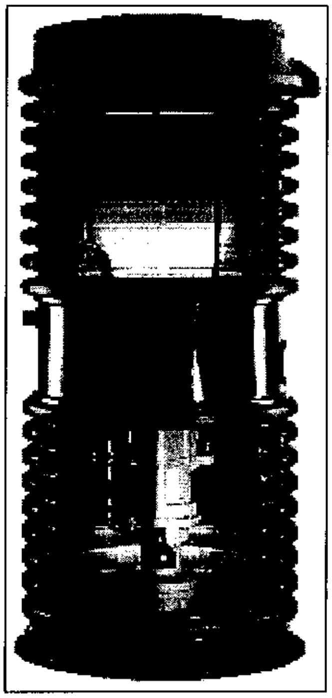
Selection of Environment One Grinder Pumps

Kennedy/Jenks Consultants had previously designed several grinder pump projects. Together, these projects involved more than 1,000 grinder pumps from three different manufacturers. Based on that experience and the O&M data collected, the Engineer recommended that the District use Environment One (E-1) grinder pumps. The E-1 grinder pumps had a proven track record of exceptional reliability and serviceability. Moreover, the E-1 pump was the only grinder pump that could efficiently satisfy the head requirements along Beach Drive.

Environment One Grinder Pump

The Environment One grinder pump is characterized by:

- A self-contained unit with integral wet well/dry well
- Field adjustable accessway to accommodate varying sewer invert and grade elevations
- Simple core design that allows replacement and/or service in the field
- A progressing cavity pump that produces a nearly constant flow rate over a wide range of head conditions
- A standard 1 hp motor that is interchangeable on any E-1 model
- Pressure switches as opposed to float switches
- Stainless steel discharge piping.



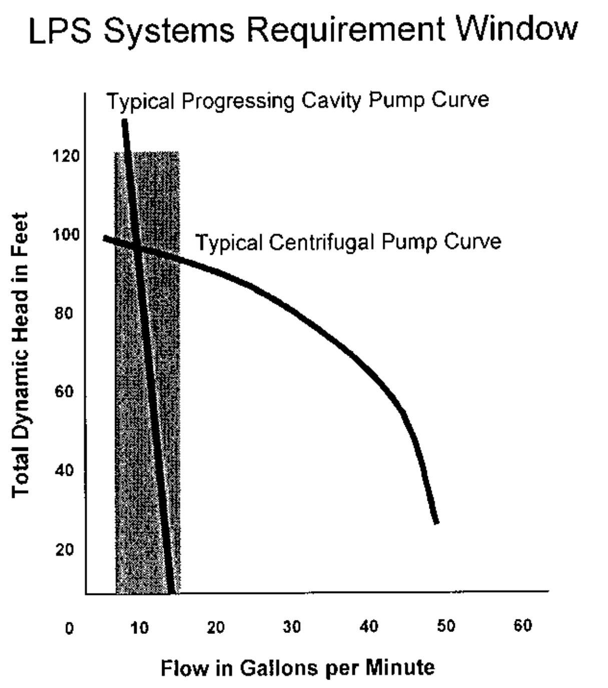
Cutaway view of E-1 Model 2010 grinder pump

Operation and Maintenance (O&M) Costs

In 1986, Kennedy/Jenks Consultants designed more than 900 E-1 grinder pumps for installation around four lakes south of Tacoma, Washington. Based on data collected by Pierce County Utility, annual maintenance costs for this system averaged $51 per pump per year between 1990 and 1994. Pierce County also had 46 centrifugal grinder pumps in a different system with average annual maintenance costs of $243 per pump during the same period. The utility attributes the difference in maintenance costs between the centrifugal and progressive cavity (E-1) pumps to the need for regularly scheduled maintenance for the float switches in the centrifugal grinder pump units. A major factor in the low maintenance costs for the E-1 pumps is the 11-year average mean time between service calls (MTBSC).

Serviceability

Simple removal and installation of the "core" to service the pump and grinder is inherent to the design of the E-1 grinder pump. The grinder pump unit consists of a high-density polyethylene (HDPE) housing and a suspended core that includes the pump, grinder, controls, and other operating parts. After the grinder pump is installed, the core can be repaired by disconnecting the electronic quick disconnect (EQD) and removing six stainless steel bolts in the accessway. District maintenance personnel can then troubleshoot the core in the field or install a replacement core and take the damaged one back to the shop for testing and repair. The homeowner experiences minimum downtime, and the District can repair and test the damaged core at its convenience in the shop.



Centrifugal vs. Progressing Cavity Pump Curves

Minimum Preventive Maintenance

One of the biggest benefits of the E-1 grinder pump is the use of pressure switches instead of float switches. Float switches are notorious for fouling with grease, and preventive maintenance is typically required for the pump to operate properly. By incorporating a sensing bell and air pressure column to actuate level controls, E-1 minimizes the need for preventive maintenance.

The E-1 grinder pump uses a progressing cavity pump rather than a centrifugal pump. The typical pump curve (right) shows that a progressive cavity pump has a nearly constant discharge rate over a wide range of head conditions, including negative head conditions. As a result, the cleansing velocity created by the reduced flow area at the point of blockage flushes sedimentation from the piping network. Typical operating pressures of the Beach Drive system range from 20-60 psi and shutoff for the pumps is 160 psi. The smaller the area in the pipe, the higher the velocity of the liquid because of the progressing cavity pump. Periodic maintenance and flushing of the force main are essentially eliminated.

System Design

The entire project consisted of:

- 26,900 feet of 3"to 8" forcemain;
- 22,400 feet of 1-1/4" to 2" pressurized discharge piping on private property; and
- 210 grinder pumps installed on private property;

Force Main Design

The entire system was hydraulically modeled on the computer to ensure that proper velocities were maintained and that no point in the system exceeded the maximum recommended pressure of 80 psi for the E-1 pump. The model calculated the total dynamic head (TDH) for each pump based upon the pipe sizes, number of pumps, and elevations of pipe mains and grinder pumps.

Oct-15-98

PRELIMINARY PRESSURE SEWER - PIPE SIZING AND BRANCH ANALYSIS
Watauga Beach Sewer Project

Prepared By:
Chuck Mayhew

This spreadsheet was calculated using pipe diameters for: SDR11HDPE

Friction loss calculations were based on a Constant for inside roughness of "C" = 150

Zone Number	Number Of Cores In Zone	Accumulated # Of Cores In Zone	Max # Of Simultaneous Operations	Max Flow In GPM	Pipe Size (Inch)	Max Velocity (FPS)	Length Of Main This Zone	Friction Loss Factor (Ft/100Ft)	Friction Loss This Zone	Accumulated Friction Loss (Feet)	Max Main Elevation	Minimum Pump Elevation	Static Head (Feet)	Total Dynamic Head (Ft)
1.00	9	9	3	33	2.00	3.57	650	2.52	16.38	128.11	40	10	30	158.11
2.00	9	18	4	44	3.00	2.19	650	0.65	4.22	111.73	40	10	30	141.73
3.00	12	30	5	55	3.00	2.74	1,000	0.98	9.82	107.51	60	15	45	152.51
4.00	20	50	6	66	4.00	1.99	950	0.41	3.85	97.69	60	10	50	147.69
5.00	30	80	7	77	4.00	2.32	2,400	0.54	12.95	93.84	35	15	20	113.84
6.00	5	85	8	88	4.00	2.65	1,100	0.69	7.60	80.89	70	25	45	125.89
7.00	4	4	3	33	3.00	1.64	900	0.38	3.43	76.72	30	19	11	87.72
8.00	15	104	8	88	4.00	2.65	1,000	0.69	6.91	73.29	28	24	4	77.29
9.00	13	13	4	44	3.00	2.19	500	0.65	3.25	69.63	14	14	0	69.63
10.00	0	117	9	99	5.00	1.95	400	0.31	1.23	66.38	15	15	0	66.38
11.00	9	9	3	33	3.00	1.64	850	0.38	3.24	68.39	20	10	10	78.39
12.00	17	143	9	99	5.00	1.95	2,400	0.31	7.36	65.15	14	11	3	68.15
13.00	4	4	3	33	3.00	1.64	550	0.38	2.10	59.89	45	42	3	62.89
14.00	11	158	10	110	5.00	2.17	1,300	0.37	4.84	57.79	10	8	2	59.79
15.00	18	176	10	110	5.00	2.17	1,000	0.37	3.73	52.95	12	9	3	55.95
16.00	32	208	11	121	5.00	2.39	2,600	0.44	11.56	49.22	12	9	3	52.22
17.00	32	240	12	132	5.00	2.60	2,200	0.52	11.49	37.66	27	12	15	52.66
18.00	32	272	13	143	6.00	1.99	3,000	0.26	7.76	26.17	12	10	2	28.17
19.00	11	283	14	154	6.00	2.14	1,200	0.30	3.56	18.41	8	8	0	18.41
20.00	3	3	2	22	3.00	1.10	500	0.18	0.90	15.75	8	10	-2	13.75
21.00	24	310	14	154	6.00	2.14	2,400	0.30	7.12	14.85	8	8	0	14.85
22.00	32	342	15	165	6.00	2.29	2,100	0.34	7.08	7.73	8	8	0	7.73
23.00	0	342	15	165	8.00	1.35	700	0.09	0.65	0.65	22	8	14	14.65

Typical model output for designing a low pressure, grinder pump system.

Grinder Pump Design

An essential phase in the design of the grinder pump system was to meet with each homeowner at the property. The visit was crucial to address homeowner questions and concerns and to lay out the grinder pump and discharge piping locations. In many cases, homeowners were planning to remodel their homes after sewer installation. By discussing how the grinder pump works and explaining some constraints associated with the grinder pump location, the homeowner and engineer could select a location that would prevent numerous, costly change orders during construction if grinder pumps had to be relocated. The engineer designed and drafted the site plan on a laptop computer in the field. The site plan was later reproduced on 11"x17" sheets for use by the contractor during construction.

Typically, the grinder pump was located near, or occasionally inside, the existing septic tank, making the plumbing of the existing house sewer to the grinder pump more efficient. The design could not have been completed successfully without these property visits to determine the location of the existing sewer hookup at the house. Although the property visits were time consuming, they were far more beneficial to the project than the cost, because change orders constituted less than 1 percent of the project cost.

Conclusion

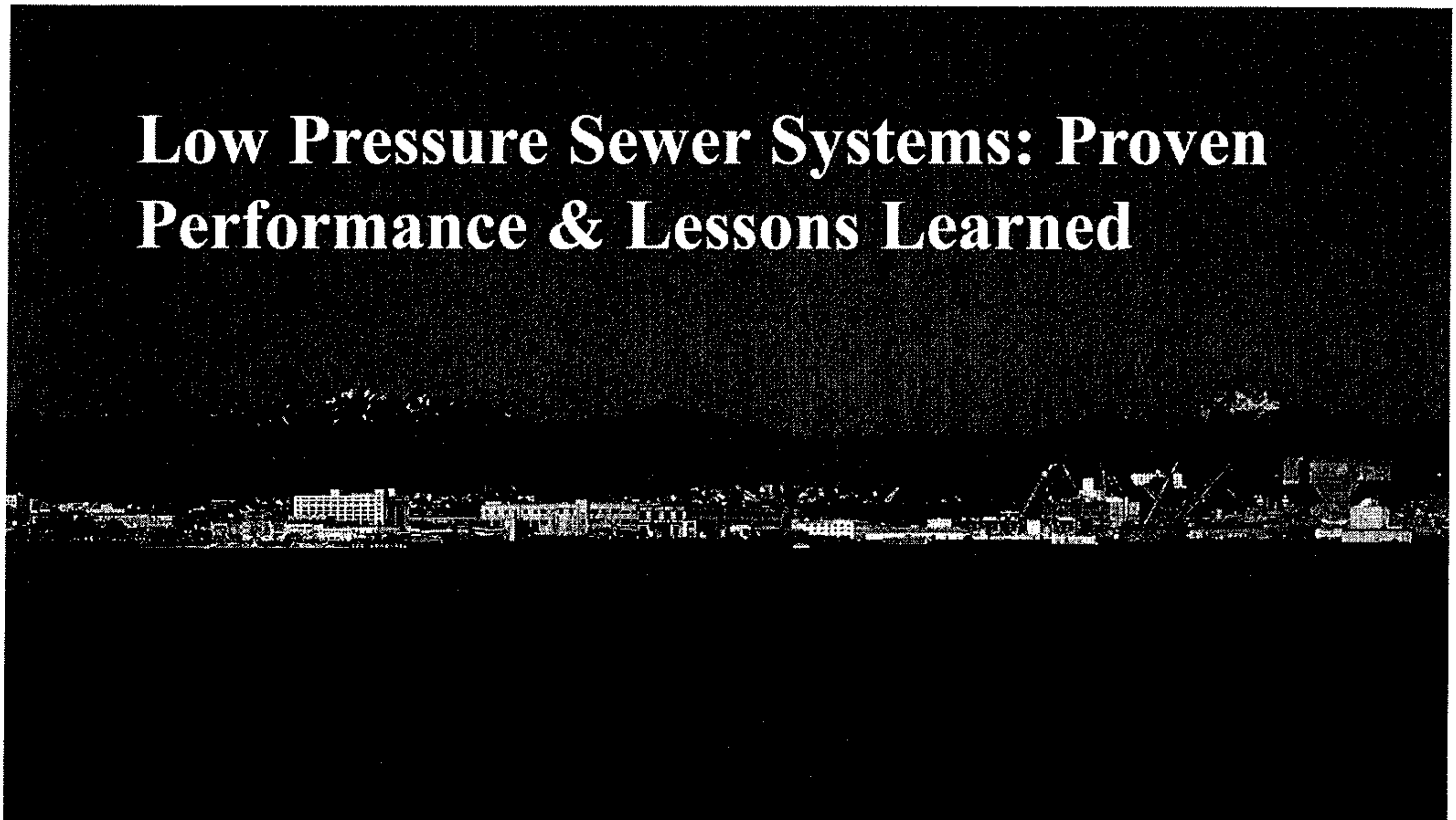
The Beach Drive Sewer Project was a unique application of an alternative technology. The needs of both the public agency providing sewer service and system maintenance, and the homeowners who were required to pay for the capital cost of the project, were satisfied. The District, homeowners, and Kennedy/Jenks Consultants successfully embraced a philosophy of working closely together to provide a sound design with analysis of alternatives and frequent coordination of efforts to meet the needs of all involved.

Chuck Mayhew *is a senior staff engineer with Kennedy/Jenks Consultants in Federal Way, WA.*

Richard Fitzwater *is General Manager of Kitsap County Sewer District No. 5 in Port Orchard, WA.*

This report is available on the Kennedy/Jenks Consultants' website at www.kennedyjenks.com.

Low Pressure Sewer Systems: Proven Performance & Lessons Learned



Executive Summary

The two-year period between 1997 and 1998 saw the installation of nearly 350 Environment One (E/One) grinder pumps along six miles of waterfront property in Kitsap County, Washington. The low pressure sewer system was designed and constructed in response to failing on-site septic systems. The capita cost of the improvements was funded through a Utility Local Improvement District (ULID). A ULID is a funding mechanism for property owners whereby an opportunity is afforded to vote on the proposed improvements and assess their property to pay for the project costs.

The sewer system was installed under two separate ULID formations and, as a result, was competitively bid and awarded to two different contractors. Beach Drive was the first project and included the installation of 295 grinder pumps and about five miles of high-density polyethylene (HDPE) pressure main. Watauga Beach was the second project and included 52 grinder pumps and one mile of HDPE pressure main. The Watauga Beach system connects directly to the upstream end of the Beach Drive system.

As construction on Beach Drive proceeded and the formation of the Watauga Beach ULID began, it became obvious that some design changes and installation practices needed to be modified to address some of the problems on Beach Drive. This paper will quantify the performance and repair history of the two projects, offer explanations for the differences and summarize the lessons learned.

Project Background

The mandate to sewer waterfront properties in Port Orchard began with the local Health District conducting on-site sanitary surveys for the hundreds of World War II era homes located along Sinclair Inlet. The results of their testing implicated 21 percent of the 215 homes as having failing on-site septic systems that contributed insufficiently treated sewage to the Inlet. The resulting Health Hazard declaration by the Health District, and impending condemnation orders, were sufficient to move local property owners to action.

The mechanism available in the state of Washington for making utility improvements and assigning the costs of the improvements to those benefiting from the improvements is a Utility Local Improvement District (ULID). Through a voting process, each property owner may approve or disapprove of the proposed improvements. If more than 50 percent of the land area approves of the project and the estimated costs, the ULID is created. To the District, a ULID is an attractive method to finance sewer improvements because it provides a way for those benefiting from the improvements to pay for their benefit. The current ratepayers in the District do not have to subsidize improvements for growth or new connections. A ULID is also attractive to many property owners because it provides a way for the District to secure funding (normally at much better interest rates than private loans or home refinancing) and provide the option of paying for the improvements with annual installments over 20 years.

Forming a ULID introduces one interesting element into a project – direct involvement with property owners in making decision on the outcome of the improvements. Since a ULID is formed by a vote of the property owners and they are going to pay for the improvements through property assessments, they want to be involved in the process of planning and design of the project. The property owner's motivation is to minimize the capital cost of the project. This approach will best serve them in the end. The District's motivation is to minimize operation, maintenance and repair costs following the construction and turn over of the system to the District. These competing interests resulted in an engineering analysis of four different sewer collection systems for Beach Drive – gravity collection, low pressure grinder pumps, vacuum system and STEP system. Each system was evaluated based on topography, waterfront conditions (including groundwater considerations) and water quality issues (odor, septage strength, etc.) and an estimated cost assigned for capital costs and ongoing O&M costs as shown in Table 1.

Once consensus was reached by property owners and the District's design engineer to use the low pressure grinder pump system, the District chose to use the Environment One (E/One) grinder pump. The E/One pump was the only grinder pump that could meet the head conditions (maximum 140 feet TDH) of the system and there was an extensive track record available from which to estimate future maintenance and repair costs.

Table 1: Sewer Collection System Alternatives

System Alternative	Estimated Construction Cost	Estimated Annual O&M Cost
Gravity Sewer System (including three lift stations)	$8,420,000	$25,000
STEP System	$2,336,000	$12,600
Vacuum System (with two vacuum stations)	$2,222,000	$14,700
Grinder Pump System	$1,912,000	$10,710

Proven Performance

The District's design engineer used data from previous E/One projects, where maintenance and repair records were kept, to provide budgetary estimates to the District for annual repair costs after completion of the project. Table 2 identifies the previous E/One projects that were available for review in 1996 to estimate annual O&M costs.

Pre-Construction Maintenance Cost Estimates

Considering the age of comparable systems, technological advancements since previous projects were installed, economies of scale and personal experience, the design engineer estimated that the District should budget $38/year/pump for O&M. Since the District would not have operating costs for the pumps (electricity for the pumps is provided by the homeowner), the average annual expense for each pump consists of service calls (labor) and repairs (parts).

A reasonable way to project maintenance and labor costs is to calculate the *mean-time between service calls (MTBSC)*. The MTBSC represents the average time between service calls on any given pump in the system.

$$\text{MTBSC} = \frac{(\text{\# Pumps}) \times (\text{Years in Service})}{\text{\# Service Calls}}$$

Again, based on previous projects, the designer estimated that the District could expect a MTBSC of 10 years, or about 3 service calls per month. It should be noted that not every service call results in a repair. Some service calls are for alarm situations or conditions that the technician can troubleshoot in the field and resolve without bringing the pump core back to the shop for repairs.

Post-Construction Maintenance Costs

The District carefully compiled data on service calls and repairs, including expenses for labor and parts, over the last seven years. The actual maintenance and repair costs for both projects combined is $23/pump/year and the MTBSC is 22 years. Table 3 shows a comparison between the pre-construction *estimates* and the *actual* post-construction data for the E/One sewer system.

Maintenance Costs: Grinder Pumps vs. Lift Stations

At one point during the design process for the Beach Drive project, the Board of Commissioners for the District considered a rate surcharge on grinder pump customers to cover what was *projected* to be higher maintenance costs than the District's existing customers. The decision was made to not charge grinder pump customers extra, but rather, wait and gather the data prior to making that decision.

The District operates and maintains 11 large sewage lift stations throughout its collection system. The District's engineer compiled the annual operating and repair costs for these lift stations and compared them to the grinder pump system on an ERU basis. An ERU represents one equivalent residential unit, a common denominator between residential and commercial usage of the sewer system. Interestingly, the District found that the annual maintenance and repair of the grinder pump system amounted to $26/year/ERU. The annual O&M (including repairs) on the major lift stations amounted to $53/year/ERU – twice as much as the low pressure sewer system. The District has since resolved to *not* charge their grinder pump customers an additional monthly fee to cover maintenance costs.

Beach Drive Project

The Beach Drive project was completed in May 1998 and had a total of 295 grinder pumps installed through 2004. The average age of the pumps is seven years and the number of service calls during that period was 111. Therefore, the MTBSC for the Beach Drive Project for the period from 1998 through 2004 is 19 years. After seven years of operation, the MTBSC was nearly double the *estimated* MTBSC projected prior to the project.

The most common causes of service calls and repairs on Beach Drive were worn stators, electrical problems stemming from damage to direct bury cables or flooding of the pump accessway (the dry well portion of the pump station) and bearing failures. These types of service calls and repairs were directly attributed to problems with design and construction. The only cause of failure that can be attributed to the pump manufacturer is premature bearing failures, which accounted for 19 service calls. However, due to the high percentage of bearing failures on Beach Drive (6 percent on Beach Drive as opposed to 2 percent on Watauga Beach), there is some consensus that some of the bearing failures were not the primary mode of failure.

Location	Number of Grinder Pumps	Average Age of Pumps	Annual O&M $/Pump
Cuyler, New York	41	17	$53.00
Fairfield Glade, Tennessee	955	16	$36.07
Pooler/Bloomingdale, Georgia	998	11	$13.24
Pierce County, Washington	900	9	$51.00
Sharpsburg/Keedysville, Maryland	780	5	$18.00

Table 2: Historical E/One Projects

Note: Data taken from "Onsite Wastewater Treatment," Dec. 11–13, 1994, American Society of Agricultural Engineers

Watauga Beach Project

The Watauga Beach project was completed in November 1998 and had a total of 52 grinder pumps installed through 2004. The average age of the pumps is 6.5 years and there were eight service calls during that period. That equates to a MTBSC for Watauga Beach of 42 years! Obviously a MTBSC of 42 years is longer than the pump station life, but it indicates that significant improvement was made during the installation of the two grinder pump projects, so that the number of service calls made during the first 6.5 years of the system's life was very low.

One of the service calls on Watauga Beach was from a faulty core repair from Beach Drive and another one was a bearing failure. The remaining six service calls were the result of installation.

Lessons Learned

What did the District learn from these two projects? It became obvious in the early stages of construction on the Beach Drive project that several things needed to be done differently to reduce the number of service calls and the amount of time and money spent on repairs due to poor installation practices. Many of the installation problems could be attributed to design issues while others were simply the result of the actual construction. The following practices were identified as causes of excessive service calls and action was taken during the design and construction of the Watauga Beach project to minimize their effects.

Sewer Lateral Connections

The Beach Drive project provided for the District's contractor to install the grinder pump station on private property and install the pressure discharge line to the main in the street. The project made provision for the 4" sewer lateral installation between the home and the grinder pump station the responsibility of the homeowner. This was done primarily as a cost-cutting measure for the homeowners, giving them the option of hiring a local plumber or installing the lateral themselves. Many of these sewer laterals ran long distances, depending on the configuration and direction of their existing plumbing and the location of the grinder pump in the yard. This provision resulted in widespread poor quality installation that allowed sandy soil to migrate into the grinder pump sump. The granular material accelerated wear on the rubber stator. This was a very common service call within the first year of operation on Beach Drive.

Ensure a Watertight System

There were three causes of pump failures/service calls on the Beach Drive project that were attributable to water getting into the electrical components of the pump, 1) in-field manufacture of accessway extensions; 2) breaching the integrity of the direct-bury cable between the pump and the control panel on the house; and 3) backups from the wet well to the accessway.

The vertical distance between the top of the pump station (which is installed slightly above grade) and the invert of the inlet pipe is a critical measurement. The District pre-ordered the grinder pump stations with a total height of 58". If the sewer line from a house was lower than 24" below grade, an extension of the accessway was required to lower the inlet elevation. Approximately two dozen field extensions were required. Several of the field joints created by the extensions ended up leaking groundwater, resulting in water contacting the "breather patch" (an opening in the power cable in the accessway that allows atmospheric pressure to the motor housing). The result was pump motor failures and service calls.

The power cable installed between the pump stations and the

Table 3: Pre- and Post-Construction Maintenance and Repair

	Pre-Project Estimate	Actual Post-Construction	Savings
MTBSC	10 Years	22 Years	12 Years
Average Number of Service Calls/Year	35 Calls	16 Calls	19 Calls
Average Maintenance $/Year	$13,186	$9,009	$4.177

Note: This data is for the combined Beach Drive and Watauga Beach systems.

control panel on the wall of each home had a direct bury rating and was installed as such. There were several cases were it was determined that either during installation or subsequent yard work by some homeowners, that the cable sheathing had been nicked and water vapor was allowed into the wiring and wicked back into the motor housing. The result was pump motor failures and service calls.

The primary cause of service calls was attributable to worn stators that prematurely failed due to the introduction of abrasive material (sandy soil) into the pump station during the installation of the sewer lateral. When a stator is worn down, the capacity of the pump diminishes and an alarm is set off. The responsibility to call the District in an alarm situation lies with the homeowner. If the homeowner fails to contact the District in a timely manner, the water from the wet well backs up through the influent sewer line and through the wet well vent pipe. The 2" PVC vent pipe has a friction fit through the plastic lid. As water backs up the vent pipe and spills onto the ground, some water also runs down the outside of the vent pipe back into the accessway, flooding the breather patch and allowing water into the motor housing. The result was pump motor failures and service calls.

These electrical failures became obvious in the first six months of installation and use by the homeowners. The design for the Watauga Beach project was under way at the time and several changes were made to prevent the same problems on the Watauga Beach project.

Applying the Lessons Learned

The first change made during the design of the Watauga Beach system was to eliminate all homeowner involvement in the construction, thus preserving the integrity of the work by holding the contractor for the District accountable for meeting the District's specifications for installation, cleaning, testing and startup. The District's contractor was required to plumb all pipe on the project, even if the contractor had to go under the house and redirect the plumbing to the new grinder pump station.

The District also pre-ordered the pump stations for the Watauga Beach project. The pump stations were ordered with a taller accessway to accommodate lower sewer line elevations, eliminating the need to add accessway and field joints during construction. In addition, the District required the direct bury cable to be installed in conduit for protection and had each vent pipe silicone caulked at the interface with the pump station lid.

Based on these changes, the District estimates that service calls were reduced on the Watauga Beach project by 20 percent, representing about a $5,300 savings on the project. In hindsight, the District realizes that, had these lessons been known prior to the Beach Drive project, the potential savings could have been $30,000.

The District also recognized the need to educate the new customer. This education included such instruction as what *not* to flush down the drain, to be careful not to get beach sand into the sewer system and not put raised gardens over the top of the pump station lid. We had to help the customer recognize that when the alarm goes off, they should silence it and immediately call the District office for service. Often, working with the customer was most difficult because they simply didn't understand how the system worked or didn't care. The District has developed ways to work closely with homeowners by sending periodic newsletters explaining how the system works and what should be avoided. The maintenance crew also helps explain problems to homeowners when service calls are made so that the problem will not happen again. These ongoing efforts have helped reduce the number of service calls.

Summary

The Beach Drive and Watauga Beach projects were designed to solve an environmental health and safety problem. Failing septic systems were polluting Sinclair Inlet and posing health risks to homeowners whose failed systems often left raw sewage pooling in their yards.

The ULID process and the District's cooperation with property owners resulted in a successful capital improvement that resolved the health hazard. After seven years of operation, the District has increased the MTBSC for the pump stations and reduced the annual maintenance costs. The District has also learned several key lessons that facilitated even greater savings on the Watauga Beach project. As a result, three key elements are recommended to others embarking on the design and construction of a grinder pump system:

1. **Interview and qualify a design engineer that has completed these types of projects before.** Find an engineer that knows the latest developments and improvements in these systems. This alone will potentially save tens of thousands of dollars in construction changes and much more in long-term maintenance and repair costs.
2. **Carefully apply local regulations and applicable bidding laws to obtain a *qualified* and *conscientious* contractor.** The quality of the work is important in keeping the system clean and problem free. Often, even though the low bidder must be accepted, a partnering relationship can be established when the Owner or Engineer make special efforts to help the contractor understand prior to the start of the project, the need to work together to avoid the types of problems outlined in this paper.
3. **Have an experienced inspector on site!** The District found that the inspector made all the difference. He knew just what to look for and where to give the contractor special instructions. In addition, the District's inspector inevitably got to know the homeowners and this helped to develop the ongoing relationship that will exist between the District and the homeowners.

About the Author

Chuck Mayhew, PE, is the district engineering for Karcher Creek Sewer District. This paper was originally presented at the Hawaii Water Environment Association Annual Conference, February 2005.

Over pressure protection for pressure sewer systems

By *David Fletcher & Stephen Wallace*

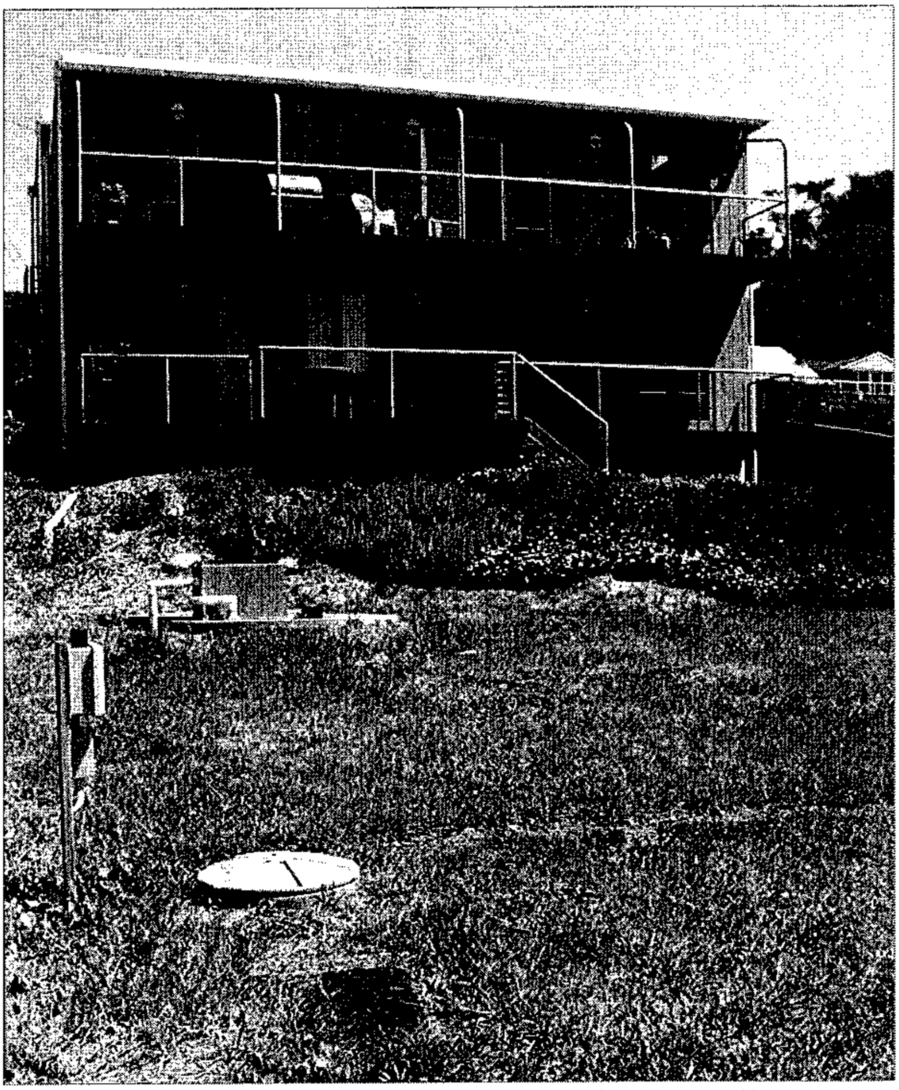
Pressure sewer systems have been around on a global basis for more than 30 years and have proven robust, reliable and the most cost effective solution (on a whole-of-life cost basis) in many applications.

In the context of Australia, the first true pressure sewer system was installed at Tooradin in South East Water's region. Tooradin is very flat and had a major issue with grey water retention at the street level, hence South East Water's requirement to upgrade the system.

The pressure sewer system installed was supplied by Environment One and has operated for more than four years with a mean time between service calls (MTBSCs) of greater than 15 years (data supplied by SE Water), well above what was expected by the client or in fact estimated by the supplier (MTBSCs typically run at greater than 10 years).

Thousands of installations later, in a very challenging project, it became apparent that although the water being discharged was very similar to that in the United States, the polyethylene piping supplied in Australia was rated very differently from that available in the Untied States, in fact so different that any of the off-the-shelf grinder pumps available in Australia could have pushed the piping to failure in the unlikely event that service personnel inadvertently left specific isolation valves shut for an extended period of time. The issue here was not the ability of the pump to produce enough pressure to cause deformation or even failure of the pipe, rather the potential for extreme static system pressures coupled with the pump discharge pressure becoming greater than the working pressure of the polyethylene pipe.

Following is a brief discussion of over pressure in pressure sewer systems, when you should consider it, how to deal with it and various methods of preventing it along with specific issues that must be evaluated to ensure that the solution provided is the correct solution for your application. It should be noted that this is not considered to be a definitive work; however, the issues identified will provide a good start point for anyone designing pressure sewer systems.



Pressure sewer systems have been used around the globe for more than 30 years and have proven robust, reliable and a cost effective solution in many situations.

What is over pressure?

Over pressure is a condition where the sum of the static head and the pump discharge pressure approaches the working rating of the pipe network. This can be made from high pressure pumps, high static head or most likely a combination of the two. In addition the over pressure condition can be exacerbated by the selection of an inadequately rated piping material.

When should over pressure be considered?

Over pressure is not limited to any specific applications and, as noted above, it can be the result of a combination of factors. As such, over pressure should be considered when designing any system. Environment

One recommends that the conditions be analysed by a professional in all cases, especially in areas of significant relief (> 40 m), when pumping downhill and when piping is only available in specific classes (for example PN 12.5 pipe may not be suitable for a specific application and may create an over pressure condition, this could be eliminated by using a high rated product, for example PN 16).

How to deal with over pressure conditions

Ultimately, the best means of dealing with over pressure conditions is to design them out, a little thought and some good ol' fashion Aussie ingenuity can go a long way. Where this is not possible, an electrical/mechanical solution may be sought.

There are many of these available and each has its place, the key is knowing when to use what. Environment One currently offers three electrical/mechanical solutions to over pressure conditions. These include:

- a pressure transducer mounted on the pump discharge line of the pump;
- a proprietary current measuring device;
- the 'M3' rotor stator combination.

Pressure transducers are commonly available and have the benefit of being adjustable to cut the pump at a variety of different discharge pressures. The down-side of the pressure transducer is that these devices were never designed to operate in a tank full of sewage and as such have proven unreliable. Should pressure transducer's be used, it is important that the impact of such a device on the system be considered. Some specific considerations that should be addressed include:

- system recovery after a power outage;
- flushing capabilities;
- airlocking.

These issues will be discussed in further detail below.

Current measurement relies on the motor drawing a specific current at a specific discharge pressure. These units have proven very successful and have an excellent track record in the Australian

Table 1. System pipe sizes and the required flow rates to move solids through the system

Pipe Size (mm)	Required flow rate to flush pipe (l/S)	Number of stations required to provide flowrate	Litres per metre of pipe	Approx metres of pipe to be flushed using number of stations in column 3
40	0.58	1	0.8	750
50	0.58	1	1.25	480
63	1.16	2	2.04	588
75	1.74	3	2.92	616
90	3.47	6	4.18	861
110	5.21	9	6.22	868
125	6.94	12	8.01	900

Based on
1. a flushing velocity of 0.6m/s (minimum)
2. a nominal 600L station capacity, will vary with different models
3. Polyethylene PN 16 PE 100 pipe to AS 4130

market. The major downfall of the current measuring device is that its accuracy is determined by the nature of the current drawn by the motor. Many motors have a relatively flat current draw in the operating range of the pump and this can reduce the accuracy of the cut out pressure.

The M3 rotor, stator combination is the most elegant solution available and comes at no additional cost. The design of the rotor stator combination is such that the pump can not physically deliver more than a specific discharge pressure. The M3 combination also has a drawback in that the maximum pressure delivered is not adjustable.

Elevated pressure versus over pressure

Whilst over pressure conditions as defined above can be a concern and should be addressed when designing pressure sewer systems, the means used to address or prevent these over pressure conditions should also be a concern to the designer. Pressure sewer systems are unique in sewerage reticulation systems in that the system must be considered on a whole rather than on a pump-by-pump basis (as is the case with the many thousands of 'pump up' solutions installed around the country. The 'pump up' solution is purely one of liquid elevation, and there is virtually zero interaction within a system where the pump up discharges into a gravity main or manhole).

Pressure sewer systems are termed 'systems' as each and every pump within the 'system' has the ability to interact with the others. This interaction requires that a designer must address the impact on the system of specific circumstances, not just on the pump or even street of pumps that are immediately affected.

The operating profile of a pressure sewer system is not consistent with a traditional sewer rising main from a pump station. A pressure sewer system has a variation of flow regimes from zero flow at periods overnight to peak instantaneous flow which lasts for a short duration at infrequent periods. As such the velocities of the sewage flow in the pipe will vary accordingly. A pressure sewer pipe section which has a high point may entrap air causing the following scenario; the flow increases from a low-flow period to an absolute peak instantaneous flow period; subsequently the air will create an additional pressure within the system, increasing up to the point of air sweeping velocity crossover and purging the air along the downstream grading pressure sewer section. Therefore the highest pressure the air lock will impose on the pressure sewer system may be at the flow point just prior to this air sweeping velocity crossover. A number of issues exist with this situation as follows:

- The crossover point may be at a high-flow rate, which the average daily peak may not reach.
- The peak flow rates required to reach the required air sweeping velocity crossover may only be for a short period of time - for example, less than a minute. This time may not be sufficient to purge the system.
- The semi-positive displacement grinder pumps may be exposed to an additional head at every operation.

This may be overcome in following ways:

- Vent air to atmosphere – where air cannot be scoured to the outlet, an alternative is to vent the air to atmosphere at an air release point. The pressure sewer system design accommodates the use of air valves to release air from the system and therefore eliminate the additional pressure ('air head') the pump would otherwise experience.
- Designing for air entrapment – where venting to atmosphere is not practical, it may become necessary to design the systems to allow the grinder pumps and other system components to overcome the additional head loss caused by the entrapped air.

If we look at a system that under extreme conditions or due to human error, could result in an over pressure event, it may be considered appropriate to simply limit the discharge pressure of the pumps to ensure that the over pressure condition can never occur. Systems have been installed with maximum discharge pressure as low as 45m and whilst this ensures an over pressure event cannot occur, it can result in other more significant issues including air locking (or binding) and pipe blockages.

In the 1970s at Grandview Lake in Indiana, it was demonstrated that air locking in pressure sewer lines can regularly require at least 40+ metres line pressure to clear the lines and in this case, the centrifugal pumps installed in the application were unable to clear the lines and, without intervention, would have resulted in mass overflows of the system. Grandview Lake is but one example of the air locking that can and will occur in pressure sewer systems. As designers, it is our role to ensure that the potential for air locking is addressed and that we ensure the system is able to achieve the pressures required to move the air through the system or that other means of relieving this condition are designed into the system such as air release valves, along with the appropriate air scrubbing systems and a rigorous maintenance schedule.

Blocking of piping systems is a far less common event and can be a result of many abnormal factors, most of which are related to poor construction techniques or unique combinations of contaminants entering the system. Trade waste discharges of grease and other solid materials will increase the likelihood of blockages and hence applications with these discharges increase the necessity for high pressures to assist in clearing these situations. In most instances a semi-positive displacement-style pump will work to clear the line as has been demonstrated in various systems throughout the country. As a blockage builds up over time the system pressure is increased with the pumps working harder and harder, usually a fluid velocity is reached at which the build-up will be removed and moved along the line to the discharge point. These elevated velocities create higher friction losses and hence higher system pressures. A system with a pump that is unable to operate at elevated pressures is more likely to require operator intervention to maintain satisfactory long term performance.

System recovery after extended power outages

In the rare event of an extended power outage, pressure sewer units will generally fill to a level that exceeds the point at which the alarm is activated. When the power is restored, all of the units will attempt to start and immediately the units that are seeing the highest pressures will thermal out and restart when the thermal device resets. This arrangement requires the unit to be designed with a robust thermal device to ensure a suitable recovery, EOne's design has proven extremely successful. If the system is designed with an overpressure device, it will struggle to recover after a power outage as each station will be 'over pressure' and will shut out. If and when the pressure is reduced, all units will restart and will immediately trip out on 'over pressure' again. This condition could continue indefinitely.

System flushing

System flushing can also be achieved (without external intervention) when a system utilises pumps that can operate at elevated pressures.

The nature of the semi-positive displacement grinder pump allows the operator to use a series of pressure sewer units operating simultaneously as a flushing facility for the system. This method of operation is particularly easy to accomplish with the small diameter pipes commonly seen in pressure sewer systems.

Table 1 demonstrates system pipe sizes and the required flow rates to move solids through the system. Columns 4 and 5 outline pipe volume and the length of pipe the combination of pressure sewer units discharging simultaneously will flush.

Overcoming high pressure/over pressure situations

- Design it out by changing the discharge location.
- Separate the system between low and high pressure systems with check valves between the two systems.
- Limit the locations (high and low) of pressure sewer unit in a development. This limits the maximum and minimum pressures a system may experience.
- Provide an intermediate sewer pump station or break tank.
- Install high pressure rated components.
- Implement management practices.
- Limit the shut-off head of the pump, utilising one of the methods described above.

It should be noted that limiting the maximum discharge pressure of the pumps in the system can have disastrous consequences in a pressure sewer system and the impacts of this course of action should be well understood before such a decision is implemented. Limiting the maximum pressure available in a system can lead to significant increases in system operating costs along with lower reliability and reduced customer satisfaction and, as we all know, that is what it is all about!

References

R. Paul Farrell, Jr., *Handbook of Grinder Pumps and Pressure Sewer Systems*

EPA-R2-72-091, *A Pressure Sewer System Demonstration*

- **David Fletcher is the regional Manager- Australasia for Environment One Corporation and has over 15 years experience in the water and waste water industry. Stephen Wallace is a Director of Pressure Sewer Solutions, Australia's most experienced team in the design and delivery of pressure sewer projects. He was involved in the introduction of pressure sewer systems into the Australian marketplace and has since been involved in the design of more than 50 systems and implementation of over 30 systems. For further information, contact (07) 5537 8807 or www.eone.com/au**