Relief Well Installation Work Plan  
Countywide Recycling and Disposal Facility  

January 7, 2008

1.0 INTRODUCTION

Order No. 2 of the December 31, 2007 Director's Final Findings and Orders (Dec. 21 F&Os) requires that Countywide submit a Relief Well Installation Work Plan (Plan) no later than January 7, 2008. The Plan is to detail “the installation of four large diameter vertical relief wells designed to remove high volumes of liquid within the facility.” Order 2 went on to specify the required contents of the Plan and to require that a schedule be proposed which must indicate that 2 of the 4 relief wells be installed no later than February 29, 2008, unless an alternative date is established pursuant to Section XII: In-Field Adjustments of the Orders.

The Plan contained herein is submitted to meet the requirements of Order 2 of the Dec. 31 F&Os.
2.0 RELIEF WELL CONSTRUCTION

2.1 Locations
During meetings between Countywide and the OEPA on December 17 and 18, 2007, four tentative locations were selected; these locations are shown on Figure C-1. OEPA selected two that would be completed first (RW-1 and RW-2). At each location, the bottom of the well is to be installed to within 15 feet of the landfill baseliner. Since the ground surface and the baseliner elevation vary at each location, the depth required to achieve this objective varies; see Table 1 for depth and construction information for each of the Relief Wells. See Figure D1 for a proposed schematic of a Relief Well.

<table>
<thead>
<tr>
<th>Countywide Landfill - Deep Relief Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
<tr>
<td>RW-1</td>
</tr>
<tr>
<td>RW-2</td>
</tr>
<tr>
<td>RW-3</td>
</tr>
<tr>
<td>RW-4</td>
</tr>
<tr>
<td>totals</td>
</tr>
</tbody>
</table>

Note - wells numbered in order of drilling
solid length includes 10 ft solid section downhole + 20 top of well casing with 5 foot stick up

2.2 Well Casing
One of OEPA’s main criteria for the relief wells were that they be constructed with large (12” to 18”) well casing. This is to allow larger amounts of water to enter and to allow larger pumps to be installed if needed.

2.2.1 Casing Material
Continuous Pipe Casing
The OEPA has expressed a desire to use a continuous pipe casing and avoid telescoped casing. The well casing would normally be designed to provide adequate resistance to radial earth pressures and long term resistance to corrosion. However, for this application, the life of the well installation is likely to be governed by buckling and shearing brought about by the large downdrag forces applied to the well casing as a result of the continued settlement of the waste column. Calculations presented as an attachment, clearly demonstrate that the axial forces acting on the well casing will be substantial, and for all but the shallowest of the 4 wells, exceed the axial strength of the well casing. It is anticipated that, ultimately, the well casings, if installed in areas experiencing settlement, will exhibit buckling and shearing behavior that may impact access and function (this would be wholly consistent with behavior observed at other sites that have installed deep wells in waste without inclusion of telescoping casings).
Galvanized steel well casing/screen is considered the most realistic material to be used for this application.

**Telescoped Pipe Casing**
Telescoped pipe casing would allow vertical settlement to shorten the casing string without buckling or shearing. This could extend the life of the well and allow the controlling factor on the lifespan to be the corrosion of the casing material. Using galvanized steel, telescoped casing would be achieved by inserting a 12 foot telescopic joint between every other 20 foot well casing unit. The approach would vary depending on which type of screen is used. For the structural tube casing as joints would be made with 14 in diameter XS pipe and be on the exterior. For the louvered screen, joints would be fabricated to fit inside the screen. Shear pin connections with high temperature O-Rings would be utilized to result joints that would withstand the stresses associated with placement but allow movement once the well construction was complete.

### 2.2.2 Screen Type and Thickness
The well screen used must resist sliding of the sand pack materials across the screen without damage. This will result from the large amount of differential settlement that will occur between portions of the well casing and the surrounding sand pack materials as the waste settles but the steel casing remains relatively stationary. As such, wire wound or screen type well screens are not appropriate for use. Slotted screen or vertical louvered type screens are considered most resistant to this sliding action. Calculation of the downdrag forces show that vertical louvered casing of 0.25 inch thickness and 12.75" diameter are generally equivalent to the structural performance of 0.375" wall thickness 12 inch structural tubing with a four horizontal slot pattern. Both type screens are currently being considered for use. Both are available within a 30 delivery period. The decision on which to use will be made based on price and availability as both are considered acceptable.

### 2.2.3 Screen Opening Size
The waste material varies in size from fine soils to larger pieces of debris. Gradation testing of the waste for establishing filter criteria was considered, but Countywide has had success using an Ohio Dot #9 stone designation for drainage systems located within the waste mass. A gradation curve for this material is attached. This material has the advantage of being heavy enough to be able to be placed around the well through standing water without significant segregation as long as the rate of placement relatively constant. The use of sands or finer aggregate materials would require pumping through a pipe to achieve placement to the depths of 190 feet through dirty water. Alternatively, a 3/16 x #10 (4.8 to 2.0 mm) mesh filter gravel available from CEI of Circleville Ohio could be used to provide a finer grained pack than the #9 stone. Using either of these materials a 0.1"(2.5 mm) wide slot opening will provide sufficient open area and prevent filter pack loss (see the attached calculations) while letting in fines that may intrude and clog the filter pack. The minimum open area would occur if the slotted structural tube is utilized. Under the proposed configuration shown in Figure D1, the open area would be approximately 7.2 sq inches per foot. Using the general rule of thumb of keeping well approach velocities to under 1 ft/sec, only 3.21 in² of opening is required to accept 10 gpm in a foot of well screen. This is less than 50% of that provided by the least open of
the screen types used and underscores the lack of need for such a large diameter well casing for the anticipated flows. However, the orders state that the wells will be 12 to 18 inches in diameter (item 1G of the 12/31/07 F&O).

2.3 Drilling of Borehole
Gas extraction wells at the site have been drilled using a large diameter (36") bucket auger. Typically, these rigs are limited to about 125 feet maximum depth. Within the reaction zone at Countywide, however, the bucket auger has not been able to advance more than about 80-100 feet.

Countywide has had success advancing deeper borings (for inclinometer installation) using the rotosonic technique. However, this technique is effectively limited to a maximum boring diameter of 8 inches at the depths required.

Therefore, new drilling techniques had to be investigated for the installation of the proposed Relief Wells. Any technique used needs to be able to accommodate the unique situation that internal temperatures within the reaction area exceed the boiling point of water (212 deg. F). Hours of discussion with drillers have led to the conclusion that, while any drilling technique used for the Relief Wells will be experimental, there are a couple of potentially-successful methods. The difficulty of advancing the boreholes and installing the well casings can not be overstated. The drilling technique may have to be modified in the field to accommodate conditions.

1. Wells to be drilled to allow 12 inch diameter well screen to be installed in up to four locations, varying in depth from a minimum of 110 ft to 200 ft. The wells will be installed in solid waste. The solid waste varies from typical municipal solid waste at temperatures of 140ºF that is moist and compact to waste that has been heated to temperatures of up to 250ºF or slightly higher and is relatively dry and in which the organic matter (wood and paper) has been converted to a charcoal like material. The nominal outer diameter of the bore hole is to be approximately 18".

2. The wells are to be drilled with water as a circulating fluid. Water may, if left uncirculated in the hole, be warmed to over the boiling point, creating the potential for steam flash of the fluid. To prevent this, the driller will be required to continue to circulate fluid or insert a heat exchanging tube that maintains the drilling fluid temperature safely below the boiling point. This may require the running of circulation pumps through the night. Drilling continuously will also be considered as a way of maintaining temperature control.

3. As an alternate to drilling with water the owner will consider use of mineral oil or other drilling fluid with ability to remain stable at temperatures over 270ºF. In the event that oils are used for the drilling fluid, no backflow prevention devices will be required.

4. The drilling is to occur with either reverse circulation dual walled drilling or rotary drilling with a temporary surface casing that extends to a depth of at least 60 feet. The temporary casing or outer casing is to sealable against the drill rods and the atmosphere to allow full isolation of the drill hole from the atmosphere. The drill string be equipped with blow out prevention devices that preclude the possibility of steam or pressurized liquid from coming back up the drill rods when the rods are broken to add or subtract segments. The temporary casing must have a diverter to send re-circulated or
regurgitated fluid and or steam to a contained drilling fluid tank. The driller is to supply the tank.

5. Once the hole has reached the target depth the drill fluid shall continue to be circulated to remove solids to a reasonable degree. The driller shall install the 12 inch diameter well casing, (made of slotted steel tubing or stainless steel) to the desired depth while continuing to circulate fluid to the degree needed to maintain temperature control. (Monitoring of the fluid temperature at depth with thermocouples will be performed). It is envisioned that a string of pipe will be used for this as the well casing is installed (assuming a 2" to 3" diameter pipe).

6. Once the well casing is in place, a closed loop of pipe will be required within the well casing to continue to have temperature control. Circulation within this pipe will be performed to control fluid temperature during sand packing, without the creating upflow currents in the borehole.

7. Sand pack of coarse sand, supplied by the owner, will be placed to within 15 feet of the ground surface. A bentonite chip seal will be installed for the remainder of the boring.

8. Drill casings are likely to be supplied by the owner. This will be determined prior to final contractual arrangements.

9. The driller should be aware that the landfill emits odorous gasses that are also potentially explosive. Positive measures to prevent gas from accumulating around the well head. Drillers will be required to be OSHA trained and respirator fitted, supplied air may be required.

10. The landfill owner will assist in disposal of cuttings, spend drill fluids etc. The management of these items adjacent to the rig will be the drillers' responsibility. Materials are to be filtered out of the drilling fluid and placed in roll off containers provided by the owner. The owner will take these materials to the on site solidification facility for solidification and will then dispose of them at the active face.

2.4 Well Casing Installation

2.4.1 Solid Casing Section
As was discussed during preliminary conversations with OEPA, it is likely that liquid will enter the well at the upper levels (upper 70 feet) of the landfill and virtually not at all in the deeper warmer zones of the landfill penetrated by the well. Based on experiences at INC-4 and INC-6, it is likely that the rate of inflow into the well may be sufficiently low as to result in water being warmed to over the boiling point in the base of the well. This will result in problems pumping and may create unstable conditions within the well. It is proposed that at least one 10 ft long solid section of well casing (unslotted or unlouvered) will be inserted in well string at a depth of 60 to 80 feet below grade or at the top of the waste layer that exhibits evidence of likely having been pyrolyzed by being heated to above the boiling point (heavy char like appearance). The area outside of the solid casing will be backfilled with a either a weak cement/bentonite grout or bentonite chip backfill. This will allow dividing the well into two distinct regions using a packer and pass through pipe, should such division prove to advantageous.

2.4.2 Surface Seal
At the surface, the upper 20 feet of the well casing will be solid to allow a surface seal to be generated, using 15 foot bentonite chip backfill.
2.4.4 Well Head
The casing will extend approximately 3 feet above grade and terminate in flange type fitting on which the mountings for the pump and discharge pipe will be fabricated. The fabrications for the pump will be set up to allow extraction of the pump through diverter. Gas Collection fittings will be connected to the flange. Electrical cables for instrumentation will pass through separate wall type seals on the side of the exposed casing.

2.5 Instrumentation
The well casing will be instrumented on the exterior at 20 foot centers using K type thermocouples screw mounted onto the casing with self tapping screws. Since the casings are heat conductive and flow will be allowed through the sand pack, the temperatures measured with represent averaged values in situ. Closer spaced measurements do not appear warranted. Thermocouples will have underground type connectors to Teflon coated wire. The wires will be passed to the surface in same abrasion resistant fabric envelopes as used for the thermistors and piezometers.

A single vibrating wire piezometer will be affixed to the pump to allow head measurements to be obtained without opening the well. The piezometer will be a non vented stainless steel unit with a pressure range of 350 kPa. The piezometer will have an operating temperature range of 0 to 300°F and also measures temperature. The piezometer has a sensitivity of .03 ft of water with an accuracy of 0.12 ft of water. The well head will have a port to measure gas pressure.
3.0 RELIEF WELL PUMP PROVISIONS

3.1 Flow Rates
The typical flow rate in landfill wells is less than 2 gpm and normally 1 gpm or less. Increasing the depth and diameter of the wells over those of typical gas wells is not likely to result in flow rates beyond those typical values, given that the permeability of waste decreases substantially with depth. Reinhart and Townsend have reported values of permeability of approximately $1 \times 10^{-6}$ cm/sec at depths of 30 meters in landfills in Florida. Therefore, pumping capacity of 4 to 5 gpm is felt to be sufficient for the installations.

3.2 Pump Selection
The pump utilized in these wells needs to be able to pump liquid at temperatures up to 230ºF and be able to withstand ambient, non pumping temperatures of up to 260ºF. Static head levels will be up to 200 ft and dynamic head losses will be associated with pumping rates of less than 10 gpm. With a 1.5 “ diameter discharge pipe with reciprocating rod inside the approximate head losses can be calculated to be similar to a 1.4” diameter pipe. A total head (TDH) of 208 feet is associated with a pumping rate of 10 gpm for a well 200 feet deep. Blackhawk reciprocating deep well pumps capable of withstanding 300ºF temperatures, type DTO3 with stainless steel screen fittings is selected. Information on this pump is attached. This pump is capable of pumping 10 gpm at up to 320 TDH.

3.3 Well Pumping
As previously discussed, conditions within the reacting zone at Countywide have proven that pumping may not be possible. Even small amounts of water entering from upper zones and falling into zones that are warmer than the boiling point of water can create unstable, conditions where steam is produced and is ejected to the top of the well on a periodic basis. This phenomenon has been observed and described as “spitting.” While not indicative of high internal gas pressures or water pressures adjacent to the well, the production of steam can cause high pressures and unstable conditions within the well. This may render physical pumping impossible and mean that the best method for removing liquid from the well may be to remove the pump and reconfigure the well head to allow diversion and routing of ejected liquid.
4.0 HEALTH AND SAFETY PROVISIONS
Prior to commencing work, the drilling contractor will be required to submit a Health and Safety Plan that addresses the normal hazards of drilling with the selected equipment, as well as the normal hazards that exist when drilling through waste and the special hazards that exist in the reacting areas within the 88-acre area at Countywide. At a minimum, the Health and Safety Plan will include provisions for safety and protection of drilling personnel including:

1. Drilling personnel must have 40-hour OSHA Hazwoper training
2. Drilling personnel must be fit-tested and certified capable of working in supplied air should it become necessary.
3. Drilling personnel to be equipped with 4-gas meters (carbon monoxide, methane, hydrogen sulfide, and oxygen) with audible alarms
4. Drilling personnel must be protected, by a fabricated physical diversion, from potential hot liquid, gas or steam which may express from the borehole
5. Drilling personnel will wear Level D PPE at all times including:
   a. ANSI approved hard hat with removable full-face shield
   b. High-visibility reflective vest
   c. Full-length pants
   d. Steel-toed boots, and
   e. Safety glasses
   f. Hearing protection
   g. Leather gloves unless conditions saturate the gloves, in which case nitrile or other impermeable non-slip gloves shall be used
6. Welding will not be permitted if explosive gas is present at the welding site above 25% LEL
7. A readily-accessible 2A and 5BC fire extinguisher shall be available.

In addition, the Plan must define an “exclusion zone” within which observers may not enter unless specifically allowed by the drilling crew chief, and must establish a procedure for keeping observers outside the a drop zone when casing or drill rod is being put in or pulled from the boring.
# 5.0 SCHEDULE

The proposed schedule for this work is outlined below:

<table>
<thead>
<tr>
<th>Item</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribute Request for Proposals from 3 Drillers</td>
<td>Jan. 9</td>
</tr>
<tr>
<td>Receive Proposals from Drillers</td>
<td>Jan. 14</td>
</tr>
<tr>
<td>Order Well Casing Materials</td>
<td>Jan. 15</td>
</tr>
<tr>
<td>Order Pumps</td>
<td>Jan. 15</td>
</tr>
<tr>
<td>Select Driller*</td>
<td>Jan. 18</td>
</tr>
<tr>
<td>Mobilize Driller</td>
<td>Feb. 4</td>
</tr>
<tr>
<td>Complete Installation of RW-1 and RW-2</td>
<td>Feb. 29</td>
</tr>
<tr>
<td>Complete Installation of RW-3 and RW-4</td>
<td>Mar. 25</td>
</tr>
</tbody>
</table>

* Driller will be selected after evaluating proposals and interviewing candidates. Selection will be based on understanding of project and challenges, adaptability of drilling technique, management commitment, and availability.

If installation and start-up operation of RW-1 and RW-2 do not meet the performance objectives outlined in the Orders, then Countywide and the OEPA will confer regarding whether or not RW-3 and RW-4 should be installed.
OBJECT

determine the stresses and structural requirements for well casings

The stresses acting on the drill casing will include those in the plane of the well casing radii as well as those in the axial direction. The major issue in the design is the ability of the well casings to withstand the axial forces generated by downdrag. The axial forces can be estimated assuming the full generation of negative skin friction and a lateral earth pressure coefficient. Calculation of the vertical loading to the pipe segment is presented below.

Input Parameters

- Waste density, assume a uniform total unit weight: $\gamma_s = 65 \frac{\text{lb}}{\text{ft}^3}$
- Skin friction coefficient between well casing and backfill, given the roughness of the well casing surface a friction angle equal to the friction angle of the sand pack is appropriate, $\delta_f = 32^\circ$.
- Lateral earth pressure coefficient, for the zone directly adjacent the well casing backfill, the stiffness of the casing and the stiffness of the waste. Downdrag studies in waste masses performed in instrumentation of telescoping risers by Dany et al suggested an equivalent hydrostatic loading of 34.5 pcf for lateral pressure determination or a $k_{Dany} = \frac{34.5 \text{pcf}}{65 \text{pcf}} = 0.531$. $A_k = 0.5$ will be used for this project.

The diameter of the well casing is $D = 12 \text{in}$

The design depth of the units are provided in the matrix below:

\[
\begin{bmatrix}
109 \\
178 \\
193 \\
197 \\
\end{bmatrix} \text{ft}
\]

The axial force, $F_{zi} := \int_0^{d_i} D \cdot \pi \cdot \tan(\delta_f) \cdot \gamma_s \cdot k \cdot z \, dz$

\[
F_Z = \begin{bmatrix}
3.79 \times 10^5 \\
1.011 \times 10^6 \\
1.188 \times 10^6 \\
1.238 \times 10^6 \\
\end{bmatrix} \text{lb}
\]
the axial compressive stress \( \sigma_a(t) := \frac{F_z}{t \cdot \pi \cdot D} \)

if a 0.25in wall casing is used

\[
\sigma_a(.25in) = \left[ \begin{array}{c}
40213.728 \\
107241.12 \\
126077.025 \\
131357.171 \\
\end{array} \right] \text{ psi if no material is removed from the wall in the form of slots}
\]

it can be seen that these are all quite in excess of the yield strength of regular steel without any regard for local buckling or hoop stress acting on the section that will further reduce the allowable stress. This represents the use of Doerr type screen.

if slotted 3/8 wall structural tube is used with slots, the material removed for the slots must be included in the calculation. A four slot pattern, such as shown in Figure 1 would remove approximately 28 deg for each slot or a total of

\[
\frac{28.4}{360} = 0.311 \text{ of the wall}
\]

therefore the axial stress becomes

\[
\sigma_a(t) := \frac{F_z}{t \cdot \pi \cdot D \cdot .69}
\]

if a 3/8in wall casing is used

\[
\sigma_a(.375in) = \left[ \begin{array}{c}
38853.843 \\
103614.608 \\
121813.551 \\
126915.141 \\
\end{array} \right] \text{ psi still far in excess of the strength of either 36 or 50 ksi steel}
\]

increasing the steel thickness to 1/2 inch does not change the outcome, except for the shallowest well.

\[
\sigma_a(.5in) = \left[ \begin{array}{c}
29140.382 \\
77710.956 \\
91360.163 \\
95186.356 \\
\end{array} \right] \text{ psi still far in excess of the strength of either 36 or 50 ksi steel for most of the wells - even if no slots were made}
\]

Conclusion

The well casing cannot be designed to resist axial failure without telescoping joints. It should be assumed the wells will eventually become impassible.
OBJECT  Determine open area and entrance velocities for slotted screen, and TDH calcs

The slot pattern is 4, 3" long by .1 inch thick slots on two inch centers

\[ A_{\text{open}} := 4 \cdot (3 \text{in} \cdot 0.1 \text{in}) \frac{6}{\text{ft}} = 7.2 \text{in}^2 \text{ft} \]

The anticipated flow rates into the well are less than 10 gpm, and more likely 1 gpm, assuming 1 foot of well screen is exposed to water and the entrance velocity is kept to 1 ft/sec, the required \( A_o \) needed is

\[ A_o := \frac{10 \text{gpm}}{1 \text{ft/sec}} \frac{1}{1.0 \text{ft}} = 3.208 \text{in}^2 \text{ft} \] of open area

Therefore the slotting pattern is more than adequate.

\[ \begin{align*}
A_{\text{rod}} := & \left( \frac{7}{16} \left(\frac{\text{in}}{2}\right) \right)^2 \pi & A_{\text{pipe}} := & \left( \frac{1.5 \text{in}}{2} \right)^2 \pi & A_{\text{pipe}} - A_{\text{rod}} = & 1.617 \text{in}^2 \\
D_{eq} := & \left( \frac{A_{\text{pipe}} - A_{\text{rod}}}{\pi} \right) \frac{1}{2} & & = 1.435 \text{in} \\
\text{hydraulic radius increase} := & \frac{1.5 + \frac{3}{16}}{\pi \cdot 1.5} & & = 1.125 \text{ so decrease the hazen coeff by 15%} \\
\text{and use a pipe diameter of 1.4} & & \text{use hazen coefficient of 85 instead of 100 for long term head loss} & \\
\text{head loss in a 1.4 inch pipe with 10 gpm for 200 feet long is 7.8 ft} & & \text{see calculation on flygt sheet} & \\
\end{align*} \]
Design pipe system

| Project: Countywide Relief Wells - Case1 | 1/6/2008 |
| Customer: | Peter J. Carey |

### Station Piping 1

| Length | 200.0 ft | Discharge conn. | 0.50 | 1 |
| Material | 90° elbow | 0.30 | 2 |
| Pressure class | Valve | 1.00 | 0 |
| Dimension | inch | Tee | 0.60 | 0 |
| C-factor | 85.000 | Check valve | 1.50 | 0 |
| Inner diam. | 1.4 inch | Outlet | 1.00 | 0 |
| Own | 0.00 | 0 |

Total: 1.10

| Water velocity | 2.1 ft /s | Loss in pipe section: | 7.8 ft |
| Total flow: | 10.0 USgpm | No of | Head losses: | 7.8 ft | Total head: | 207.8 ft |
| Static Head: | 200.0 ft | 1 | ft | ft | ft | ft |

Hazen-Williams
Specializing in Groundwater Control for over 75 Years!

Doerr bridge slot well screen and casing are made in America and delivered directly from our factory to your job site. Doerr's MAX-FLOW and GRAVEL-GUARD bridge slot well screen represents what well screen was meant to be for any soil condition.

Doerr's bridge slot well screen is more efficient than saw slotted pipe, less expensive than stainless steel wire wrapped screen and tolerates handling abuse and UV exposure significantly better than PVC pipe.

Materials: Choose from Mild Steel, Galvanized Mild Steel and Stainless Steel.

Slot Size Selection: Slot openings are available from 0.03 (.76mm) to .185 (4.7mm).

Area Opening Percentage: The filtering area openings range from 2.8% to 25% depending upon the slot size you select.

Wall Thickness: Four standard material thicknesses are available from stock (10 gauge, 7 gauge, .219 and .250 inch).

Length Selection: All well screen and casing can be manufactured in continuous lengths from 4 feet (1.2mm) to 40 feet (12.2mm) in increments of 4 feet.

Diameter Selection: All well screen and casing is available in 12 popular diameter sizes standard to the water well industry (8.625 inches/.219m to 48 inches /14.6m). For larger diameters contact customer service.

Customer Service: All well screen and casing is manufactured to your exact specifications ensuring an optimum producing water well every time and on time.

Sales Assistance: For more information regarding these products, contact us for the name of the Authorized Doerr Dealer nearest your location.

Doerr Bridge-Slot Well Screen Features

<table>
<thead>
<tr>
<th>Die Formed Slots</th>
<th>Uniform Slot Size</th>
<th>Vertical Bridge Slots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reusable</td>
<td>Sized Joints At No Cost</td>
<td>Fast Delivery</td>
</tr>
<tr>
<td>High Collapse Strength</td>
<td>Customized Options</td>
<td>Clog Resistant Design</td>
</tr>
</tbody>
</table>

G-90 Galvanized Protection on Gravel-Guard

Steel water well screen has been known to perform over 50 years under...
normal conditions. However, certain soil conditions require extra protection. The American Galvanizer's Association recommends a G-90 finish for 12 years of additional corrosion protection. This is what you get with Doerr’s G-90 Gravel-Guard Bridge-Slot Well Screen. Gravel-Guard Galvanized Well Screen will last longer than mild steel and is 75% less cost when compared to stainless steel.

What's Different About Doerr's Screen Design?
We set out to reduce the size of each opening while still producing a lot of total open area. Instead of relying on punched holes, we built a well screen with one continuous row of perforated bridge-slots encircling the circumference and running the full length of the casing screen. The carefully sized slots are much narrower than any possible punched hole, so even fine-grained sand can be kept out of the water well.

The amount of open area this bridge-slot design makes possible is remarkable. By way of comparison, a 14-inch diameter punched pipe has about 10.9 square inches of open area per lineal foot. Doerr bridge-slot well screen of the same diameter with a 0.040 wide slot has 20.8 square inches per lineal foot of well screen. This increased open area lets a lot of water enter the well very slowly. Unlike punched well screen, bridge-slot screen retains 100% of it’s steel for maximum tensile strength.

How Important Is Controlling the Open Area?
It is very important, but there are some other things to consider too. Like slot size. The exact size of the screen slot is determined by analyzing the formation samples brought up during the drilling. We want to make the slots as wide as possible without letting any gravel-pack material through.

Strength is important too. Well screen takes a lot of punishment during installation and has to resist crushing and collapse pressures which, in a deeper well can be very high.

Material also makes a difference. Where ground water is corrosive, stainless steel or galvanized steel is recommended to provide a long service life. Where water is less corrosive or when price is a consideration, low carbon mild steel is used to achieve excellent results.

Your driller can answer any questions you may have about Doerr Well Screens or you can contact us directly. We have spent more than 100 years making better screens to make better wells. We like to share what we have learned with our customers.
PARTICLE SIZE DISTRIBUTION
ASTM C 136

Number 9 stone

PROJECT NAME: REPUBLIC/CWRDF/CQA/OH
SAMPLE ID: Sample #3
TYPE: Bag

Depth: -

<table>
<thead>
<tr>
<th>Screen slot</th>
<th>.1&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size in millimeters</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>90</td>
</tr>
</tbody>
</table>

COBBLES | GRAVEL | SAND | FINES

Golder Associates Inc.
Trident Pneumatic Piston Pump
Patented Top-Head-Drive Piston Pump

Description
The Trident Pneumatic Piston Pump Model DT-03 is powered by compressed air. The control motor is located at surface grade for easy installation and maintenance. Industrial-quality air pressure is used to power the pump motor. Power to the pump is direct from grade through the sucker rod assembly. The pump removes water and product (e.g. oil, solvents, leachate) from a four (4) inch (10.16 cm) diameter well casing or greater to depths of 216 feet (65 meters). The fluid inlet is located at the bottom of the pump intake cylinder and removes water or product to 0 submergence depth.

Performance and Technical Data

<table>
<thead>
<tr>
<th>Performance</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Depth</td>
<td>Stroke Length</td>
</tr>
<tr>
<td>216'</td>
<td>12&quot; (30.48 cm)</td>
</tr>
<tr>
<td>Flow Range</td>
<td>Maximum External Diameter</td>
</tr>
<tr>
<td>0 to 16.8 US GPM / 63.6 LPM</td>
<td>3.9&quot; (9.9 cm)</td>
</tr>
<tr>
<td>24.192 US GPD / 91,584 LPD</td>
<td></td>
</tr>
<tr>
<td>Discharge per Stroke</td>
<td>Total Cylinder Length</td>
</tr>
<tr>
<td>.28 US Gallons per stroke</td>
<td>30&quot; (76.2 cm)</td>
</tr>
<tr>
<td>Note: flow does not vary with depth</td>
<td></td>
</tr>
<tr>
<td>Maximum Discharge Pressure</td>
<td>Connection of Riser Pipe</td>
</tr>
<tr>
<td>216 feet of water or 93 psig</td>
<td>3&quot; (7.62 cm)</td>
</tr>
<tr>
<td>(operating discharge pressure based on 120 psi air supply)</td>
<td></td>
</tr>
<tr>
<td>Maximum Lift</td>
<td>Connection to Sucker Rod</td>
</tr>
<tr>
<td>216 feet of water</td>
<td>7/16&quot; - 20</td>
</tr>
<tr>
<td>Maximum Strokes per Minute</td>
<td>Recommended Internal Diameter of Bore Hole</td>
</tr>
<tr>
<td>60 (Variable speed (stroke) control adjusts to well conditions; liquid drawn down to top of strainer)</td>
<td>4-5&quot; (10.16 cm - 12.7 cm)</td>
</tr>
<tr>
<td>or greater diameter</td>
<td></td>
</tr>
<tr>
<td>Weight of Cylinder</td>
<td>Discharge Size</td>
</tr>
<tr>
<td>12 lbs. (5.44 kg)</td>
<td>3&quot; NPT</td>
</tr>
<tr>
<td>Installation</td>
<td>Unit can be installed vertically or horizontally</td>
</tr>
<tr>
<td>Driver Weight</td>
<td>Driver Rod Weight</td>
</tr>
<tr>
<td>8 lbs.</td>
<td>12 lbs./100'</td>
</tr>
<tr>
<td>Foot Valve Assembly Weight</td>
<td>Minimum Well Casing Size</td>
</tr>
<tr>
<td>20 lbs.</td>
<td>4&quot;</td>
</tr>
<tr>
<td>Pneumatic Air Connection</td>
<td>3/8&quot; NPT 3/8&quot; OD Tubing</td>
</tr>
</tbody>
</table>

Model DT-03

Flow Range
0-16.8 US GPM
63.6 LPM

Operational Depth
216 Ft.
65 M

Well Casing Size
Minimum 4 in.
10.16 CM
Trident Pneumatic Piston Pump®

Model DT-03

Materials of Construction:
(Materials of construction can be modified to meet specific applications)

Above Ground
Drive Motor                  Stainless Steel/Aluminum
Stuffing Box Seal           Nitrile/Viton
Stuffing Box                Delrin®
Discharge Tee               Stainless Steel
Well Head                   PVC/ABS

Downhole
Drive Rod                   Fiberglass
Drive Rod Connector         Stainless Steel
Drive Piston Seal           Nitrile/Viton
Drive Piston Check Ball     Stainless Steel
Drive Piston                Delrin®
Piston Cylinder             Stainless Steel/PVC
Foot Valve Check Ball       Stainless Steel
Foot Valve                  Delrin® with Stainless Seat
Intake Screen               Stainless Steel/PVC

Dimensions (in inches)
A  Above Well Height        30.25"
B  Driver Height            23.5"
C  Discharge Tee &          6.75"  Well Seal Height
D  Driver Diameter          8"
E  Foot Valve Assembly      35"
F  Foot Valve Length        30"
G  Intake Screen Length     5"
H  Downhole Diameter        3.9"

Trident DT-03 Pneumatic Motor Air Pressure Requirements

Trident DT-03 Pneumatic Motor Pump Flow Performance