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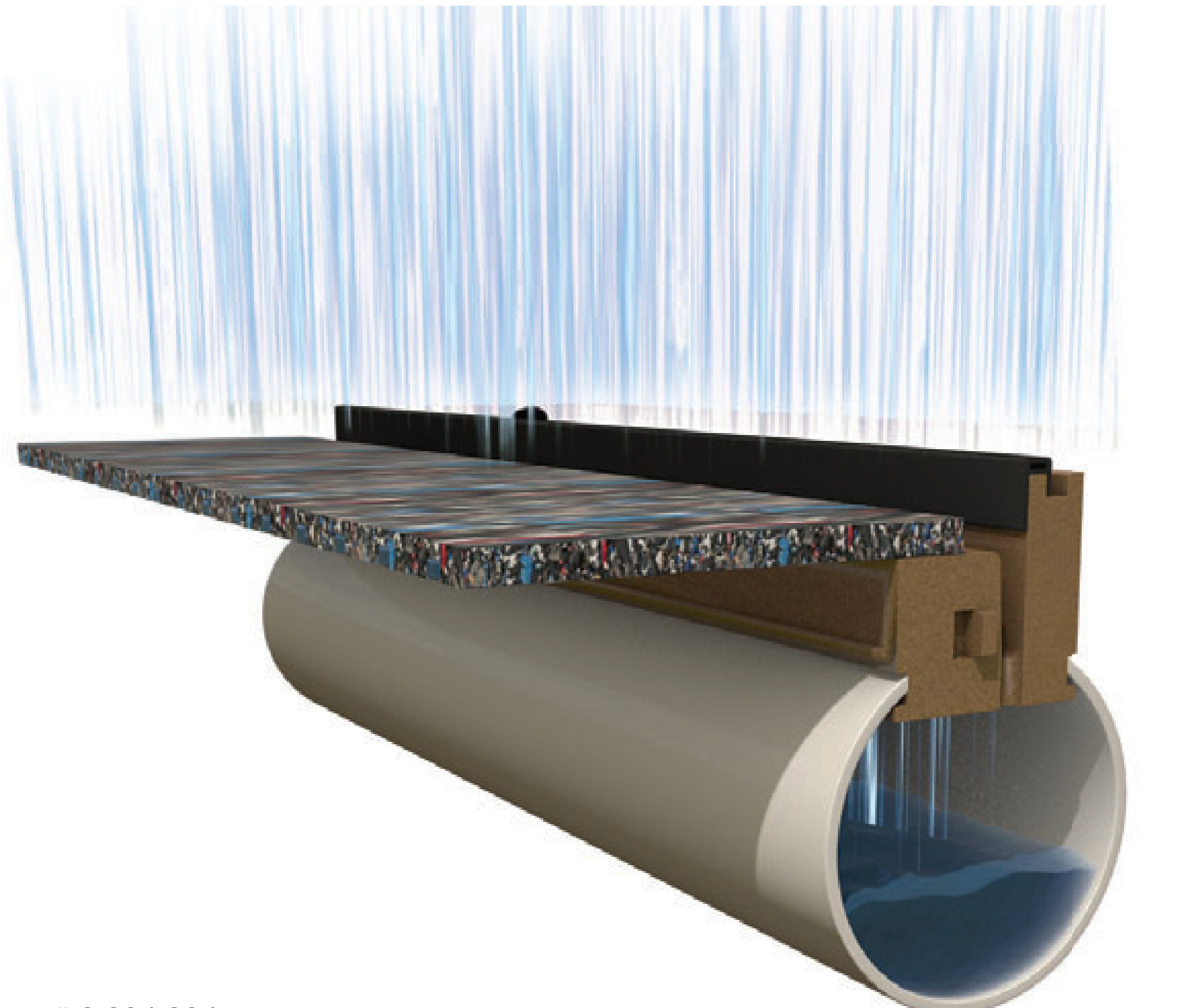

U.S. Patent # 8,894,324

# TERMINATOR™
## TECHNICAL MANUAL

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# COMPONENT PROPERTIES

The **XT-8 Collector** is manufactured from polymer concrete, which is a blend of polyester thermoset resin and select quartz aggregates. It is delivered assembled to an 8-inch PVC foam core pipe. PVC couplers are provided for every 1-meter joint. The Protective Cap is resilient, durable and UV resistant for years of service. Rope Turf Wedge is a non-biodegradable nylon and installation hardware is delivered with the Terminator.

### *fig. 2a* - XT-8 COLLECTOR

| MATERIAL | COMPONENT | FEATURES | STANDARD | SPECIFICATIONS |
|---|---|---|---|---|
| Polymer Concrete | XT-8 Collector | Separate drain orifices for track and turf, ADA compliant, 1 meter long, 8" ID pipe | ASTM C 579<br>ASTM C 307<br>ASTM C 580<br>ASTM C 140 | 17,000 psi Compressive, 4,500 Tensile, 2,000 Bending strengths |
| | 90° Corner Piece | 90°, reversible L & R | | |
| | D-Area Adapter | Fits XT-4, reversible L & R | | |
| | Catch basin | Offset mount, single or double stage, 8" pre-formed outlet cutout | | |
| Polyvinyl Chloride (PVC) | Pipe | Large capacity, self cleaning, roughness coefficient = 0.10 | ASTM D2466 - 13 | Schedule 40, 8.0" ID, 8.5"OD |
| Nylon Rope | Turf Wedge | Easily removed for turf replacement or repair | ASTM D2256 / D2256M | 5/8" dia., non-biodegradable nylon |
| Thermoplastic Elastomer (TEP) | Protective Cap | 3 M (9.84 FT) lengths, fits either side of track slot | ASTM D2240 | 60 Durometer, 3/8" high |
| Zinc plated steel hardware | Intallation kit | 8" x 3/8" eye bolt, washer & nut | ASTM B633 - 13 | |

### *fig. 2b* - PROPLAY 23D PAD

| PROPERTY | TYPICAL VALUE | UNIT | STANDARD |
|---|---|---|---|
| Thickness | 23(0.91) | mm(in) | EN 1969 |
| Density | 11.86 | lbs/ft³ | |
| Format | | | Die-cut, interlocking puzzle piece panels |
| Dimensions | 88.58 x 35.43 | in | Tolerance of +-5mm |
| Weight | 18.08 | lbs/panel | |
| Tensile strength | 260(38) | kPa(psi) | EN 12230 |
| Compressive strength<br>at 25%<br>at 50%<br>at 75% | <br>27<br>83<br>424 | psi | ASTM D 3575 |
| Dynamic load test | 28 | % | EN ISO 3386-1 |
| Static load test | 26 | % | |
| Resistance to accelerated aging | Pass | | EN12224 |
| Expected lifetime | >100 yrs | | ISO/TR 13434 |
| Resistance to chemicals & bacteria | Pass | | ASTMF925<br>ASTM G22-76 |
| Stability after aging | 0.3 | % | EN 13744 + EN 13817 |
| Thermal expansion | 0.17 | mm/m | ISO 4897 |
| Thermal conductivity | 0.05 | W/m.K | EN 12667 |

**ProPlay 23D Shock & Drainage Pad** is manufactured of a precise blend of recycled, post-industrial polyethylene flakes that are thermally bonded. The recycled polyethylene (PEX) is a closed-cell (non-absorbent) and cross-linked (physically stable) product. The sheets are bonded to a PET geotextile for stability and which also serves as a filtration fabric. Panels are an interlocking puzzle-piece design that provides dimensional stability and ease of installation. Drainage channels are sized and spaced to provide maximum lateral drainage…the best in the industry.

# SPORTS PERFORMANCE PROPERTIES - PROPLAY 23D

A series of sports performance tests were run with ProPlay 23D under three different pile heights of carpet, each with two different sand/rubber ratios. These six combinations represent common systems used in the US today. Random brands of synthetic turf and fibers were used. Past tests have shown that brand does not have a significant impact on results. Results can be influenced by and may vary due to installation technique and sieve size of sand and SBR particles.

G-Max impact attenuation, HIC heights and three components of the Advanced Artificial Athlete, shock absorption, energy restitution and vertical deformation, were tested. Results fell within the guidelines of The Synthetic Turf Council and FIFA 1 & 2-Star. For reference, control tests were run on the systems using no pad.

### *fig. 3a* - SPORT PERFORMANCE TEST RESULTS - PROPLAY 23D

| | | SBR/SAND WEIGHT RATIO 30/70 | | | | | SBR/SAND WEIGHT RATIO 50/50 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pile height | Infill depth | G-Max | HIC | SA* | VD* | ER* | G-Max | HIC | SA | VD | ER |
| 1 ⅝" | ⅞" | 98 | 1.39 | 65 | 9.4 | 39 | 94 | 1.28 | 67 | 10.2 | 39 |
| 2" | 1¼" | 92 | 1.48 | 64 | 9.7 | 38 | 87 | 1.63 | 68 | 10.6 | 38 |
| 2 ¼" | 1 ½" | 84 | 1.62 | 67 | 10.4 | 39 | 81 | 1.66 | 70 | 11.5 | 38 |

**Performance Guidelines**

| | Community Fields | Stadium Fields | Authority |
|---|---|---|---|
| G-max | <165 | <165 | STC |
| Head Injury Criterea (HIC) | >1.3 m | >1.3 m | FIFA |
| Shock Absorption | 55-70% | 60-70% | FIFA |
| Energy Restitution | 30-50% | 30-50% | IRB |
| Vertical Deformation | 4-11 mm | 4-10 mm | FIFA |

### *fig. 3b* - CONTROL TEST RESULTS - NO PAD

| | | SBR/SAND WEIGHT RATIO 30/70 | | | | | SBR/SAND WEIGHT RATIO 50/50 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pile height | Infill depth | G-Max | HIC | SA* | VD* | ER* | G-Max | HIC | SA | VD | ER |
| 1 ⅝" | ⅞" | 241 | 0.66 | 38 | 4.9 | 50 | 202 | 0.74 | 46 | 6.1 | 47 |
| 2" | 1¼" | 189 | 0.87 | 46 | 6 | 44 | 157 | 1.00 | 55 | 7.4 | 41 |
| 2 ¼" | 1 ½" | 169 | 0.92 | 54 | 7.2 | 39 | 127 | 1.02 | 59 | 8.5 | 40 |

## DEFINITIONS

**G-Max** – The maximum negative acceleration on impact or the measure of how much force the surface absorbs and how much is returned to the athlete. Higher G-Max = less absorption.

**HIC (Head Injury Criteria)** – The measure of the likelihood of injury arising from an impact, stated as "fall height". It is an integration of the peak deceleration (G-Max) with respect to time. This is because a lower peak deceleration experienced for a longer period of time can be as dangerous as a higher force experienced for a shorter period of time. At an HIC of 1000, statistical risk of death from brain trauma is greater than zero.

***SA - Shock Absorption** – The dissipation of kinetic energy (the primary element of G-Max measurements).

***ER - Energy Restitution** – The proportion of kinetic energy retained by two objects before and after collision. This coefficient measures bounciness. If the coefficient is close to one hundred, then the collision is elastic and bouncy, if it is close to zero then collision is more plastic.

***VD - Vertical Deformation** - Vertical deformation indicates the ability of a surface to deform under load. High deformation can affect the safety of the athlete, causing instability of the foot, while low deformation may cause injuries as a result of immediate impact force.

# TERMINATOR DRAINAGE TESTING PROTOCOL

Because ASTM D4716, "Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head" cannot adequately describe and evaluate the performance of a geosynthetic within an infill turf system, a unique and custom test method was developed. The purpose of this test was to evaluate the performance of all components of a closed synthetic turf sport field using a resilient drainage pad underlayment and the XT-8 outlet orifice. Tests were performed in September 2013 and June 2014 at the Hydraulics Lab, North Carolina State University School of Engineering, Raleigh, NC.

The test method evaluated quantitative and qualitative characteristics including outlet flow, flow depth, pad hydraulic performance and buoyancy effects. It was configured to evaluate a single XT-8 outlet weir and a four foot width of resilient drainage pad. Interpolations from these values take into account that there are 3.66 outlets per linear foot of XT-8 Collector and 4.0 feet of pad in the test apparatus.

The test apparatus consisted of a flume that measured drainage performance in as close to "real world" conditions as practical.

fig. 4a

The 4' wide by 8' long test apparatus consisted of a confined wooden deck. A full width weir was constructed at both 4 foot ends of the deck. The weir at the inflow end settles flow and decreases frictional losses while maintaining a level uniform flow condition over the full width. The weir at the outflow end provides a basin for overflow. The XT-8 Collector orifice outlet was mounted in the middle of the deck at the lower end of the platform and placed flush with the plywood deck. The deck and weir structure was set at a 0.5% slope toward the drainage orifices. The ProPlay 23D Pad, synthetic turf and infill (50/50 sand/rubber) were then assembled in the fixture.

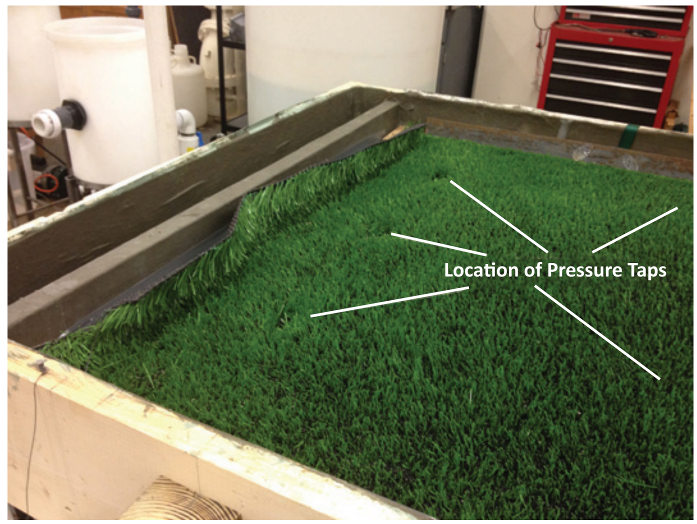



fig. 4b

Flow was measured at the influent side using an orifice plate meter (fig. 4a). Water levels at the top, center & outlet were measured by five piezometer taps and pressure cells mounted into the platform (fig 4b). The depth (head) of water at the piezometer taps was used to develop a plot of flow vs. depth above the orifice over a prescribed range of inflow amounts. Data collected: inflow at multiple flow rates, depth of water at orifice, observed flow conditions. The full series of tests was run three times each, ranging from a low flow condition to the point at which water overtopped the outflow weir. Each interval was allowed to stabilize in the test platform before recording final depths at the taps. The extent of ponding and system flotation was observed and noted for each interval. (Complete test results available on request)

# INTERCEPT CAPACITY AND BUOUYANCY

### *fig. 5a* -TERMINATOR SYSTEM DEPTH VS. FLOW

| WATER DEPTH mm(in) above liner | FLOW CAPACITY gpm/lf | FLOW CAPACITY 800 LF OF TERMINATOR cfs | PONDING OBSERVED | FLOTATION OBSERVED |
|---|---|---|---|---|
| 1.0 (.04) | 1.4 | 2.5 | N | N |
| 5.0 (.20) | 6.0 | 10.7 | N | N |
| 10.0 (.39) | 11.2 | 20.0 | N | N |
| 15.0 (.59) | 16.0 | 28.5 | N | N |
| 20.0 (.79) | 20.3 | 36.2 | N | N |
| 25.0 (.98) | 24.1 | 43.0 | N | N |
| 30.0 (1.18) | 27.5 | 49.0 | N | N |
| 35.0 (1.38) | 30.4 | 54.2 | N | N |
| 40.0 (1.57) | 32.8 | 58.5 | N | Y |
| 45.0 (1.77) | 34.7 | 61.8 | N | Y |

Blue rows represent water within the drainage pad. Green rows represent water levels into the turf cross section.

Based on a series of three tests at a wide range of flow rates, a trend line was developed to represent the average intercept capacity of the Terminator system. Fig. 5a, above, contains the relevant portion of that trend line. The highest depth value shown here (45mm) represents water at a depth equivalent to the full thickness of the shock/drainage pad (23mm) and approximately ⅞" (22mm) of infill material. This is equal to a flooded turf system with NO visual ponding.

The center column shows an example of the Terminator intercept capacity on a typical two acre field. By applying the Rational Method (Q=CIA) to this typical field, as in the below example, one can easily see that the depth of 45mm will never be reached.

**Assumptions:** **Runoff coefficient = .95**
**Rainfall Intensity = 8" per hour**
**Area = 2 acres**

**Therefore:** **Q = .95 x 8 x 2 = 15.2 cfs**

This value falls somewhere between 5 and 10 mm of water depth, well within the cross section of the pad. By extension, it would require a rainfall intensity of more than 19" per hour just to reach the top of the pad in this example. Even at that level, no flotation of the system was observed.

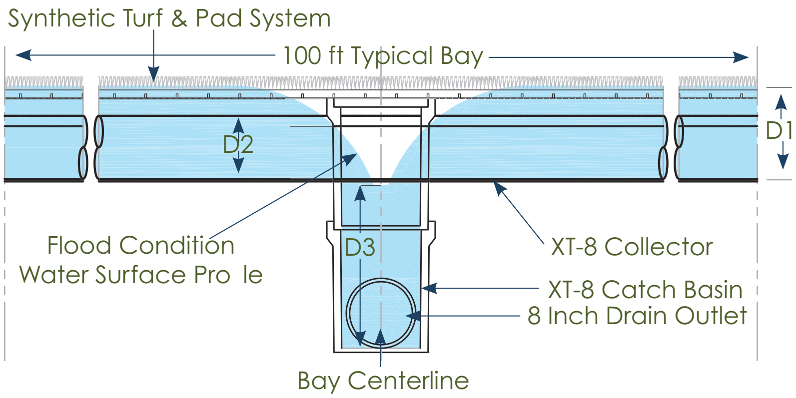
A separate test was performed to measure the amount of overburden (weight of turf and infill) required to prevent flotation at various water depths. For the test, a typical monofilament turf with a 42 oz. face weight was used with a 50/50 ratio of silica sand and SBR infill. ***Important: This is to be used only as a point of reference. Take into account the specific turf and infill combination and weight specified.***

At a water depth equal to the thickness of the pad (23.4mm), a combined turf and infill weight of 2.4 psf was required to prevent floatation (fig. 5b). This is well below most turf and infill specifications, and as seen in the Depth vs Flow chart, is equivalent to a drainage capacity of more than 36 cfs on the sample field.

### *fig. 5b* - BUOYANCY NEUTRAL POINT

| WATER DEPTH mm(in) | INFILL WEIGHT REQUIRED TO PREVENT BUOUYANCY psf |
|---|---|
| 11.4 (0.45) | 0.0 |
| 13.5 (0.53) | 0.4 |
| 16.0 (0.63) | 0.8 |
| 17.3 (0.68) | 1.2 |
| 19.6 (0.77) | 1.6 |
| 21.1 (0.83) | 2.0 |
| 23.4 (0.92) | 2.4 |
| 25.7 (1.01) | 2.8 |
| 27.9 (1.10) | 3.0 |

# INLET & DISCHARGE CAPACITIES




A HydroCAD Stormwater Modeling program was developed to evaluate a synthetic rain event applied to a stormwater drainage network comprised of the XT-8 Collector and associated catch basin. The drainage network included a two section catch basin with an 8 inch outlet supporting two equal 50 foot sections of XT-8 Collector entering from both sides. The model yielded an event that flooded the system to the theoretical elevation of a typical running track or adjacent walkway. The XT-8 was analyzed as a ponding structure with a nominally non-sloping outlet. The resulting model generated a runoff event of approximately 2.0 cfs at the catch basin outlet.

***fig. 6a* - RUNOFF & DISCHARGE CAPACITIES**

| SINGLE OUTLET | | BOTH OUTLETS | | CATCH BASIN OUTLET | |
|---|---|---|---|---|---|
| D1 (ft) | Q1 (cfs) | D2 (ft) | Q2 | D3 (ft) | Q3 (cfs) |
| 0.9 | **1.00** | 0.9 | | | |
| 0.8 | 0.86 | 0.8 | | | |
| 0.7 | 0.71 | 0.7 | **2.00** | | |
| 0.6 | 0.56 | 0.6 | 1.89 | | |
| 0.5 | 0.41 | 0.5 | 1.57 | | |
| 0.4 | 0.28 | 0.4 | 1.25 | | |
| 0.3 | 0.16 | 0.3 | 0.94 | | |
| 0.0 | 0.00 | 0.0 | 0.00 | 1.8 | **2.00** |
| | | | | 1.7 | 1.93 |
| | | | | 1.6 | 1.85 |
| | | | | 1.5 | 1.78 |
| | | | | 1.4 | 1.69 |
| | | | | 1.3 | 1.61 |
| | | | | 1.2 | 1.52 |

***fig. 6b* - TESTED FLOW RATES, PROPLAY 23D**

| PROPERTY | VALUE | UNIT | STANDARD |
|---|---|---|---|
| Water infiltration rate | >18,000(708) | mm/hr (in/hr) | EN 12616 |
| Lateral drainage (in-plane flow rate) | 0.16(0.77) | l/s/m (gpm/ft) | ASTM D 4716 |

***fig. 6c* - CALCULATED FLOW RATES, XT-8 COLLECTOR**

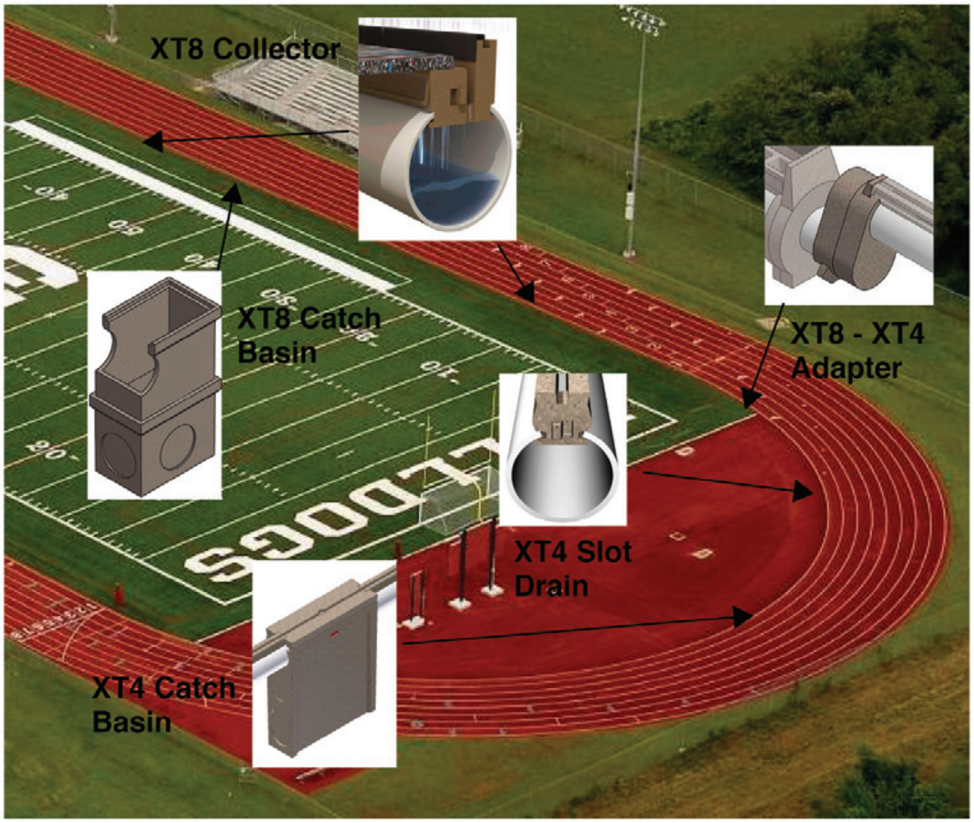
| COMPONENT | VALUE | UNIT | STANDARD |
|---|---|---|---|
| XT-8 Collector flow rate per 8" pipe | 1.0 (448) | cfs (gpm) | TR20 HydroCad |
| TERMINATOR Catch Basin discharge rate | 2.0 (897) | cfs (gpm) | TR20 HydroCad |
| TERMINATOR Track Drain Slot intercept capacity | 0.66 (3.22) | l/sec/m (gpm/ft) | Sheet Flow Calculation |
| TERMINATOR System Field Drain Slot intercept capacity | 6.79 (32.8) | l/sec/m (gpm/lft) | NCSU Hydralics Lab |

## CALCULATING REQUIRED NUMBER OF CATCH BASINS

Using local climate data and factors influencing the runoff coefficient for a given site, calculate the maximum design runoff in cubic feet per second (cfs). Each two-stage catch basin has a handling and discharge capacity of 2 cfs, so divide total runoff by 2.

**Example:**
**Design runoff = 11.8 cfs / 2 = 5.9**
**Use 6 equally spaced catch basins.**

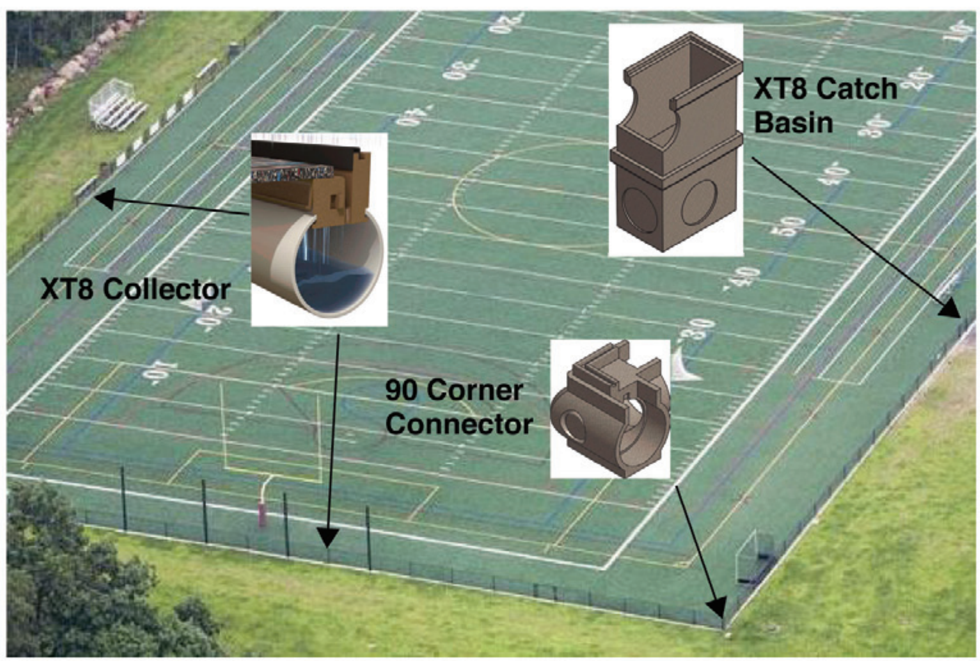
# SYSTEM DESIGN OPTIONS




Track & Field Layout

When a synthetic turf field is surrounded by a track, the Terminator XT-8 is installed along the sidelines, as the drainage and anchoring point for the turf. At the D areas, where track-to-track is installed, use the XT-4 Slot Drain for surface drainage. Adapters are provided for a smooth, continous transition from XT-8 to XT-4. If the D area is synthetic turf (not shown), the XT-8 would be installed along the perimeter.

For stand-alone synthetic turf fields, Terminator XT-8 is used for the entire perimeter to drain and anchor the turf. Pre-fabricated 90 degree corner pieces are provided for simple installation.




Stand-alone Field Layout

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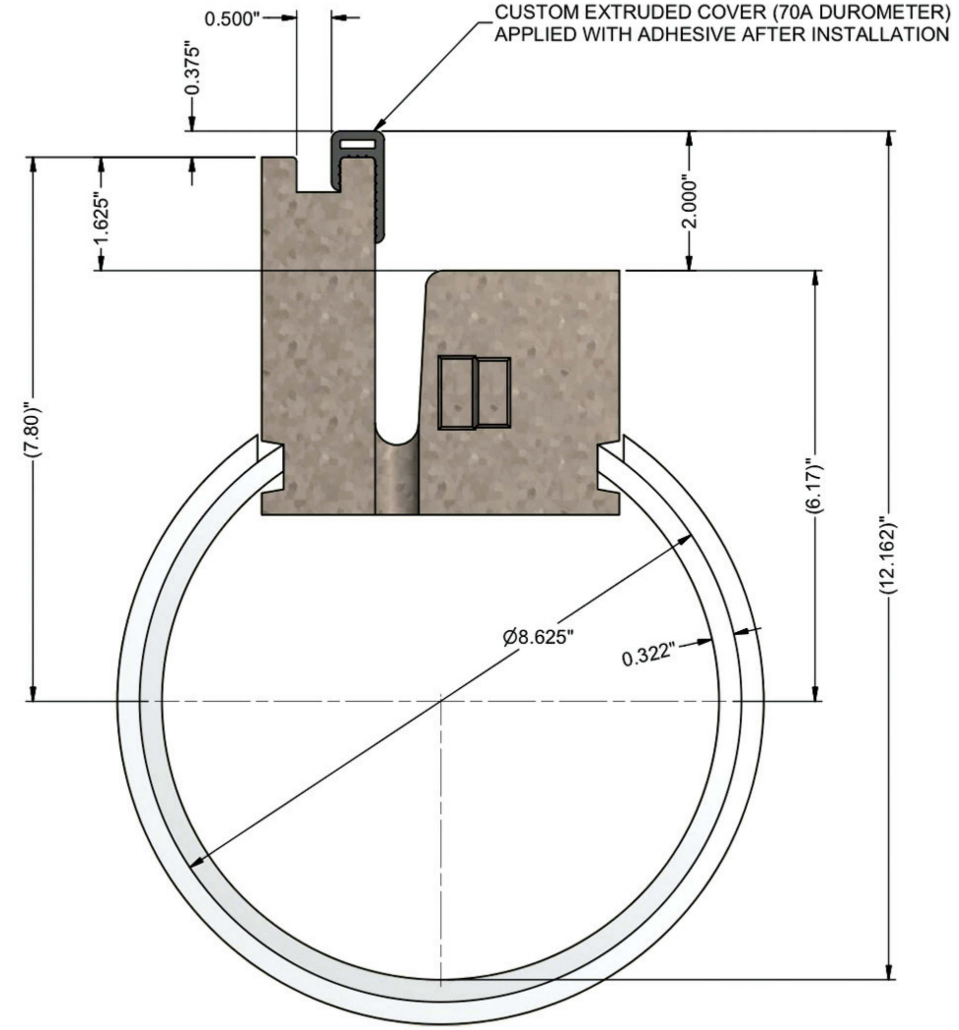


ASSEMBLY END VIEW
SCALE 1 / 2

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