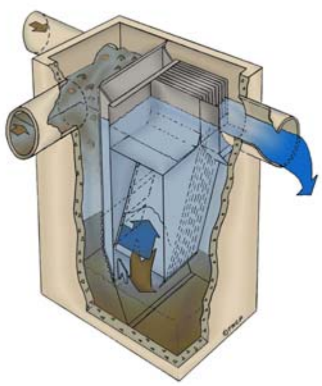
Terre Kleen™ Design Manual

Introduction to Inclined Plate Sedimentation Technology:

Inclined plate sedimentation technology has been used in the drinking water industry for 70 years.
Terre Kleen™ has adapted this technology to the stormwater industry (US Patent 6,676,832 B2).

Terre Kleen™ is an inclined plate hydrodynamic separator. The Terre Kleen™ separator is contained within a HS-25 precast concrete structure. Each stacked overlapping plate is inclined 55º, creating a settling cell containing 6.4 ft^2 of **horizontally projected sedimentation surface area** in a precast structure area of only 1.08 ft^2. This design results in the lowest cost of sedimentation surface area in the industry.



The precast concrete structure has two (2) chambers. Stormwater enters the inlet/primary chamber where oil, grease, trash and debris are floated and **permanently captured** and coarse sediment settles. The storm water exits through a screened orifice below the floatable layer and above the settled layer. The equally spaced inclined plates in the grit chamber divide the flow into equal parallel portions for treatment (Picture highlights flow arrow concept for one cell in a nine cell Terre Kleen™ TK09).

The flow enters near the bottom of the inclined plates; parallel treatment of the divided water flow occurs as it rises to the top of each plate, where the water discharges over each cell weir and recombines for discharge through the effluent pipe.
Gravity separates the sediment particles from the water flow and the sediment slides on the inclined surfaces to a collection hopper located below the plates. Baffles separate the captured sediment in the hopper from the main flow to prevent re-suspension or scour.

Terre Kleen™ NO BY-PASS Treatment Design: (See figure 1)

1) **Design storm flow:** ②Terre Kleen™ treats the entire flow and removes sediment as required under the permit. All floatables such as oil, grease, trash and debris are removed from the entire flow.
2) **Exceeding design storm flow:** ③Terre Kleen™ treats the entire flow; sediment in design storm flow is removed as required under the permit; sediment in the excess flow is removed at a rate below the permit rate. All floatables such as oil, grease, trash and debris are removed from the entire flow.
3) **Excessive storm flow:** ④⑤excessive flow, such as 50/100-year storms do **not** by-pass the Terre Kleen™ Treatment for design and excess design flows are as stated above. The volume of the storm flow unable to flow through the inclined plates enters the **internal flow through duct** located between the inlet chamber and the grit chamber. When the excessive flow exceeds the capacity of the internal flow through duct, this excess water exits the inlet chamber through a screen located at the top of the baffle wall and proceeds over the "excess flow weir". All floatables such as, trash and debris trapped oil inside the oil booms remain in front of the screen.

4) **Maintenance:** Cleanout of captured pollutants is required to maintain the design efficiency of the Terre Kleen™. When the captured sediment and/or other pollutants reach the recommended maintenance levels they must be removed to prevent interference with continued operations. THSS recommends locating the Terre Kleen™ where a commercial vacuum truck has direct access to the device under its own power. Disposal cost of the Terre Kleen content is about **50% to 70% less** than other systems because the overlapping settling cells reduce the volume of water per effective settling area

FIGURE 1: Terre Kleen™ Drawing

Plan drawings and details (AutoCAD), suggested specifications, Installation instructions and Maintenance instructions are at www.terrestorm.com.

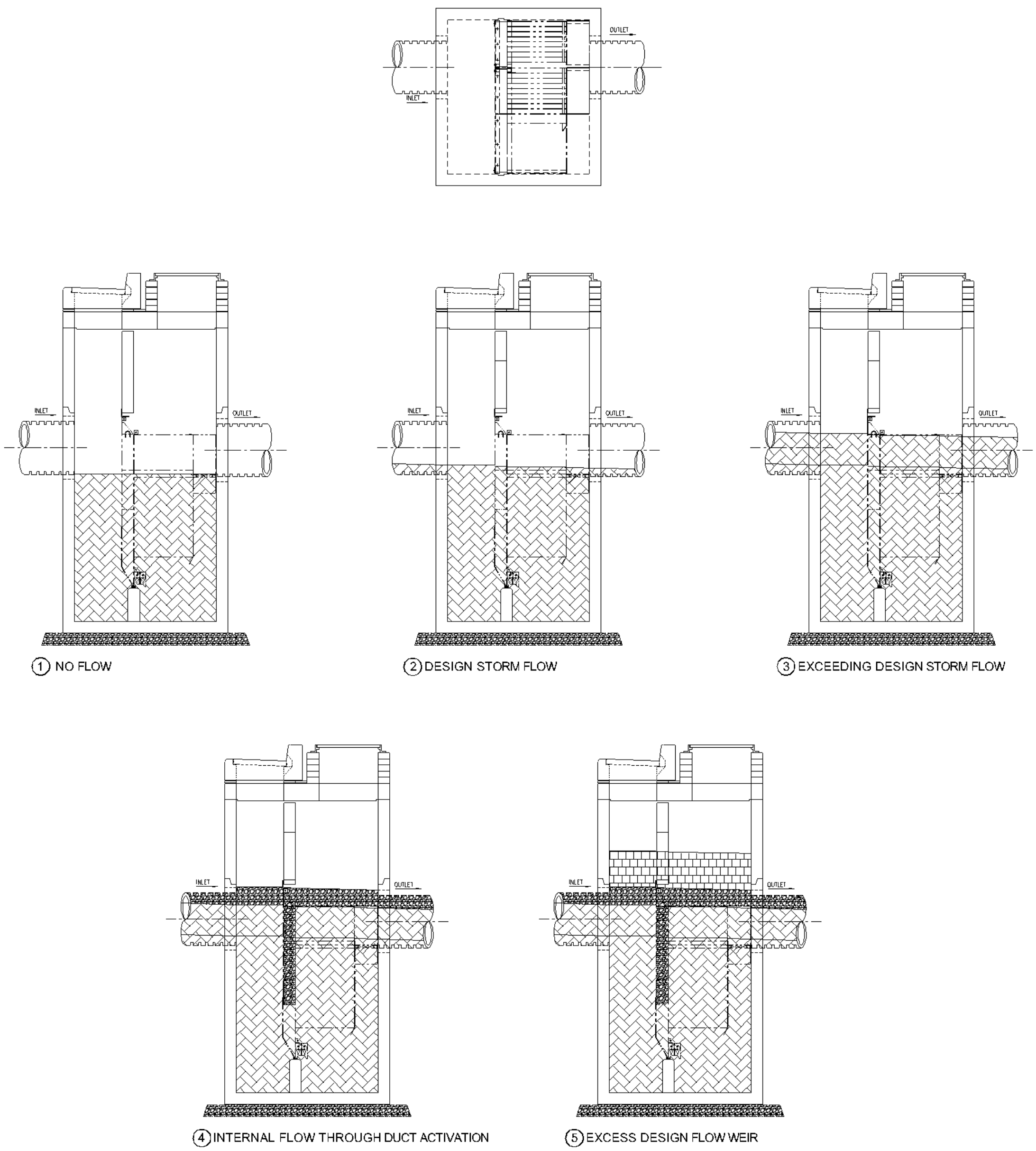


Figure 1

Terre Kleen™ Models

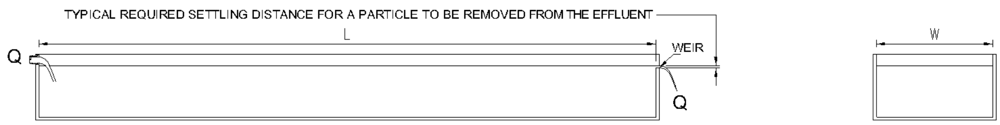
Terre Kleen™ models are designated by the number of inclined plates. **Table 1** shows the actual settling area (6.408 ft² x the number of cells) compared to the structure footprint creating the resulting **INCLINED PLATE RATIO , which** shows the benefit of the inclined plate design.

TABLE 1

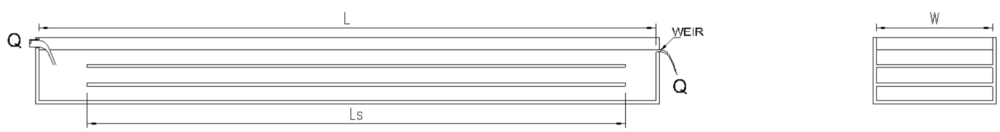
	TK01	TK02	TK05	TK09	TK18	TK27	TK36	TK45	TK54
Settling area	8 ft^2	13 ft^2	32 ft^2	57 ft^2	115 ft^2	172 ft^2	230 ft^2	288 ft^2	346 ft^2
Structure area				29.3 ft^2	42.3 ft^2	55.3 ft^2	79.5 ft^2	93.75 ft^2	108.8 ft^2
Inclined Plate Ratio				196%	272%	311%	290%	308%	318%

FIGURE 2: Inclined Plate Technology Efficiency

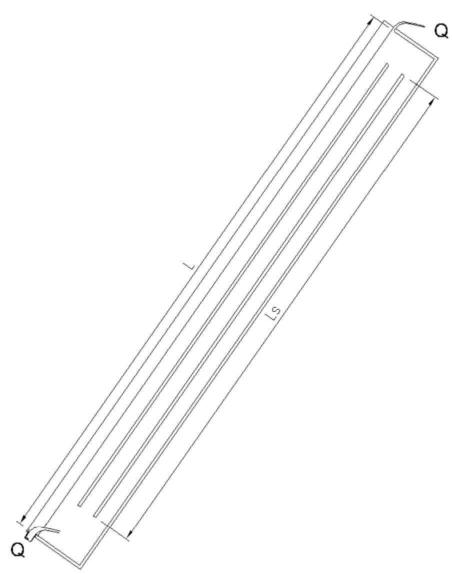
Figure 2a is a conventional sedimentation basin. The Q/ (L x W) is the effective rate at which the water rises towards the overflow weir.
Figure 2b is a horizontal basin where additional floors increase the settling area.
Figure 2c is the equivalent of basin **2b with overlapping inclined plates.**
Figure 2d is the basin adapted to facilitate sediment collection in a hopper and multiple settling cells to maximize settling efficiency and system economy.



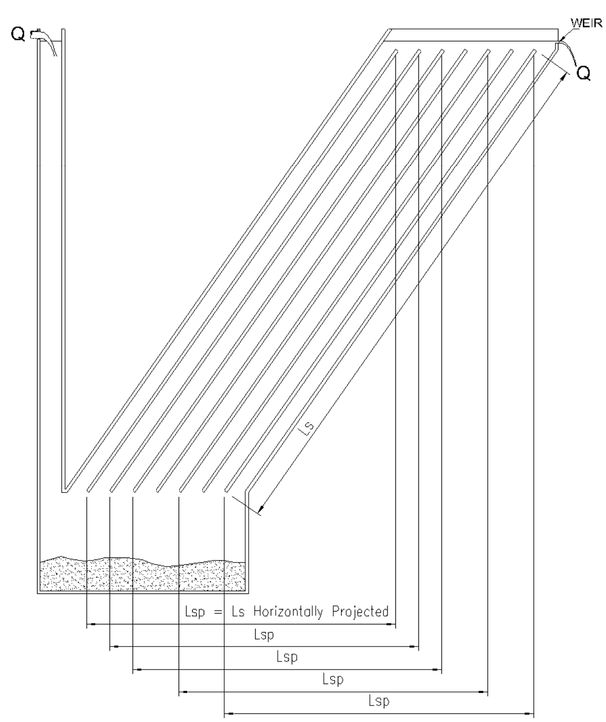
2a CONVENTIONAL SETTLING AREA = L x W



2b STACKED SETTLING AREA = 3 (Ls x W)



2d INCLINED SETTLING AREA
3 (Ls x Cos(55°) x W)



2d STACKED INCLINED SETTLING AREA = 8 (Ls x Cos(55°) x W)

Figure 2
Sizing the Terre Kleen™

The Terre Kleen™ performance has been independently verified :

1. **EPA ETV NSF Joint Verification Statement and Report**
   i. 100% removal rate of 200µm or greater particles in field test
2. **Penn State University (PSU) laboratory test**
   i. 78% net weighted annual TSS removal per NJCAT protocol
3. **Alden Laboratory NJCAT Protocol Test (Only manufacturer that matched or exceeded protocol requirements)**
   i. 54% net weighted annual TSS removal

Empirical data suggests that the actual **Particle Size Distribution (PSD)** for "street surface contaminants" is coarse.

Sansalone, John J. ,Koran, Joseph M., Smithson, Joseph A., Buchberger, Steven G., (1997), Characteristics of Solids Transported from an Urban Roadway Surface WEFTEC 1997

Sartor, James D. and Gail B. Boyd, (1972), Water Pollution Aspects of Street Surface Contaminants, EPA-R2-72-081

Shaheen, Donald G. (1975) Contributions of Urban Roadway Usage to Water Pollution, EPA 600/2-75-004

Using the Terre Kleen™ independent 3rd party tests and adapting them to the above referenced empirical data; applying the relationships set forth in Stokes' Law, **Chart 1** provides suggested treatment design flow and peak flows for Terre Kleen™:

Stokes Law:

$$V_{\text{particle settling}} = \frac{2 \times R^2 \times g \times (\gamma_{\text{particle}} - \gamma_{\text{water}})}{9 \times \nu_{\text{kinematic}}}$$

Stokes' Law calculates the settling velocity of particles in water under certain conditions. The law sets forth the proportional relationship between the water, the particles, and Gravity. This is useful in understanding the performance of a hydrodynamic separator when density and particle size are changed.

Clearly, if **g** was zero, the V particle settling would be zero. Gravitational force is vertically downward, therefore, the correct settling area of a cell is the cell's horizontally projected area. (see calculation for the stacked inclined plates of a Terre Kleen™

The particle size **R** affects the settling speed exponentially. A comparison of different Particle Size Distributions illustrates this relationship and its effects: when a d_{50}=70 Micron is compared to a d_{50} = 100 Micron the settling speed of the 100 Micron particle is $100^2/70^2$ = 2.04 faster. In this case, a particle size increase of 42% gives a settling speed increase of 204%. This means design capacity increases exponentially as the particle size increases.

Plan drawings and details (AutoCAD), suggested specifications, Installation instructions and Maintenance instructions are at www.terrestorm.com.

FOR EXAMPLE :

Assumed site conditions are:

1. Average water temperature is 60 degrees Fahrenheit
2. Particle Size Distribution (PSD) d_{50} is 150µm
3. Average Particle Density is 140 lbs/ft^3

Temperature of the water may change average particle size may change particle density may change. All affect the performance directly or exponentially in case of particle size. Therefore we offer a small range of variables and the relative performance of Terre Kleen in CFS.

Terre Kleen™ Sizing Chart

Chart 1 illustrates the design flows and peak flow capacities of the various Terre Kleen™ models. This Chart reflects to achieve a 60% net annual weighted TSS removal efficiency.

Using Chart 1 as a reference, with the site conditions identified, the site specific Terre Kleen™ can be determined.

CHART 1

Terre Kleen Model	Settling area in sedimentation chamber	Design[1] Capacity d_{50}=50 Micron	Design flow head loss	Design[1] Capacity d_{50}=110 Micron	Design flow head loss	Design[1] Capacity d_{50}=150 Micron	Design flow head loss	Design[1] Capacity d_{50}=200 Micron	Design flow head loss	Peak flow	Peak[2,4] head loss	max pipe Diam.	Standard[5] Sediment Storage	Standard[5] Trash and Oil volume	Minimum grade to pipe invert[3]	Standard pipe invert to device bottom
TK01	8 SqFt	0.1 cfs		0.5 cfs		1.0 cfs	0.03 In.	1.7 cfs		2.5 cfs	0.08 In.	18 In.	66 CF	192 Gallon	2.52 Ft	6.25 Ft
TK02	13 SqFt	0.2 cfs		0.8 cfs		1.6 cfs	0.04 In.	2.8 cfs		4.0 cfs	0.21 In.	18 In.	66 CF	123 Gallon	3.27 Ft	6.25 Ft
TK05	32 SqFt	0.4 cfs		2.1 cfs		3.9 cfs	0.10 In.	6.9 cfs		10.0 cfs	0.56 In.	18 In.	132 CF	236 Gallon	3.27 Ft	6.25 Ft
TK09	57 SqFt	0.8 cfs	0.09 In.	3.7 cfs	1.93 In.	6.9 cfs	6.70 In.	12.3 cfs	21.30 In.	15.0 cfs	33.00 In.	24 In.	80 CF	140 Gallon	3.27 Ft	6.25 Ft
TK18	115 SqFt	1.5 cfs	0.10 In.	7.5 cfs	2.44 In.	13.9 cfs	8.37 In.	24.7 cfs	26.44 In.	28.0 cfs	35.00 In.	36 In.	116 CF	203 Gallon	3.27 Ft	6.25 Ft
TK27	172 SqFt	2.3 cfs	0.11 In.	11.2 cfs	2.71 In.	20.8 cfs	9.36 In.	37.0 cfs	29.62 In.	42.0 cfs	39.00 In.	42 In.	151 CF	265 Gallon	3.27 Ft	6.25 Ft
TK36	230 SqFt	3.1 cfs	0.13 In.	15.0 cfs	2.94 In.	27.8 cfs	10.11 In.	49.5 cfs	32.06 In.	56.0 cfs	42.00 In.	52 In.	216 CF	327 Gallon	3.27 Ft	6.25 Ft
TK45	288 SqFt	3.9 cfs	0.13 In.	18.7 cfs	3.08 In.	34.9 cfs	10.71 In.	62.0 cfs	33.81 In.	70.0 cfs	44.00 In.	60 In.	257 CF	389 Gallon	3.27 Ft	6.25 Ft
TK54	346 SqFt	4.7 cfs	0.16 In.	22.5 cfs	3.58 In.	41.9 cfs	12.41 In.	74.5 cfs	39.25 In.	77.0 cfs	43.00 In.	72 In.	299 CF	452 Gallon	3.27 Ft	6.25 Ft

1. Design flow rates based on Weighted Removal according to NJDEP lab protocol and adjusted for a particle density 140lbs/ft^3 and 60 degree Fahrenheit water temperature.
2. Peak headloss is defined by the standard insert clearance and defines peak flow. Higher flows at reduced treatment rates are optional and avoid external by-pass.
3. Add 9" for grade adjust and frame and cover, otherwise cast into the lid.
4. Excess design overflow through a screen is possible above insert.
5. Special designs are available to increase these values

NOTE :

The specific size Terre Kleen™ chosen for each specific site will depend upon the site conditions. The **Engineer of Record** must make a determination regarding:

1. size of drainage area
2. site characteristics regarding type of soil, particle size distribution and sediment concentration
3. design of collection and transportation system, which will include pipes sizes and rates of flow
4. specification of treatment flow
5. specification of peak flow
6. sediment removal rate required by the permit/regulations
7. Additional removal and storage requirements for trash, oil.
8. Space limitations and access conditions
9. Maintenance monitoring methods (i.e. manual or automatic)

Additional Considerations:

Terre Kleen™ is fully assembled inside a rectangular precast concrete structure designed and engineered by Terre Hill Stormwater Systems to meet the site-specific service conditions:

1. Terre Hill Storm water Systems provides the Engineer of Record for structural integrity of Terre Kleen™ based on the peripheral site data provided by the Engineer of Record for the site.
2. Buoyancy conditions may require a bottom flange to be part of the structure.
3. Traffic loading affects the design of the lid.
4. Pipe inverts may require the casting of access manholes into the lid to gain elevation.
5. Inlet grates may be placed above the primary chamber to allow the Terre Kleen™ to be the last inlet in a design.
6. Pipes may enter the primary chamber between 9 and 3 o'clock at various angles. The discharge is typically at 6 o'clock.

7. The exterior of the structure may be coated to resist acid surroundings.
8. The Terre Kleen™ insert is a welded plate assembly manufactured from marine grade aluminum (#5052). Hardware is stainless steel and seals are neoprene rubber.
9. Lids contain the Terre Kleen™ logo and the words “Stormwater Treatment Device”.
10. Oil absorption booms that absorb and permanently remove ¼ gallon of oil are placed in the inlet/primary chamber
11. An additional screening/floatables chamber may be placed prior to Terre Kleen™ at locations where site conditions/use may warrant, such (i.e. malls, stadiums, race tracks and other areas where throw away containers are used)
12. A treatment train design is recommended. Use of the Terre Kleen™ as a pretreatment device will remove oil, grease, litter, trash, debris and sediment prior to discharge into a filter, a detention or infiltration basin, rain garden, bio-retention area or other treatment structures.
13. Pretreatment with a Terre Kleen™ will preserve the functionality of the subsequent treatment BMPs; protect its useful life; and reduce maintenance costs by: 1) preventing pollutants from entering those devices and 2) concentrating pollutant removal in the easily accessible Terre Kleen™.

Terre Hill Stormwater Systems manufactures a complete line of stormwater treatment and management structures designed for NPDES permit compliance:

Terre Kleen™
Terre Arch™ (patent pending 11/569,437)
Terre Box™
Terre Hill Watertight Joint Seal System™ (patent pending 12/150,722)
Terre Filter™ (patent pending 61/191,484)

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Please visit our web site : www.terrestorm.com

Terre Hill Stormwater Systems is a division of Terre Hill Concrete Products. Terre Hill Concrete Products designs, engineers, and manufactures precast concrete infrastructure products for storm sewers, sanitary sewers, bridges, culverts and highway projects.

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