July Construction Stormwater Quality Workshop July 16–19, 2018

Effective Design of Sediment Basins

Introduction

- Welcome
- Introduction

One DPP Rule for Water Quality

Rules Relating to Water Quality

DPP Administrative Rules
Title 20

References

CITY AND COUNTY OF HONOLULU

STORM WATER BEST MANAGEMENT PRACTICE MANUAL

CONSTRUCTION

AUGUST 2017

SE-2 – SEDIMENT BASIN

Sediment Basins (§20-3-41)

- §20-3-41 Sediment Basins. (a) Sediment basins are excavated or depressed areas that are used to collect and detain runoff to allow suspended solids to settle out of storm water before storm water is Discharged to off-site areas.
- (b) The use of sediment basins shall be mandatory for Category 5 Projects with 5 acres of Disturbed Area or greater unless they are determined to be unnecessary or impracticable for the Project based on site conditions

Sediment Basins (§20-3-41)

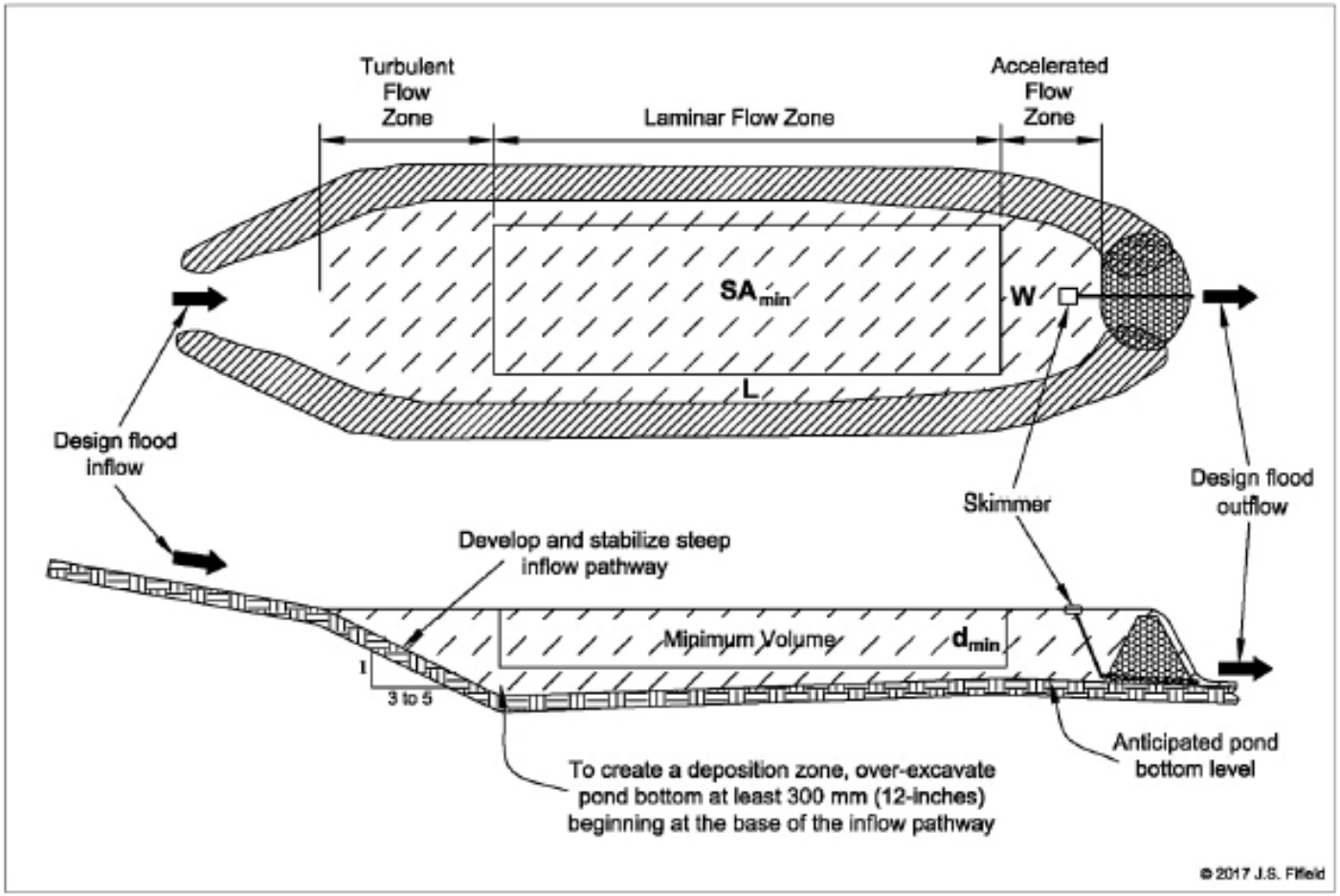


Figure 4 Illustration of parameters for designer an effective SCS (from Fifield & Evans, 2017)

Sediment Basins Design Parameters

Use City BMP Manual:

WQR requirements:

- 2-yr 24-hr storm or 3600 cubic feet per acre (equivalent to 1” rainfall)
- Depth: 3feet (2 ft. settling zone and 1 ft. storage zone)
- Length- Depth ratio must be less than 200
- Draw-down time between 36 and 72 hours.

Sediment Basins Design Parameters

Example

- A=10 acre residential Development
- Design Volume - Honolulu Design rainfall = 1” , that is 3,600 ft^3/acre

Use City BMP Manual:

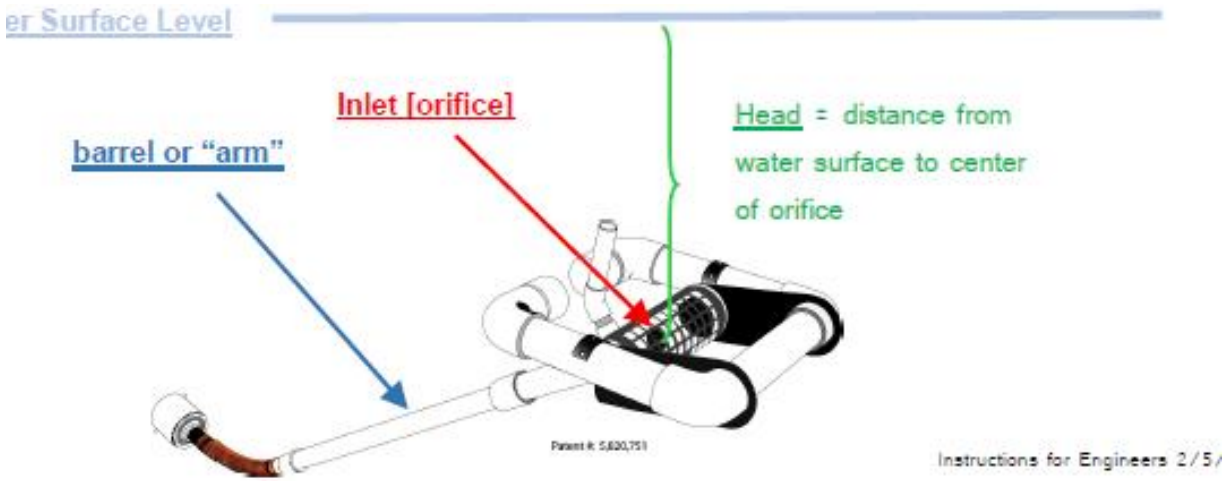
- Design min. V=36,000 ft^3;
- Depth: 2 ft. settling zone and 1 ft. storage zone; Length- Depth ratio must be less than 200; Draw-down time between 36 and 72 hours.
- S_{min}. = 36,000/2 = 18,000 ft^2;
- L:W=3 min. (W*3W)=18,000; W = 80’ L = 240’
- Pre-treatment, Skimmer/Perf Riser & Spillway

Discharge Outlet Control Device

Effectiveness order:

1) Skimmer
2) Perforated pipe riser

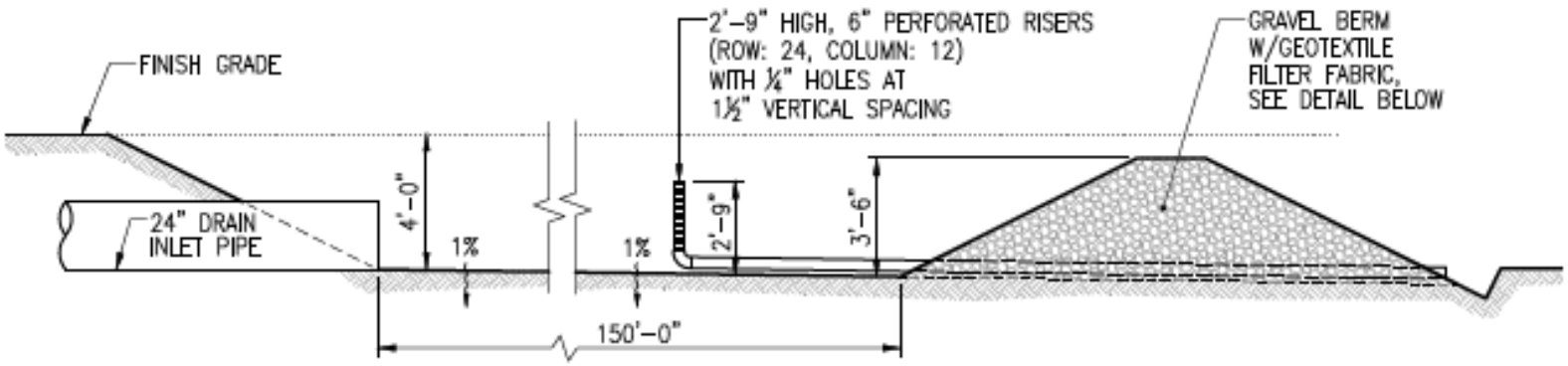
Discharge Control Device - Skimmer



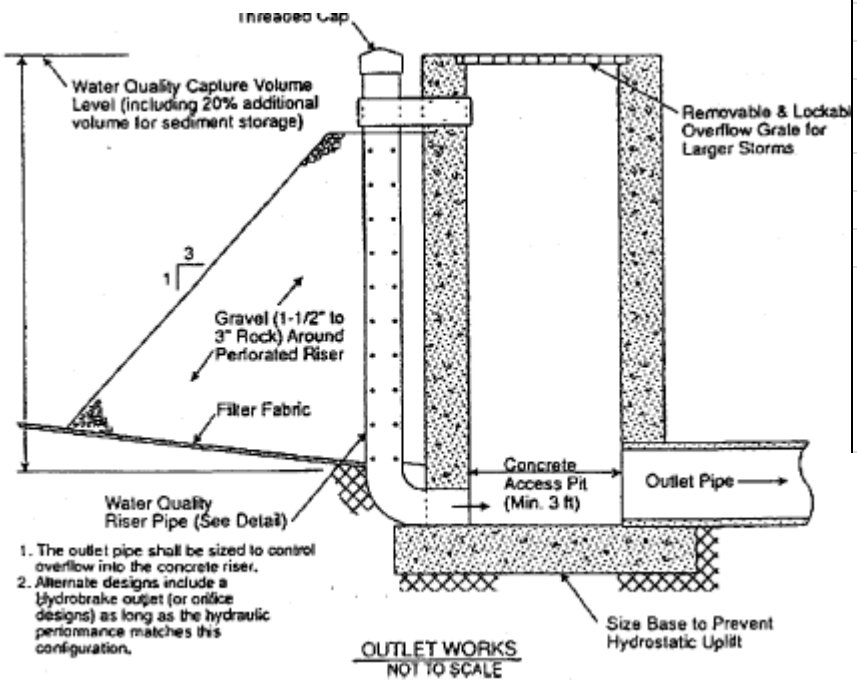
FLOW CAPACITIES (IN CU. FT.) FOR THE *FAIRCLOTH SKIMMER*®

Skimmer size	1.5"	2"	2.5"	3"	4"	5"	6"	8"
24 hours	1,728	3,283	6,234	9,774	20,109	32,832	51,840	97,978
2 day	3,456	6,566	12,468	19,548	40,218	65,664	103,680	195,956
3 day	5,184	9,849	18,702	29,322	60,327	98,496	155,520	293,934
4 day	6,912	13,132	24,936	39,096	80,436	131,328	207,360	391,912
5 day	8,640	16,415	31,170	48,870	100,545	164,160	259,200	489,890
6 day	10,368	19,698	37,404	58,644	120,654	196,992	311,040	587,868
7 day	12,096	22,981	43,638	68,418	140,763	229,824	362,880	685,846

Discharge Control Device – Perf Riser



Discharge Control Device - Perf Riser



$$Q = C_h \frac{2A_h}{3h_h} (2g)^{1/2} h^{3/2}$$

Table 1 - Extended Detention Calculations

	Full Pond
Riser Diameter (in.)	6
Hole Diameter (in.)	0.25
Area of Each Hole (in2)	0.049063
Area of Each Hole (ft2.) =	0.000341
# of Rows	21
# of Columns	12
Area of all holes up to and include indicated row (ft2.) =	0.172
Discharge Coefficient	
Distance from d/2 below the centerline of the lowest hole to d/s above the centerline of the highest submerged hole (ft.) (where d is the vertical spacing between holes (ft.), (assumes that bottom of pond is d/2 from bottom hole)	2.625

Riser Diameter (in.)	Hole Diameter (in.)			
	1/4"	1/2"	3/4"	1"
4	8	8	-	-
6	12	12	9	-
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter (in.)	Area of Hole (in2)
1/8"	0.013
1/4"	0.049
3/8"	0.11
1/2"	0.196
5/8"	0.307
3/4"	0.442
7/8"	0.601
1"	0.785

Discharge Control Device - Perf Riser

Table 1 - Extended Detention Calculations

		Water level at: Row Number(water level at 1/2 hole spacing above hole)																							
	Full Pond	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Riser Diameter (in.)	6																								
Hole Diameter (in.)	0.25																								
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Area of Each Hole (ft2.) =	0.000341																								
# of Rows	24																								
# of Columns	12																								
Area of all holes up to and include indicated row (ft2.) =	0.172	0.004	0.008	0.012	0.016	0.020	0.025	0.029	0.033	0.037	0.041	0.045	0.049	0.053	0.057	0.061	0.065	0.070	0.074	0.078	0.082	0.086	0.090	0.094	0.098
Discharge Coefficient		0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611
Distance from d/2 below the centerline of the lowest hole to d/s above the centerline of the highest submerged hole (ft.) (where d is the vertical spacing between holes (ft.), (assumes that bottom of pond is d/2 from bottom hole)	2.625	0.125	0.250	0.375	0.500	0.625	0.750	0.875	1.000	1.125	1.250	1.375	1.500	1.625	1.750	1.875	2.000	2.125	2.250	2.375	2.500	2.625	2.750	2.875	3.000
Head on riser pipe measured from d/2 below the centerline of the lowest hole to the water surface (h=hn)	2.625	0.125	0.250	0.375	0.500	0.625	0.750	0.875	1.000	1.125	1.250	1.375	1.500	1.625	1.750	1.875	2.000	2.125	2.250	2.375	2.500	2.625	2.375	2.500	2.625
Discharge (cfs)		0.005	0.013	0.025	0.038	0.053	0.069	0.088	0.107	0.128	0.149	0.172	0.196	0.221	0.248	0.275	0.302	0.331	0.361	0.391	0.423	0.455	0.391	0.423	0.455
Average Discharge (cfs)		0.002	0.009	0.019	0.031	0.045	0.061	0.078	0.097	0.117	0.139	0.161	0.152	0.175	0.198	0.212	0.237	0.264	0.279	0.259	0.275	0.302	0.294	0.310	0.338
Volume (cu ft)		1159	1765	2387	3028	3686	4363	5058	5772	6503	7255	8025	8816	9625	10455	11304	12173	13064	13974	14906	15859	16833	17829	18846	19885
Net Volume (cu ft)			606	622	641	658	677	695	714	731	752	770	791	809	830	849	869	891	910	3602	953	974	996	1017	1039
Drain Time for Detension Pond Volume Draining from 1/2 vertical spacing above indicated row to 1/2 below (hours)		0	18.61	9.11	5.71	4.03	3.08	2.46	2.04	1.73	1.51	1.33	1.45	1.29	1.16	1.11	1.02	0.94	0.91	3.86	0.96	0.90	0.94	0.91	0.85
Total Drain Time (hours)	65.9																								

Tracking Trend – Sediment Basin Design

Sediment Basins Design Parameters

Volume required per WQR:

- 2-yr 24-hr storm
- 3600 cubic feet per acre (equivalent to 1” rainfall)

Misconception = Volume is the only criteria to consider

Sources (Dr. Fifield)

Misconception based on EPA

1) 3-inch rain is representative of a 2-yr, 24-hr storm
2) A 3-inch rainfall will generate 1-inch runoff
3) 90% of runoff events will have a volume of 3,600 ft^3/acre

Sediment Basins Design Parameters

Modeling by Dr. Fifield shows

1) 1,800 ft^3/acre for arid and semi-arid climates
2) 3,600 ft^3/acre for humid climates
3) 5,400 ft^3/acre for tropical climates

Sediment Basins Design Parameters

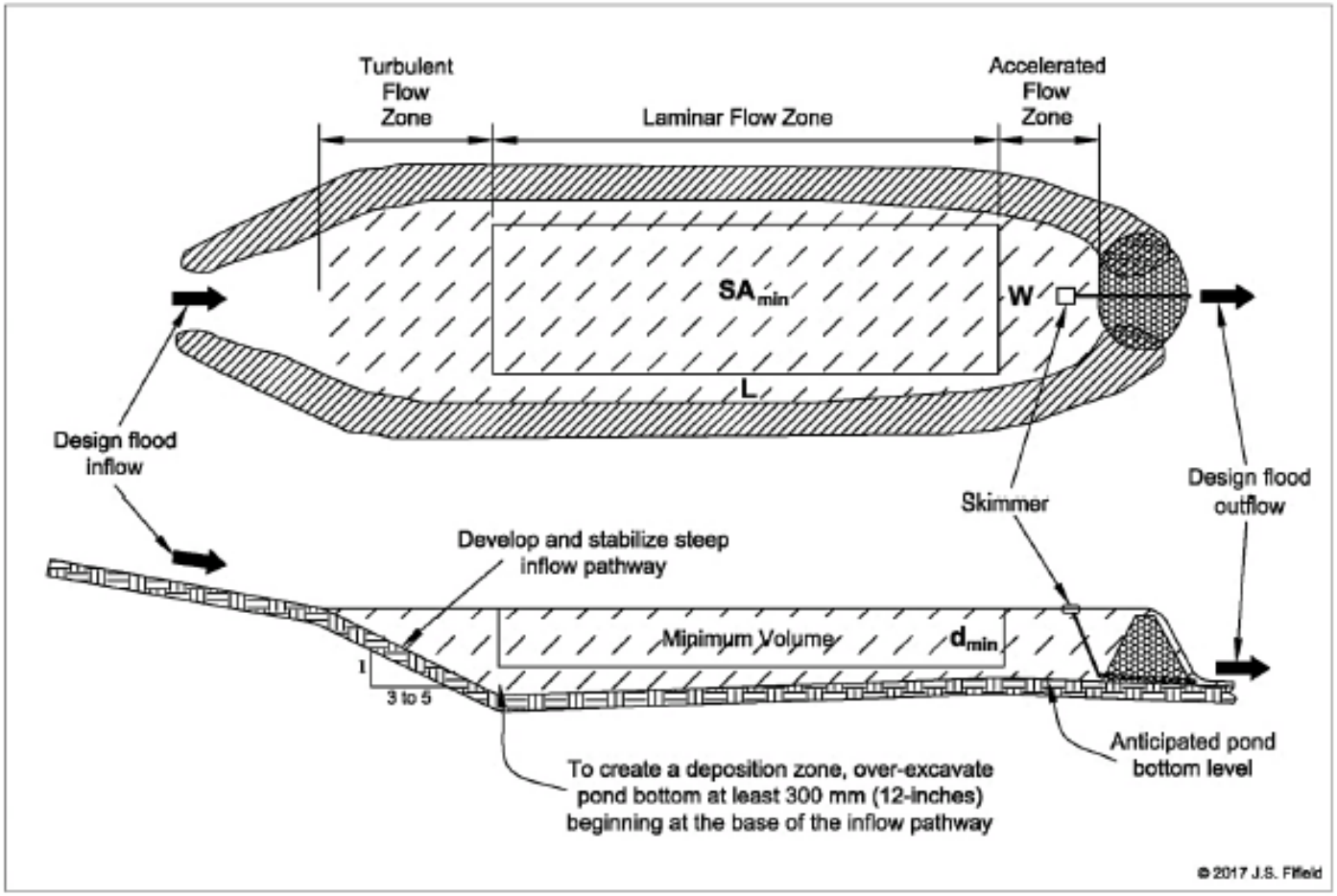

Figure 4 Illustration of parameters for designer an effective SCS (from Fifield & Evans, 2017)

Sediment Basins Design Parameters

Based on Dr. Fifield, the parameters to be considered in the sediment basin design:

- Soil particle size
- Discharge rate
- Long internal flow path
- Detention time (non-flood flow)
- Minimum treatment runoff volume
- Storage volume
- Spillway
- Outlet
- Discharge Devices
- (Skim Box/Perf risers)

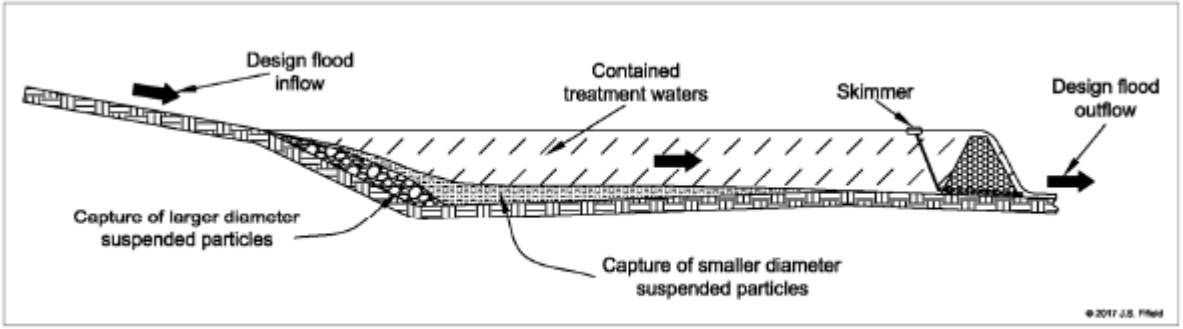

Figure 1 Illustration of an effective sediment containment system (from Fifield & Evans, 2017)

Sediment Basins Design Parameters

- Soil particle size

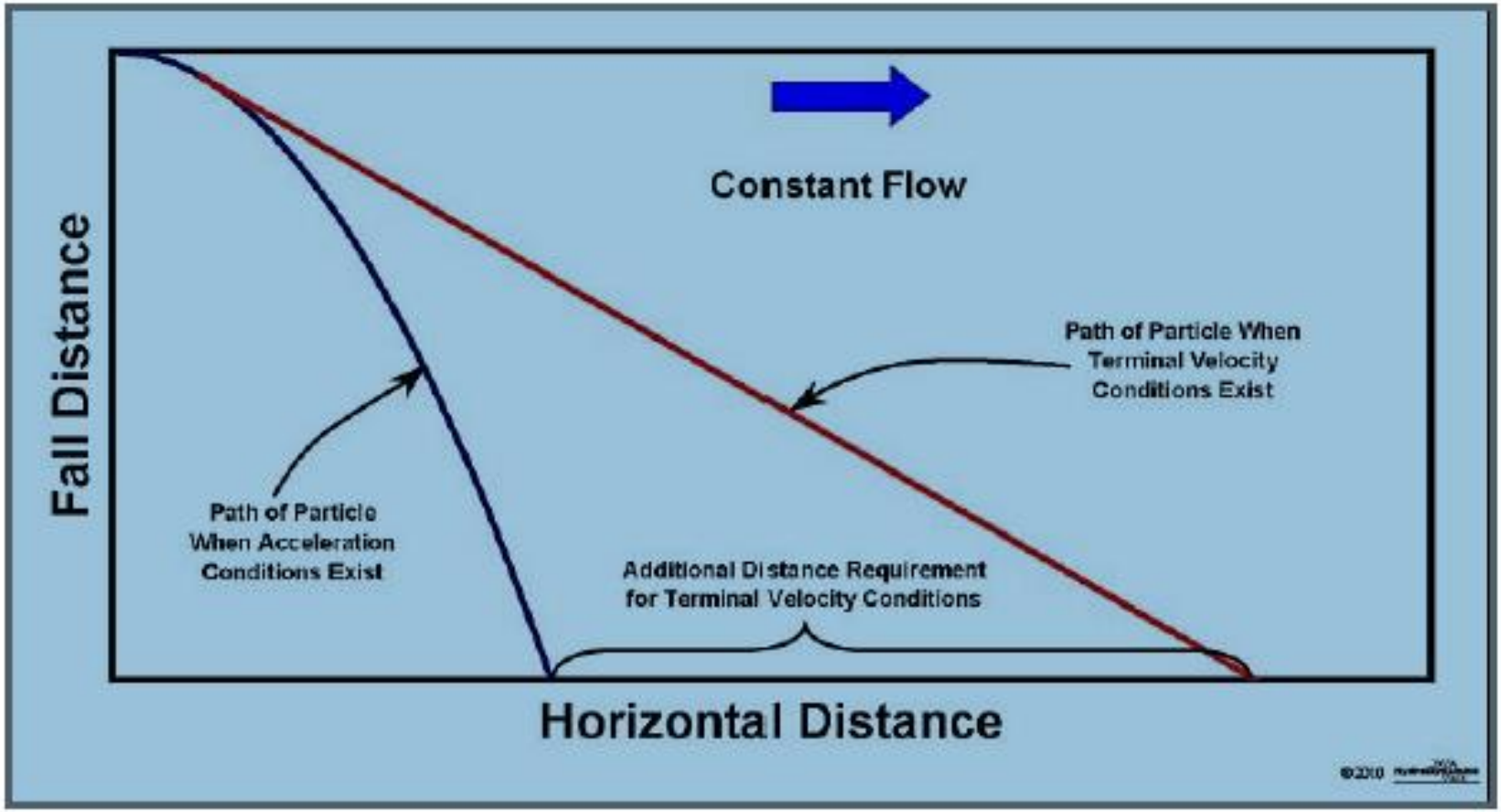

Figure 2 Illustration of how suspended particles may fall through a water column (from Fifield, 2011)

Sediment Basins Design Parameters

- Soil particle size

Table 1 Terminal velocities for small suspended particles (SG = 2.65) at different water temperatures as calcula by Stokes' Law (from Fifield, 2011).

Diameter (microns)	Diameter (mm)	Settling Velocity in 10^{-5} Metres per Second					Type of Particle
		0°C	5°C	10°C	15°C	20°C	
10	0.01	5	6	7	8	9	Fine Silt
20	0.02	20	23	27	31	35	Medium Silt
30	0.03	44	52	60	69	78	
40	0.04	78	92	107	122	139	Coarse Silt
50	0.05	122	143	167	191	217	
60	0.06	176	207	240	275	313	
70	0.07	239	281	327	375	426	Very Fine Sand
80	0.08	312	367	427	490	556	
90	0.09	395	465	540	620	704	
100	0.10	488	574	667	765	869	
		32°F	41°F	50°F	59°F	68°F	

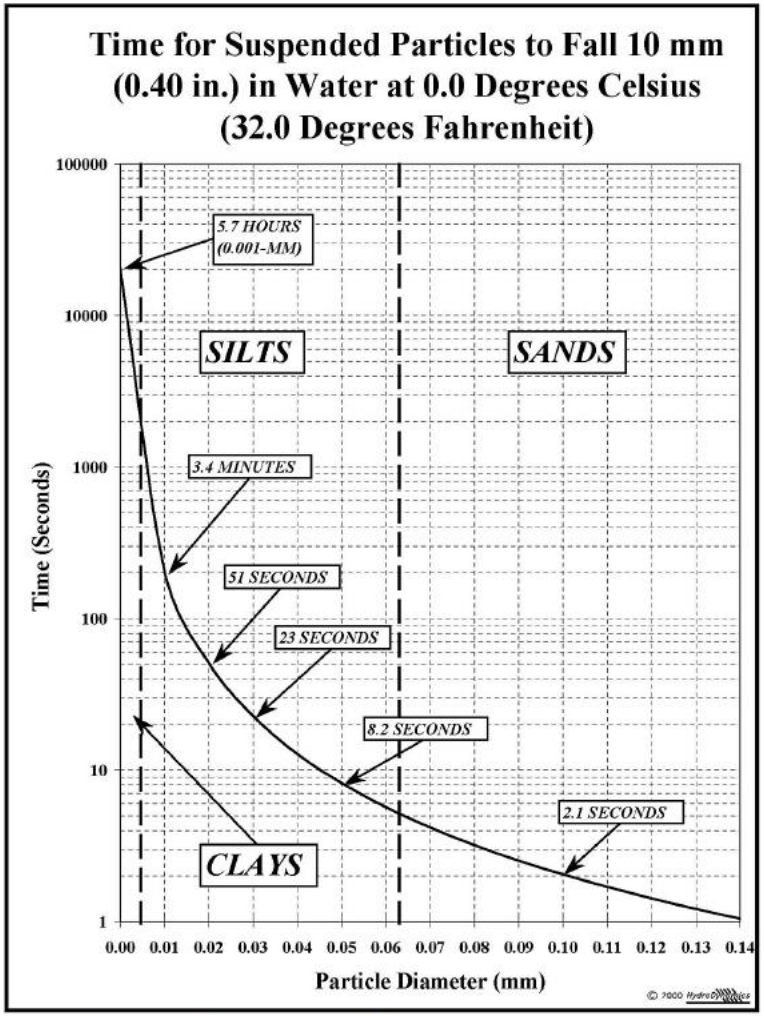

Figure 3 Illustration of how soil particles might fall through water at 0°C (32°F).

Sediment Basins Design Parameters

- Discharge Rates

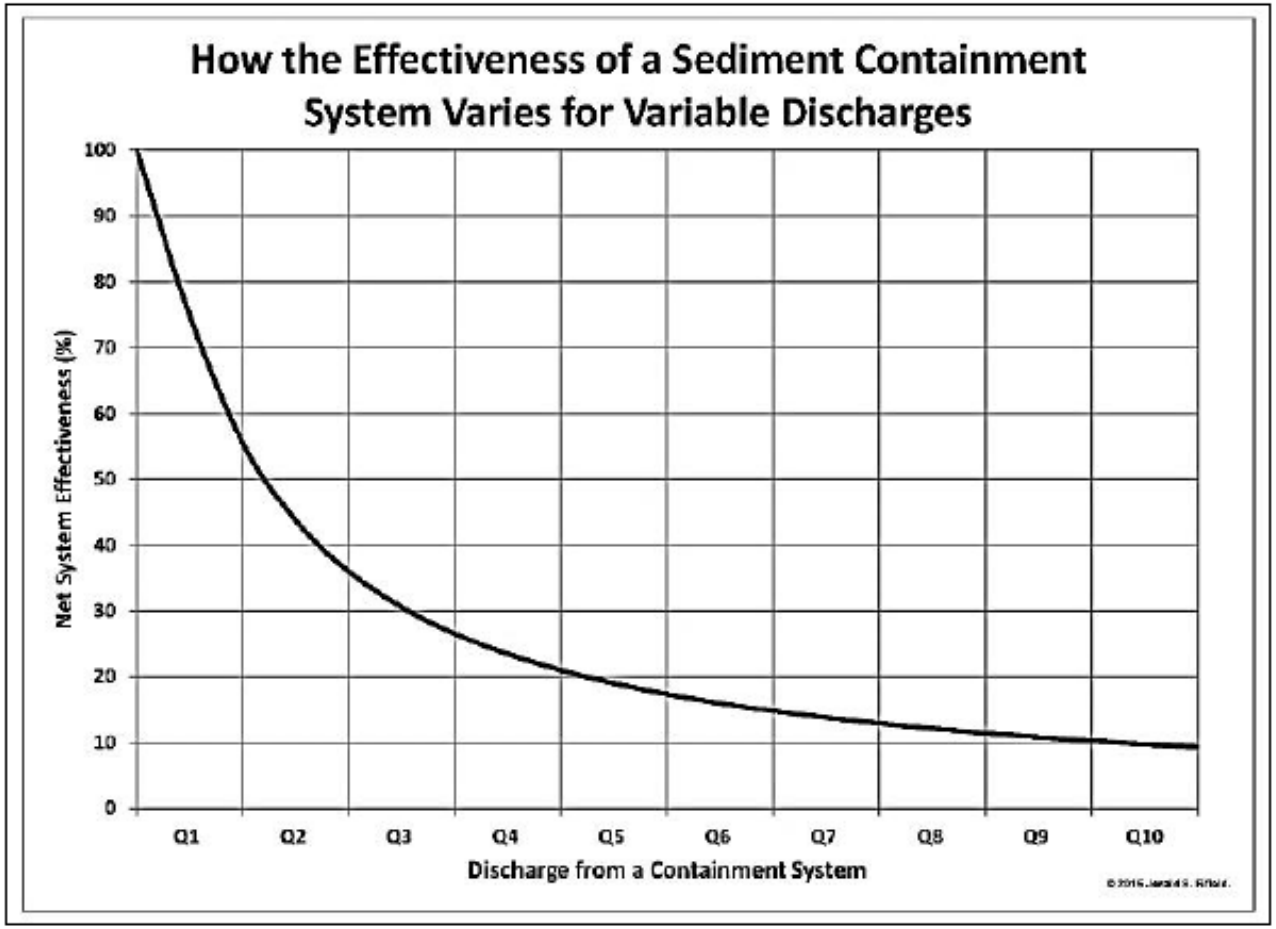

Figure 5 How SCS effectiveness may vary with discharge rates (from Fifield, 2011)

Sediment Basins Design Parameters

- Equations to design sediment basins

EQUATIONS FOR AN EFFECTIVE SCS

Fifield (2011) and Fifield and Evans (2017) developed the following equations for estimating SCS parameters assuming uniform internal flows exist within the laminar flow zone.

Minimum Pond Surface Area: $SA_{min} = L \times W = Q_{outflow} \div V_{term}$

Minimum Internal Flow Distance: $L = (L{:}W \times SA_{min})^{0.5}$

Minimum Containment Volume: $Vol_{min} = d_{min} \times SA_{min}$

Minimum SCS Volume: $Vol_{scs} = (1 + \Psi) \times Vol_{min} = (1 + \Psi) \times d_{min} \times SA_{min}$

where d_{min} = minimum depth of the containment volume (m or ft.)
L = flow length of rectangular volume (m or ft.)
W = width of rectangular volume (m or ft.)
$L{:}W$ = Length-Width Ratio
$Q_{outflow}$ = Discharge from the SCS (m^3/sec. or $ft.^3$/sec.)
V_{term} = Terminal velocity of design-size particles (m/sec. or ft./sec.)
Ψ = Storage adjustment factor $\geq 15\%$

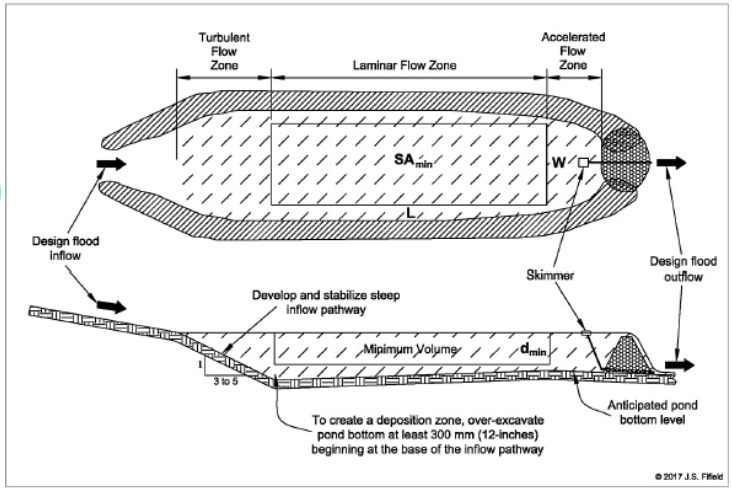

Figure 4 Illustration of parameters for designer an effective SCS (from Fifield & Evans, 2017)

Sediment Basins Design Parameters

- Example
  - A=10 acre
  - 10-yr 1-hr storm Q = 15 ft^3/sec
  - Design Volume - Honolulu Design rainfall = 1” , that is 3,600 ft^3/acre

Step 1 – Min. Containment Volume

- Vol = 10*3600 = 36,000 ft^3/sec

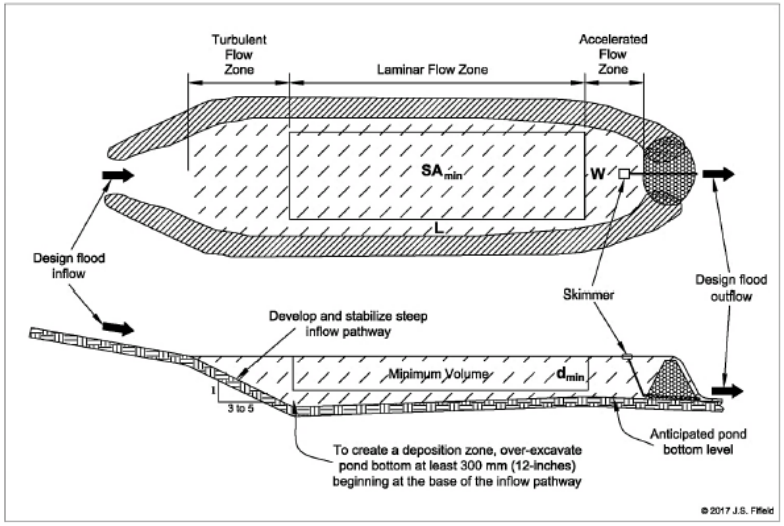

Figure 4 Illustration of parameters for designer an effective SCS (from Fifield & Evans, 2017)

Sediment Basins Design Parameters

- Step 2 – Min. surface area

Assuming 15 micron soil particle

V=0.00072 ft/sec

S_{min} = Q/V = 15/0.00072 = 20,800 ft^2

Diameter (microns)	Diameter (mm)	Settling Velocity in 10^{-5} Metres per Second					Type of Particle
		0°C	5°C	10°C	15°C	20°C	
10	0.01	5	6	7	8	9	Fine Silt
20	0.02	20	23	27	31	35	Medium Silt

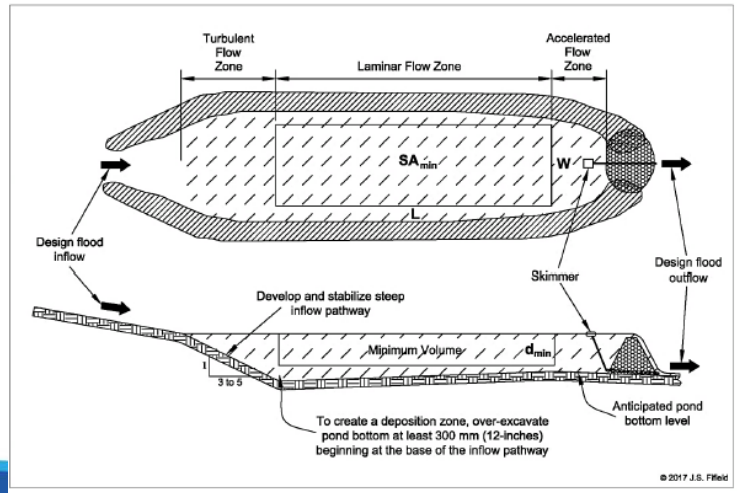

Figure 4 Illustration of parameters for designer an effective SCS (from Fifield & Evans, 2017)

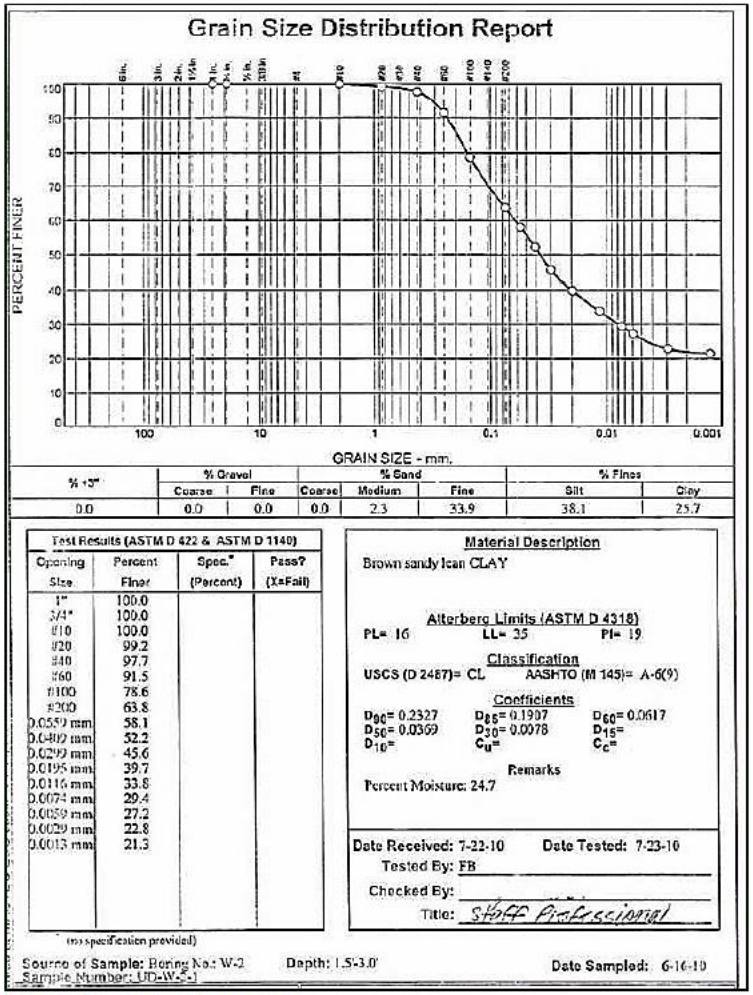

Figure 8 Example of a soil sieve analysis

Sediment Basins Design Parameters

- Step 3 – Min. Internal Flow Length

  $L=(L:W*S_{min})^{0.5}$

  $L:W = 3.0$

  $L=(3*20800)^{0.5}= 250ft; W= 83\ ft$

- Step 4 – Min. depth:

  $D_{min} = Vol/S_{min}$

  $=36000/20800=1.73$, say 2 ft

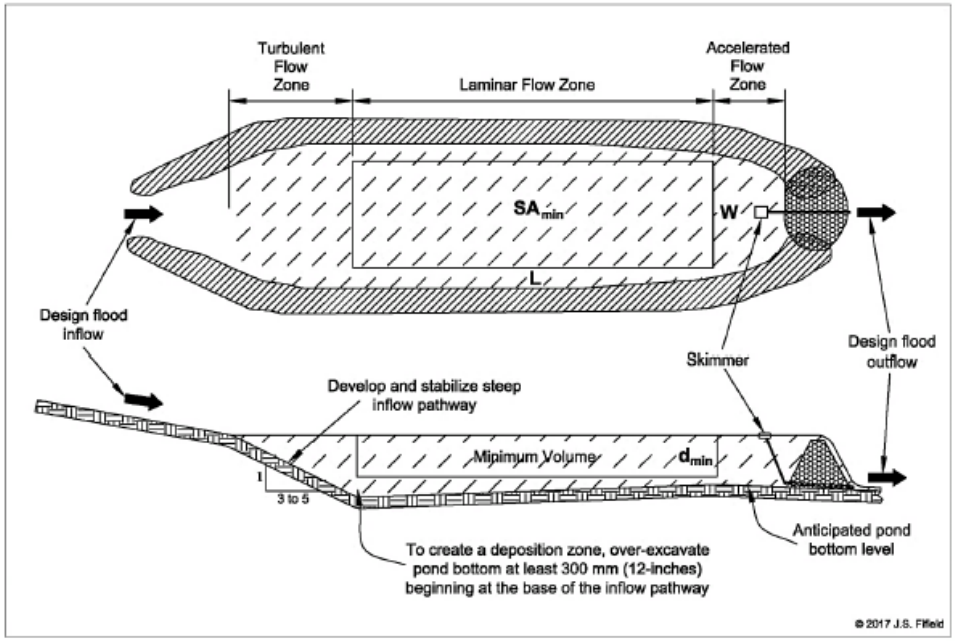

Figure 4 Illustration of parameters for designer an effective SCS (from Fifield & Evans, 2017)

- Step 5 – Assuming storage Factor of 30%;

  SB Vol = 36000*1.3 =46,800 ft^2

Sediment Basins Design Parameters

Effectiveness of Sediment Basin:

About 35% of soil particle are smaller than 15 microns (assumed), the efficiency is 100%-35%=**65%**

To increase efficiency:

1) Increase surface area
2) Add chemical (polymers)

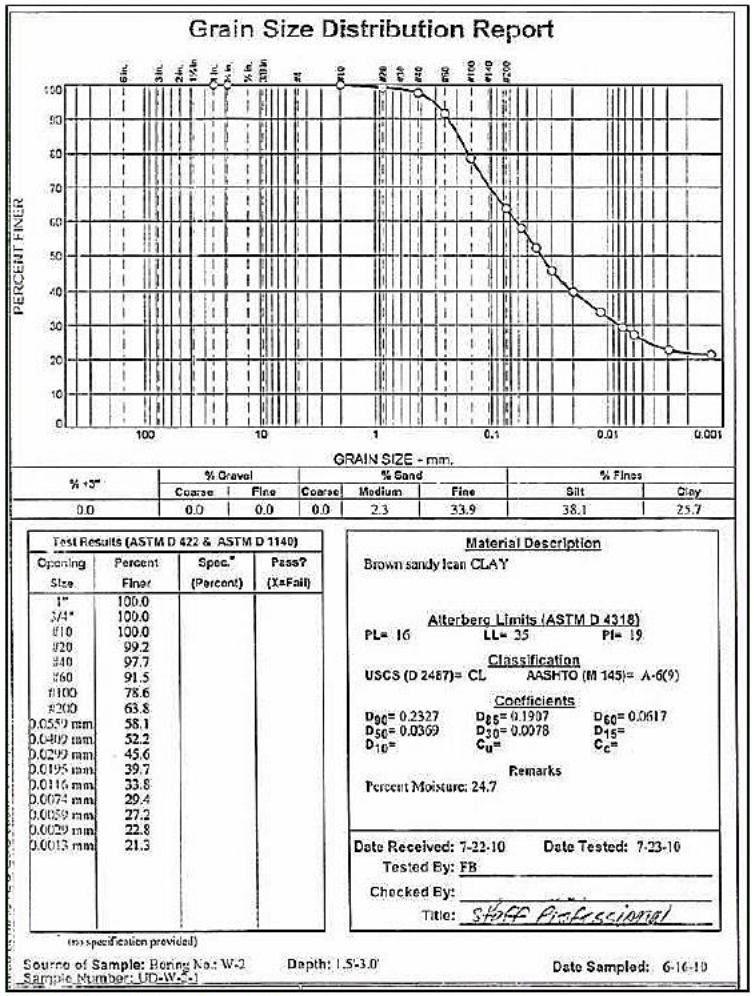

Figure 8 Example of a soil sieve analysis

Sediment Basin Design

- **Needs sound engineering Design**

Design parameters to be considered:

- Soil particle size
- Discharge rate
- Long internal flow path
- Detention time (non-flood flow)
- Minimum treatment runoff volume
- Storage volume
- Spillway
- Outlet
- Discharge Devices
- (Skim Box/Perf risers)
- Chemicals

Thank You!
Any Questions?