THE DEVELOPMENT OF SEDSPREAD: A HYDROLOGICALLY ROBUST CONSTRUCTION SITE SEDIMENT BASIN DESIGN TOOL

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SEDIMENT BASINS

Definition: sediment control practices intended to temporarily detain and treat sediment-laden stormwater prior to discharging offsite.

- Designed to provide storage and detention time to allow for suspended sediment to settle through gravity.
- Standardized guidance on sediment basin design typically implement the following common features intended to facilitate the retention of sediments: (1) volume sizing factors (VSFs), (2) typical sizing geometries, (3) baffles, (4) dewatering mechanisms, and (5) chemical treatment.

Problem: a one-size fits all approach is not applicable across all construction sites, as local hydrologic and soil conditions influence the proper design of basins.

RESEARCH OBJECTIVE

Develop a user friendly spreadsheet tool to aid with sediment basin designs

Goal: to provide designers the ability to easily implement hydrologic based designs to allow for appropriately sized and configured sediment basins based upon the regionally specific design criteria [i.e., 1,800 or 3,600 ft³/ac (125 or 250 m³/ha) VSF, 2-yr, 24-hr rainfall event, or manual input].

SEDSPREAD DEVELOPMENT

SEDspread was developed as a spreadsheet workbook containing eight worksheets to allow users to design sediment basin geometry and volumes, surface skimmer sizing, size of auxiliary spillway, and baffle configurations. In addition, a stage-storage relationship plot and dewatering schedule of the designed basin are included in the output.

Basin Design Worksheet: includes all required inputs to design the basin and is divided into two primary sections: (1) user provided inputs and (2) regulatory design guidance.

User Inputs: includes inputs for basin parameters, site geometry constraints, surface skimmer design, basin configuration, basin capacity, auxiliary spillway design, and baffle design. The user input section of the worksheet is used to compare design parameters with the selected regulatory design guidance. When designed parameters fail to meet the regulatory design guidance, displays are prompted indicating where sizing adjustments are required.

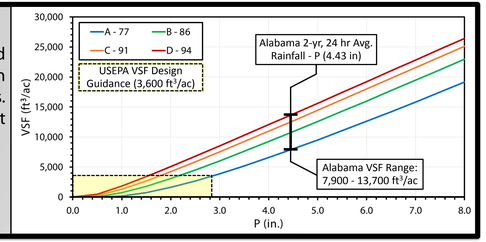
GIS BASED CURVE NUMBER & RAINFALL

- **Curve Numbers (CN):** CN's for "Developing Urban Areas w/ Newly Graded Areas", applied to hydrologic soil classes mined from CONUS-Soil datasets.
- **Precipitation depth (P):** 2-yr, 24-hr design rainfall depths mined from NOAA Atlas 14 Precipitation Frequency Data Server.
- Data attributed by ZIP code to determine highest occurring per boundary.

VOLUME SIZING FACTOR (VSF)

Using 2-yr, 24-hr storm basin sizing method recommended, SEDspread determines an appropriate VSF based on CN and P inputs. VSF in ft³/ac (m³/ha) equals the total direct runoff volume per unit of drainage area.

$$VSF = \frac{\left[P - 0.2\left(\frac{1000}{CN} - 10\right)\right]^2}{P + 0.8\left(\frac{1000}{CN} - 10\right)} * \frac{43{,}560}{12}$$



User Notes: 1) user is required to know the sediment basin drainage area (C1B) and spillway design flow rate (C20); 2) Select regulatory design guidance criteria to follow; 3) Cells or parameters for user to change are in RED, all other cells/parameters will be automatically calculated; 4) ★ denotes parameter does not comply with regulatory design guidance or site geometry constraints ; 5) ✦ denotes parameter does not comply with regulatory design recommendations; 6) ✓ denotes design within regulatory guidance or recommendation.

Project & Location: Designer: Date: 08/01/2015

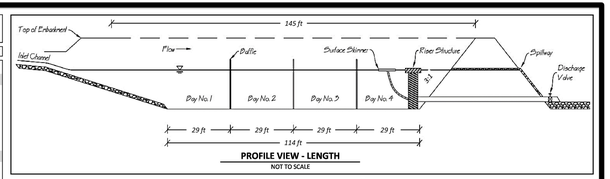
User Provided Input Parameters (Red)

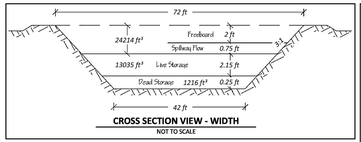
Site Parameters: Auburn, AL		Site Geometry Constraints (Optional)	
System of Units	U.S.	Max Length Available	500 ft
Sizing Method	2-Yr, 24-Hr	Max Width Available	500 ft
Project Zip Code	36832	Max Depth Available	10.0 ft
Site Curve Number	88.98		
2-Yr, 24-hr Rainfall	4.18 in.		
Volume Sizing Factor	10,866 ft³/ac	CLICK WHEN RED TO SIZE SEDIMENT BASIN	
Design Sediment Basin Volume	13,039 ft³		
Contributory Drainage Area	1.20 ac		
		Surface Skimmer Design	
Spillway Design Flow Rate	20.0 ft³/s	Desired Detention Time	72 hrs
Live Storage Safety Factor	1.00	Required Dewatering Rate	181.1 ft³/hr
Minimum Regulatory Volume Requirement	4,320 ft³	Recommended Orifice Size	2.1 in

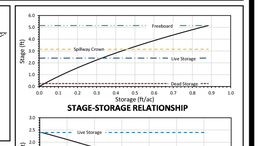
Basin Configuration		Basin Capacity	
Length to Width Ratio (L:W)	2.0	Total Storage Depth (Spillway crest elevation)	2.25 ft
Side Slopes (H:V)	3.0	Total Basin Depth	5.00 ft
Dead Storage Depth	0.10 ft	Dead Storage Volume	494 ft³
Live Storage Depth	2.15 ft	Live Storage Volume	13,039 ft³
Top Length	145.0 ft	Total Storage Volume (without overflow)	13,533 ft³
Top Width	72.5 ft	Spillway & Freeboard Volume	24,221 ft³
Bottom Length	115.0 ft	Total Basin Volume	37,753 ft³
Bottom Width	42.5 ft	Total Basin Surface Area	10,515 ft²

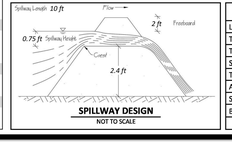
Auxiliary Weir Spillway Design		Baffles	
Spillway Length	10 ft	No. of Bays	4
Freeboard above Crown	2.00 ft	T-Post Spacing	3.0 ft
		T-Post Stake Depth	2.0 ft
Spillway Crest Elevation	2.25 ft	Bay Length	28.8 ft
Spillway Height	0.75 ft	No. of T-Posts Required	64
Spillway Flow Elevation	3.00 ft	T-Post Length Required	5.5 ft
Design Flow Rate	21.8 ft³/s	Height of Baffle Required	3.00 ft
		Length of Baffle Required	363 ft

Regulatory Design Guidance	ALDOT		
Storage Sizing			
Volume Design Storm Event	2-yr, 24-hr		
Spillway Design Storm Event	10-yr, 24-hr		
Min. Volume Requirement	3,600	ft³/ac	✓
Min. Surface Area Requirement	-	ft²/ft²	
Max. Contributing Drainage Area	10	ac	✓
Recommended Drainage Area	2.0	ac	✓
Geometry			
Recommended L:W Ratio	10	ft/ft	★
Max. L:W Ratio	-	ft/ft	
Min. L:W Ratio	2.0	ft/ft	✓
Min. Side Slopes H:V	3.0	ft/ft	✓
Min. Basin Width:Depth Ratio	-	ft/ft	
Recommended Live Storage Depth	4.0	ft	✓
Min. Dead Storage Depth	0.0	ft	✓
Max. Dead Storage Depth	1.0	ft	✓
Min. Total Depth	2.0	ft	✓
Max. Total Depth	5.0	ft	✓
Spillway & Surface Skimmer			
Recommended Spillway Length/Flow Ratio	-	ft/ft³	
Min. Spillway Length	-	ft	
Freeboard above spillway flow	2.0	ft	✓
Min. Detention Time	-	hrs	
Max. Detention Time	72	hrs	✓
Baffles			
No. of Bays	4		✓
Baffle T-Post Spacing	4.0	ft	✓
T-Post Stake Depth	2.0	ft	✓
Maintenance Requirements			
Maintenance Required When:	Sediment Reaches 1/3 Height of Bay 1 Baffle		
Other Notes			
-			









DESIGN SUMMARY

LIVE STORAGE VOLUME:	13,035 ft³	
TOP LENGTH:	145.0 ft	
TOP WIDTH:	72.5 ft	
SIDE SLOPES (H:V):	3:1	
TOTAL BASIN DEPTH:	5.15 ft	
AUX. SPILLWAY LENGTH:	10 ft	
SKIMMER ORIFACE SIZE:	2.1 in	
BAFFLE HEIGHT:	3 ft	

FOR CONCEPTUAL DESIGN PURPOSES ONLY

PROJECT:	DATE:
DESCRIPTION:	REVISION:
LOCATION:	DESIGNED BY:
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BASIN GEOMETRY SIZING

Using geometric relationships for a trapezoidal prism, equations were developed to determine the top width (W_{TOP}), bottom width (W_{BOT}), bottom length (L_{BOT}), dead and live storage volume (V_{DS} & V_{LS}), spillway and freeboard volume (V_{FB}), total volume (V_{Total}), and total basin surface area (SA).

Based on performed calculations of V_{LS} and input basin configuration parameters, a VBA encoded button CLICK WHEN RED TO SIZE SEDIMENT BASIN can then be used. When clicked, the VBA runs Excel's solver tool to determine a L_{TOP} that results in the calculated V_{LS} equal to the design sediment basin volume.

A green outlined button indicates code successfully solved for design parameters.

$$V_{total} = \frac{D_T}{6}\left[L_{TOP}W_{TOP} + (L_{TOP} + L_{BOT})(W_{TOP} + W_{BOT}) + L_{BOT}W_{BOT}\right]$$

AUXILIARY WEIR AND SURFACE SKIMMER DESIGN

Auxiliary weirs allow flow to pass through the basin when storage is exceeded. Weir flow depth is calculated based on the design spillway flow rate, Q_{SW} (ft³/s or m³/s), and length of spillway, L_{SW} (ft or m), using the broad crested weir equation.

Appropriate sizing of the floating surface skimmer is necessary to achieve dewatering within the desired dewatering time. SEDspread calculates the required dewatering rate, Q_{skim} (ft³/hr or m³/hr), by dividing the calculated V_{LS} of the basin by the user defined desired dewatering time (T_{skim}). This is used to select a skimmer orifice diameter based on open orifice relationships.

$$D_{SW} = \left[\frac{Q_{SW}}{(2/3)^{\frac{3}{2}} g^{\frac{1}{2}} L_{SW}}\right]^{\frac{2}{3}} \qquad Q = C_d\left(\frac{1}{4}d^2\right)\sqrt{2gh} \qquad \emptyset_{skim} = xQ_{skim}^{\frac{2}{5}}$$

DESIGN OUTPUTS

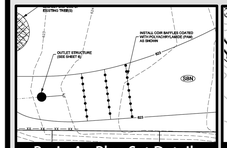
- Calculated design parameters are provided in the **Basin Design Worksheet** and are summarized in the **Cut Sheet Worksheet**.
- **Cut Sheet** depicts a summary of the designed basin configuration on a typical CAD drawing. Design dimensions are overlaid on CAD drawings, which are linked to parameters in the **Basin Design Worksheet**.
- Two plots depicting the stage-storage relationship and dewatering schedule are also included.

CASE STUDY

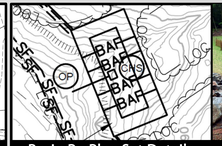
Used to demonstrate the applicability of the developed design tool in improving current design practices. Two projects in Auburn, AL with sediment basins were identified: (1) Basin A located on a commercial development, and (2) Basin B located on a residential subdivision.

Original Design Basis: 3,600 ft³/ac (250 m³/ha) of drainage

SEDspread Design Basis: 2-yr, 24-hr rainfall event



Basin A - Plan Set Details



Basin B - Plan Set Details

Basin B - As Built

Basin A - As Built

Design Summary for Basin A and Basin B using SEDspread

Parameter	Basin A	Basin B
ZIP Code	36830	36832
CN	92.9	89.0
2-yr, 24-hr P, in. (cm)	4.18 (10.61)	4.18 (10.61)
Calculated VSF, ft³/ac (m³/ha)	12,148 (850.0)	10,724 (750.4)
Contributory Drainage Basin, ac (ha)	1.73 (0.70)	6.3 (2.55)
Calculated Volume, ft³ (m³)	22,669 (641.9)	74,148 (2099.6)
As-Designed Volume, ft³ (m³)	6,228 (176.4)	22,680 (642.3)
Factor of Difference	3.6	3.3

Comparing the input parameters, we see that although the projects are located in the same city, CN values differ, resulting in a VSF difference of 12% between the two sites. The calculated storage volumes for Basin A is 22,669 ft³ (642 m³), which is 3.6 times larger than the originally designed containment volume. Similarly, Basin B was under designed to the 2-yr, 24-hr rainfall event by a factor of 3.3.

CONCLUSIONS

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- Developed to effectively design sediment basins based on geospatially derived hydrologic data.
- Allows designers to efficiently and effectively design sediment basins using local hydrologic conditions.
- SEDspread designs enhance communication between designers and construction personnel to facilitate proper basin construction.