MEMORANDUM

TO : **Brant Gary, Interim City Manager**
Michael Leech, Director of Public Works

FROM : **James Andrews, P.E., City Engineer**
Marcus McRae

DATE : **October 12, 2020**

SUBJECT : **Sidewalk Charter Amendment Propositions – Engineering Fiscal Impact**

As requested, we estimated the engineering fiscal impacts related to the proposed Charter Amendment Propositions associated with sidewalk improvements. The calculations below assume 4-foot sidewalks and provide fiscal impacts per block for sidewalks on one side of the street and fiscal impacts per block for sidewalks on both sides of the street. An average block length of 555 LF was assumed. Each fiscal impact also includes a cost per linear foot that may be applied to determine a city wide fiscal impact based on the linear feet of sidewalk in the city.

PROPOSITION A

Proposition A requires a detailed written information consisting of the exact location of such each proposed sidewalk in relationship to all trees, landscaping, fencing, sprinkler systems, and drainage lines, and a hydrological study performed by an independent engineer not otherwise affiliated with the city or the project, such written information to be provided to each such owner on or before the date that is six (6) months prior to the city council's consideration of the ordinance for construction of such sidewalk.

We evaluated the engineering fiscal impact for two (2) different sidewalk construction project scenarios for Proposition A. The first scenario consists of a "Comprehensive Infrastructure Project" where a new sidewalk(s) is constructed as part of a total block reconstruction project. The second scenario consists of new sidewalk construction as a "Stand-Alone Sidewalk Project" without improvements to the adjacent roadway.

"Comprehensive Infrastructure Project" – Estimated Design and Engineering Fee

The potential impact for a "Comprehensive Infrastructure Project" where design has occurred for sidewalk installation, but the sidewalk was removed from the construction contract would be the cost of design phase services paid for the design of the proposed sidewalk. Engineering and design fees can be based on a percentage of the estimated construction cost of a project. To determine the estimated fiscal impact to the City, should the already designed sidewalks be removed from construction, we reviewed the estimated construction cost with and without

sidewalks for the Group C Phase 3 project. According to Kaluza Inc., the firm selected by the City to design and perform construction administration services for the Group C Phase 3 project, their 90% cost estimate for the construction cost is estimated at $4,323,150.15 with sidewalks and $4,153,165.00 without sidewalks. For this fee analysis, 10% of the estimated construction costs are assumed for engineering and design fees with 8.0% of that comprising of all design elements of and 2.0% of the fee comprising of construction administration services. Applying 8.0% design fees, the difference between the fees is approximately $13,600.00. Group C Phase 3 anticipated approximately 5,000 LF of sidewalk installation therefore the engineering and design for sidewalks for this particular project was approximately $2.75 per linear foot of sidewalk. Therefore, it is estimated that the fiscal impact for a 555 LF residential block would be approximately **$1,525** for sidewalk on one (1) side of the roadway and **$3,050** for a sidewalk on both sides of the roadway.

"Stand-Alone Sidewalk Project" – Estimated Design and Engineering Fee

The potential fiscal impact for "Stand-Alone Sidewalk Project" where design has occurred, but has not been authorized for construction would be the cost for the design fees. Engineering design fees for "Stand-Alone Sidewalk Projects" is approximately 10% of the estimated construction costs with 8.0% of the fee comprising of all design elements and 2.0% of the fee comprising of construction administration services. For example, Group D Phase 1 estimated a construction cost of approximately $1.5 Million. An 8.0% engineering and design fee for a project of this size would be $120,000. Group D Phase 1 was estimated to include the installation of approximately 15,000 linear feet of sidewalks. Therefore the engineering and design for "Stand-Alone Sidewalk Projects" would be approximately $8 per linear foot of sidewalk designed. With an average block length of 555 LF the fiscal impact of engineering and design fees would be **$4,440** per block for sidewalk on one side of the street, and **$8,880** per block for sidewalks on both sides of the street.

Additional Surveying Efforts

Proposition A would result in an increased level of effort for surveying services. The Scope of Services for topographic survey typically does not include locating every residential sprinkler system component. Typically provisions are included in the design drawings and the construction contract to mitigate damages to residential sprinkler systems. Contractors are typically responsible for restoring the project site to its original condition or better, including sprinkler systems. However, should the design drawings and surveying scope of services include the location of residential sprinkler systems, the increased level of efforts for would result in an increased surveying price for services of approximately 50% for surveying services. Average linear for cost for full topographical survey work in Bellaire has been approximately $3.50 per linear foot. The 50% cost increase would result in a total linear foot cost of $5.25. The fiscal impact based on the price increase would be approximately **$975** per block.

Independent Hydrological Study

It is estimated that the fiscal impact for an independent hydrological study, would be approximately **$750** per residential block for an engineer to review the hydrological impact of additional impervious cover based on similar calculations provided with this memo and coordinate with the City as needed.

PROPOSITION B

Proposition B indicates that no sidewalks shall be constructed by the City of Bellaire on any block zoned by the city for residential use without the written approval of at least fifty percent (50%) of the owners of real property located on such block, such approval to be obtained no more than three (3) months prior to the commencement of such construction.

Proposition B does not appear to have any fiscal impact from and Engineering and Design Standpoint.

PROPOSITION C

Proposition C indicates that the city of Bellaire shall not construct any sidewalk on any block zoned by the city for residential use, unless the city concurrently eliminates the impact of such additional impervious material used in the sidewalk construction on surface water discharge/runoff within the city.

We evaluated the effects of increased impervious cover that would occur by installing a 4' sidewalk on one and both sides of the street and quantified how much additional runoff would occur due to the sidewalk.

Attached are calculations for determining the additional runoff/flow (Q) caused by a sidewalk on a modeled block segment. We used a 1,000 LF residential block length with the following assumptions based on the different residential zones for lot coverage:

55% Maximum Lot Coverage

- 60 LF Right-Of-Way
- 70 LF Lot Width
- 120 LF Lot Depth
- 28 LF Road Width
- 17 LF Driveway Width
- 28 Lots

60% Maximum Lot Coverage

- 50 LF Right-Of-Way
- 50 LF Lot Width
- 100 LF Lot Depth
- 28 LF Road Width
- 17 LF Driveway Width
- 38 Lots

The 1,000 LF block runoff analysis is applicable to the City's 555 LF average residential block length, as well as all other blocks, due to the fact that the percentage increase of runoff is relative to the percentage increase of impervious cover over a particular drainage area.

With these assumptions, we determined the additional impervious cover that would be added by installing a 4' sidewalk on one and both sides of the street and quantified how much additional runoff would occur due to the sidewalk.

In accordance with City of Houston Infrastructure Design Manual, the runoff coefficients (C value) were calculated using the assumptions above along with the different sidewalk scenarios previously mentioned. Higher C values refer to higher percentage of impervious cover therefore resulting in higher flowrate/runoff. The true C value for your block model demonstrates that the C value that would be used for a design project of .55 (COH IDM standard value) actually exceeds the true C values that we calculated for this model block segment.

Description	**C Value**
No Sidewalk	.530
4' Sidewalk on one side of street	.536
4' sidewalk on both sides of street	.542
Design Standard C Value for lots < ¼ acre	.55

The attached Figures 1 thru 4 show the flowrate/runoff (Q) without sidewalk, with 4 sidewalk on one side of the road and with 4' sidewalk on both sides of the road. These flowrate calculations demonstrate that the amount of additional impervious cover caused by the sidewalk creates a very small increase in additional runoff. These calculations were performed for a 2 year and 100 year rainfall event. Both rainfall events demonstrated the same result of not requiring an increase in required pipe capacity due to the addition of a 4' sidewalk. Ultimately, in a "Comprehensive Infrastructure Project," all runoff for a particular drainage area is captured in the proposed underground storm sewer system designed by the Engineer.

We also looked at the "worst case scenario" where a new sidewalk would be installed on a block segment that did not have existing storm sewer. This is where the runoff, and the additional runoff from sidewalks, would be conveyed in the roadway gutter. These calculations were performed in order to determine what, if any, measures would need to occur to mitigate the increase in runoff. We used Manning's equation for depth of flow as a basis for determining the depth of flow in a curb and gutter section for the sample 1000 LF block segment. The attached calculation illustrates the change in water surface elevation (or depth of flow) in the gutter line for the block segment with and without sidewalk. The difference in depth is an increase of approximately 0.04 inches of depth in the gutter line. In order to mitigate this additional depth we would need to grade the gutter line from the assumed .30% slope to a

.31% slope to bring that increase in depth down to what it would be without sidewalks on that block.

Mitigation requirements are site specific and will vary based on the size of the drainage area, the existing storm sewer system in place, if any, topography of adjacent block segments, downstream outfall conditions, and the ability of a block segment to allow over land sheet flow. In general, increased impervious cover does result in increased runoff.

Should a scenario occur where a "Stand-Alone Sidewalk Project" proposed on a block segment where the increased impervious cover results in an increase runoff amount that exceeds the capacity of an existing inlet; the fiscal impact to mitigate the additional runoff would be the cost of the removal of the existing inlet(s) and the installation of a curbside inlet(s) capable of accepting the additional capacity. According to the most recent street reconstruction bids the City has received for Capital Improvements Projects, the cost for removal and replacement of inlets is approximately $4,500 each. Therefore, replacing an inlet on a roadway with sidewalks installed on one (1) side of the street to accommodate the additional runoff could result in approximately **$4,500** per residential block. Streets with sidewalks being installed on both sides of the street could result in inlet replacement on both sides of the street resulting in approximately **$9,000** per residential block.

Should a scenario occur where a "Stand-Alone Sidewalk Project" is proposed on a block segment where there is no existing underground storm sewer system; the fiscal impact to mitigate the additional capacity required in the streets gutter line could be to grind or remove and replace the existing gutter line to gain capacity for the additional runoff. According to most recent street reconstruction bid the City has received for Capital Improvements project, the cost for such work is approximately $15 per linear foot. With an average block length of 555 LF the cost for performing mitigation efforts on one (1) side of the road will be approximately **$8,325** per block for one side of the roadway, and **$16,650** per block for both sides of the roadway.

Should a scenario occur where a "Stand-Alone Sidewalk Project" is proposed on a block segment where there is no existing underground storm sewer system and grinding of the gutter line is not sufficient; the fiscal impact to mitigate the additional capacity required would be the installation of new inlets, new underground storm sewer and a junction structure to tie in to a local storm collector. As previously stated, mitigation requirements are site specific. However, if this scenario occurs it is assumed that the fiscal impact would consist of the installation of an inlet(s), 100 linear feet of 24" storm sewer, pavement replacement, and a junction structure to provide mitigation measures. According to most recent street reconstruction bids the City has received for Capital Improvements project, the cost for inlets is approximately $4,500 each, 24"

RCP is $75 per linear foot, a 4’x4’ junction structure is $5,000 each and concrete pavement replacement is $65 per square yard. This mitigation effort would cost approximately **$21,000**

Figure 1

Drainage Calculations Worksheet

Calculate runoff flowing into existing outfall, and required pipe size:

Criteria:

1.) Use rational method for runoff calculations. (Q=CiA)

2.) Rainfall intensity based on COH Formula: $I=b/(d+t_c)^e$

where b= 75.01 2-year Storm

d= 16.2

e= 0.8315

and $t_c = 10(A)^{0.1761} + 15$ (in minutes)

3.) C = Runoff coefficient

C = .6(Ia)+.2

Ia = Impervious Area/Total Area

ASSUMPTIONS

- 1,000 LF Residential Block
- 60 LF Right - Of - Way
- 70 LF Lot Width
- 120 LF Lot Depth
- 28 LF Road Width
- 17 LF Driveway Width
- 28 Lots
- 55% Maximum Lot Coverage

Total Area for 1000 LF Residential Block = 6.89 Acres

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
2-year storm w/ No SW	**6.89**	0.530	29.047	3.151	**11.503**	3	**3.83**	**26.51**	**30.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
2-year storm w/ 4' SW	**6.89**	0.536	29.047	3.151	**11.633**	3	**3.88**	**26.66**	**30.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
2-year storm w/ 4' SW Both Sides	**6.89**	0.542	29.047	3.151	**11.763**	3	**3.92**	**26.81**	**30.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Pipe Diameter Installed, (in)
Maximum C (Runoff Coefficient) for Pipe	**6.89**	0.678	29.047	3.151	**14.719**	3	**30.00**

***C = .55 is standard design value for Residential Lots < 1/4 Acre

C' Factors Used in City of Houston	
0.35	Residental Lots > 1/2 Acre
0.45	Residental Lots 1/4 to 1/2 Acre
0.55	Residental Lots < 1/4 Acre
0.65	MultiFamily less than 20 units / acre
0.80	MultiFamily 20 or greater units / acre
0.80	Parking / Business District
0.65	Industrial District Light areas
0.75	Industrial District Heavy areas
0.30	Railroad Yards
0.18	Parks / Open area

Figure 2

Drainage Calculations Worksheet

Calculate runoff flowing into existing outfall, and required pipe size:

Criteria:

1.) Use rational method for runoff calculations. (Q=CiA)

2.) Rainfall intensity based on COH Formula: $I=b/(d+t_c)^e$

where b= 125.4 100-year storm

d= 21.8

e= 0.75

and $t_c = 10(A)^{0.1761} + 15$ (in minutes)

3.) C = Runoff coefficient

C = .6(Ia)+.2

Ia = Impervious Area/Total Area

ASSUMPTIONS

- 1,000 LF Residential Block
- 60 LF Right - Of - Way
- 70 LF Lot Width
- 120 LF Lot Depth
- 28 LF Road Width
- 17 LF Driveway Width
- 28 Lots
- 55% Maximum Lot Coverage

Total Area for 1000 LF Residential Block = 6.89 Acres

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
100-year storm w/ No SW	**6.89**	0.530	29.047	6.586	**24.039**	3	**8.01**	**38.33**	**42.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
100-year storm w/ 4' SW	**6.89**	0.536	29.047	6.586	**24.311**	3	**8.10**	**38.55**	**42.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
100-year storm w/ 4' SW Both Sides	**6.89**	0.542	29.047	6.586	**24.583**	3	**8.19**	**38.76**	**42.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*			Pipe Diameter Installed, (in)
Maximum C (Runoff Coefficient) for Pipe Installed	**6.89**	0.636	29.047	6.586	**28.849**	3			**42.00**

***C = .55 is standard design value for Residential Lots < 1/4 Acre

Maximum C = 0.00

C' Factors Used in City of Houston	
0.35	Residental Lots > 1/2 Acre
0.45	Residental Lots 1/4 to 1/2 Acre
0.55	Residental Lots < 1/4 Acre
0.65	MultiFamily less than 20 units / acre
0.80	MultiFamily 20 or greater units / acre
0.80	Parking / Business District
0.65	Industrial District Light areas
0.75	Industrial District Heavy areas
0.30	Railroad Yards
0.18	Parks / Open area

Figure 3

Drainage Calculations Worksheet

Calculate runoff flowing into existing outfall, and required pipe size:

Criteria:

1.) Use rational method for runoff calculations. (Q=CiA)

2.) Rainfall intensity based on COH Formula: $I=b/(d+t_c)^e$

where b= 75.01 2-year Storm

d= 16.2

e= 0.8315

and $t_c = 10(A)^{0.1761} + 15$ (in minutes)

3.) C = Runoff coefficient

C = .6(Ia)+.2

Ia = Impervious Area/Total Area

ASSUMPTIONS

- 1,000 LF Residential Block
- 50 LF Right - Of - Way
- 50 LF Lot Width
- 100 LF Lot Depth
- 28 LF Road Width
- 17 LF Driveway Width
- 38 Lots
- 60% Maximum Lot Coverage

Total Area for 1000 LF Residential Block = 5.74 Acres

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
2-year storm w/ No SW	**5.74**	0.558	28.603	3.177	**10.175**	3	**3.39**	**24.94**	**30.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
2-year storm w/ 4' SW	**5.74**	0.564	28.603	3.177	**10.285**	3	**3.43**	**25.07**	**30.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
2-year storm w/ 4' SW Both Sides	**5.74**	0.566	28.603	3.177	**10.321**	3	**3.44**	**25.12**	**30.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Pipe Diameter Installed, (in)
Maximum C (Runoff Coefficient) for Pipe	**5.74**	0.807	28.603	3.177	**14.719**	3	**30.00**

***C = .55 is standard design value for Residential Lots < 1/4 Acre

C' Factors Used in City of Houston	
0.35	Residental Lots > 1/2 Acre
0.45	Residental Lots 1/4 to 1/2 Acre
0.55	Residental Lots < 1/4 Acre
0.65	MultiFamily less than 20 units / acre
0.80	MultiFamily 20 or greater units / acre
0.80	Parking / Business District
0.65	Industrial District Light areas
0.75	Industrial District Heavy areas
0.30	Railroad Yards
0.18	Parks / Open area

Figure 4

Drainage Calculations Worksheet

Calculate runoff flowing into existing outfall, and required pipe size:

Criteria:

1.) Use rational method for runoff calculations. (Q=CiA)

2.) Rainfall intensity based on COH Formula: $I=b/(d+t_c)^e$

where b= 125.4 100-year storm

d= 21.8

e= 0.75

and $t_c = 10(A)^{0.1761} + 15$ (in minutes)

3.) C = Runoff coefficient

C = .6(Ia)+.2

Ia = Impervious Area/Total Area

ASSUMPTIONS

- 1,000 LF Residential Block
- 50 LF Right - Of - Way
- 50 LF Lot Width
- 100 LF Lot Depth
- 28 LF Road Width
- 17 LF Driveway Width
- 38 Lots
- 60% Maximum Lot Coverage

Total Area for 1000 LF Residential Block = 5.74 Acres

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
100-year storm w/ No SW	**5.74**	0.558	28.603	6.629	**21.230**	3	**7.08**	**36.02**	**42.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
100-year storm w/ 4' SW	**5.74**	0.564	28.603	6.629	**21.458**	3	**7.15**	**36.21**	**42.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*	Min. Area (ft^2)	Min. Pipe Diameter, (in)	Pipe Diameter Installed, (in)
100-year storm w/ 4' SW Both Sides	**5.74**	0.566	28.603	6.629	**21.534**	3	**7.18**	**36.28**	**42.00**

Description	Acres	C	TC	I	Q, (cfs)	Assumed Flow V.(f/s)*			Pipe Diameter Installed, (in)
Maximum C (Runoff Coefficient) for Pipe	**5.74**	0.758	28.603	6.629	**28.849**	3			**42.00**

***C = .55 is standard design value for Residential Lots < 1/4 Acre

C' Factors Used in City of Houston	
0.35	Residental Lots > 1/2 Acre
0.45	Residental Lots 1/4 to 1/2 Acre
0.55	Residental Lots < 1/4 Acre
0.65	MultiFamily less than 20 units / acre
0.80	MultiFamily 20 or greater units / acre
0.80	Parking / Business District
0.65	Industrial District Light areas
0.75	Industrial District Heavy areas
0.30	Railroad Yards
0.18	Parks / Open area

55%

CLIENT _____ PREPARED BY _____ DATE _____

PROJECT _____ CHECKED BY _____ DATE _____

* 1000 LF Block
* 60' R-O-W
* Lot Width → 70'
* Lot Depth → 120'
* Road → 28'
* SW 4' one side
  ↳ 4' Both Side
* Dway → 17'
* 28 Lots

$C = .6(I_a) + .2$

$I_a = \frac{\text{Impervious Area}}{\text{Total Area}}$

$I_{a(1\,side)} = \frac{168,024}{300,000} = .56$

$C_{(1\,side)} = .6(.56) + .2 = \boxed{.536}$ @55%

$I_{a(Both)} = \frac{171,072}{300,000} = .57$

$C_{(Both)} = .6(.57) + .2 = \boxed{.542}$ @55%

$I_{a(No\,SW)} = \frac{164,976}{300,000} = .55$

$C_{(No\,SW)} = .6(.55) + .2 = \boxed{.530}$ @55%

Total Area

* TA = 1000 * (120 + 60 + 120) = 300,000 SF

Impervious Area

* Road = 1000' * 28' = 28,000 SF
* SW = (1 side) = 762 LF * 4' = 3,048 SF

  (Both) = 2968 SF * 2 = 6,096 SF
* Driveway = 17' Dway * 16' ROW = 272 SF

  272 SF * 28 Lots = 7616 SF
* Lots = Area / Lot = 70 * 120 = 8400 SF

  @ 55% Imp ≈ 4620 SF/Lot * 28 = 129,360 SF

  @ 60% Imp ≈ 5040 SF/Lot * 28 = 141,120 SF

Total Impervious Area = 168,024 SF (1 side) @55%

Total Impervious Area = 171,072 SF (Both Sides) @55%

Total Impervious Area = 164,976 SF (No SW) @55%

CLIENT _____ PREPARED BY _____ DATE _____

PROJECT _____ CHECKED BY _____ DATE _____

60%

* 1000 LF Block
* 50' R-o-w-
* Lot Width → 50'
* Lot Depth → 100'
* Road → 28'
* Dvwy → 17'
* 38 Lots

$C = .6(I_a) + .2$

$I_a = \frac{\text{Impervious Area}}{\text{Total Area}}$

$I_{a(1\,side)} = \frac{151,814}{250,000} = .607$

$C_{(1\,side)} = .6(.607) + .2 = \boxed{.564}$

$I_{a(Both)} = \frac{154,522}{250,000} = .618$

$C_{(Both)} = .6(.618) + .2 = \boxed{.566}$

$I_{a(No\,SW)} = \frac{149,106}{250,000} = .596$

$C_{(No\,SW)} = .6(.596) + .2 = \boxed{.558}$

Total Area

* Total Area = 1000 * (100 + 50 + 100) = 250,000 SF

Impervious Area

* Road = 1000' * 28' = 28,000 SF
* SW = (1 side) = 677 LF * 4' = 2,708 SF

(Both) ~ 2708 * 2 = 5,416 SF

* Dvwy = 17' Dvwy * 11' R-o-w = 187 SF

187 SF * 38 Lots = 7,106 SF

* Lots = 50' x 100' = 5000 SF x 38 = 190,000

@ 60% Imp = 114,000 SF

Total Impervious Area = 151,814 SF (1 side)

Total Impervious Area = 154,522 SF (Both)

Total Impervious Area; 149,106 SF (No SW)

CLIENT _____ PREPARED BY _____ DATE _____

PROJECT _____ CHECKED BY _____ DATE _____

Depth of Flow

$$y = z\left(\frac{Q\,n\,S_x}{S^{1/2}}\right)^{3/8}$$

y = Depth of Flow (ft)
z = 1.24
Q = runoff/flowrate (cfs)
n = roughness
S = Longitudinal Slope
S_x = Pvmt cross slope

No SW

$$y = 1.24\left(\frac{5.928\,(0.13)(.025)}{(.003)^{1/2}}\right)^{3/8}$$

$Q = \underset{\text{Total}}{11.503}$ cfs / $\underset{\text{One Side}}{5.928}$ cfs
$S = .003$, $S_x = .025$

$y = .353$ ft $\approx$ $\boxed{4.24\text{ in}}$ deph in gutter on each side of road.

w/ SW

$$y = \left(\frac{6.062\,(0.13)(.025)}{(.003)^{1/2}}\right)^{3/8}$$

$Q = \underset{\text{Total}}{11.633}$ / $\underset{\text{SW side}}{6.062}$ cfs
$S = .003$, $S_x = .025$

$y = .356$ ft $\approx$ $\boxed{4.28\text{ in}}$ depth in gutter on SW side of road.

* Slope required to mitigate additional depth goes from <u>.3%</u> to <u>.314%</u>