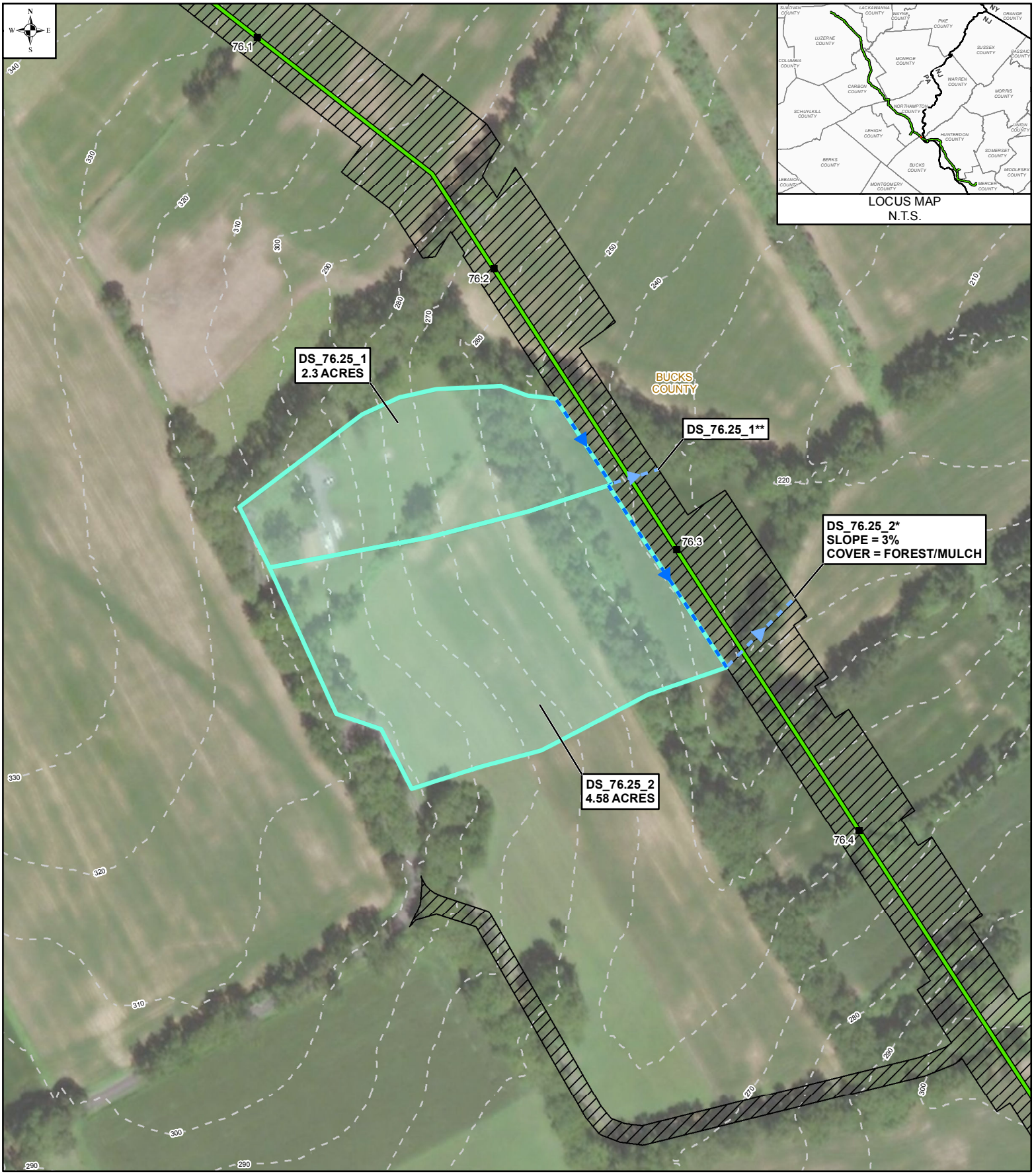
Appendix 2E
Bucks County



LEGEND

- 1R — MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_76.25

BUCKS COUNTY, PENNSYLVANIA

DRAWN BY:	SNP 10/2018	**APPROVED BY:**	MJD 10/2019	**SCALE:**	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	**REV. DATE:**	10/2019	**REV.:**	1

0 100 200 FEET

PennEast PIPELINE

DWG NO: PAGE 100 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_76.25_1
2.3 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 76.25_1	100	0.02	0.090	2.01

$$T_{c\,(sheet\ flow)} = \left[\frac{2(\quad)(n)}{3(\quad)^{0.5}}\right]^{0.4673}$$

n	Type of Cover
0.02	smooth pavement
0.1	bare parched soil
0.3	poor grass cover
0.4	average grass cover
0.8	dense grass cover

(L = 150' maximum)

SHALLOW CONCENTRATED FLOW:

PATH NUMBER	LENGTH (ft)	TYPE OF COVER	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 76.25_1	309	SHORT GRASS	0.123	2.44	2.11
	148	FOREST	0.101	0.80	3.08

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
7.20

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 76.25_1	1	PASTURE	0.50	0.22	0.11	0.31
	2	OPEN SPACE	0.28	1.47	0.41	
	3	INDUSTRIAL	0.69	0.15	0.10	
	4	FOREST	0.20	0.46	0.09	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	7.20	4.38	5.15	5.63	4.38	5.15	5.63

DETERMINE PEAK RUNOFF RATES (Q = C x I x A)

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.31	4.38	2.30	3.14	3.69	4.04

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: BUCKS COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_76.25_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	2.3		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.14		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	6.11		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	4.89		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.19		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	10 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	10.00		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.00		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.25		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.038		
S_C (CRITICAL SLOPE)	(FT/FT)	0.013		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.017		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ Total Channel Depth, whichever is greater.
5. Permissible velocity lining design method is not acceptable for channels with a bed slope of 10% or greater. Shear stress lining design method is required for channels with a bed slope of 10% or greater. Shear stress lining design method may be used for any channel bed slope.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_76.25_2
4.58 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 76.25_2	100	0.4	0.100	7.94

$$T_{c\,(sheet\ flow)} = \left[\frac{2(\quad)(n)}{3(\quad)^{0.5}}\right]^{0.4673}$$

n	Type of Cover
0.02	smooth pavement
0.1	bare parched soil
0.3	poor grass cover
0.4	average grass cover
0.8	dense grass cover

(L = 150' maximum)

SHALLOW CONCENTRATED FLOW:

PATH NUMBER	LENGTH (ft)	TYPE OF COVER	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 76.25_2	308	SHORT GRASS	0.136	2.57	2.00
	93	FOREST	0.108	0.83	1.87
	49	SHORT GRASS	0.143	2.63	0.31

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
12.13

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 76.25_2	1	PASTURE	0.50	2.03	1.02	0.36
	2	OPEN SPACE	0.28	1.59	0.45	
	3	FOREST	0.20	0.96	0.19	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	12.13	3.64	4.34	4.84	3.64	4.34	4.84

DETERMINE PEAK RUNOFF RATES (Q = C x I x A)

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.36	3.64	4.58	6.01	7.17	8.00

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: BUCKS COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_76.25_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	4.58		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	6.01		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	17.56		
PROTECTIVE LINING[2,6]		SC150		
n (MANNING'S COEFFICIENT)[2]		0.039		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	3.86		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.87		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	9.09 / 0		
D (TOTAL DEPTH)	(FT)	1.50		
CHANNEL TOP WIDTH @ D	(FT)	13.64		
d (CALCULATED FLOW DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	9.09		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	4.55		
R (HYDRAULIC RADIUS)		0.45		
S (BED SLOPE)[3, 7]	(FT/FT)	0.03		
S_C (CRITICAL SLOPE)	(FT/FT)	0.032		
$.7S_c$	(FT/FT)	0.023		
$1.3S_c$	(FT/FT)	0.042		
STABLE FLOW?	(Y/N)	N		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	0.50		
FREEBOARD BASED ON STABLE FLOW	(FT)	N/A		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

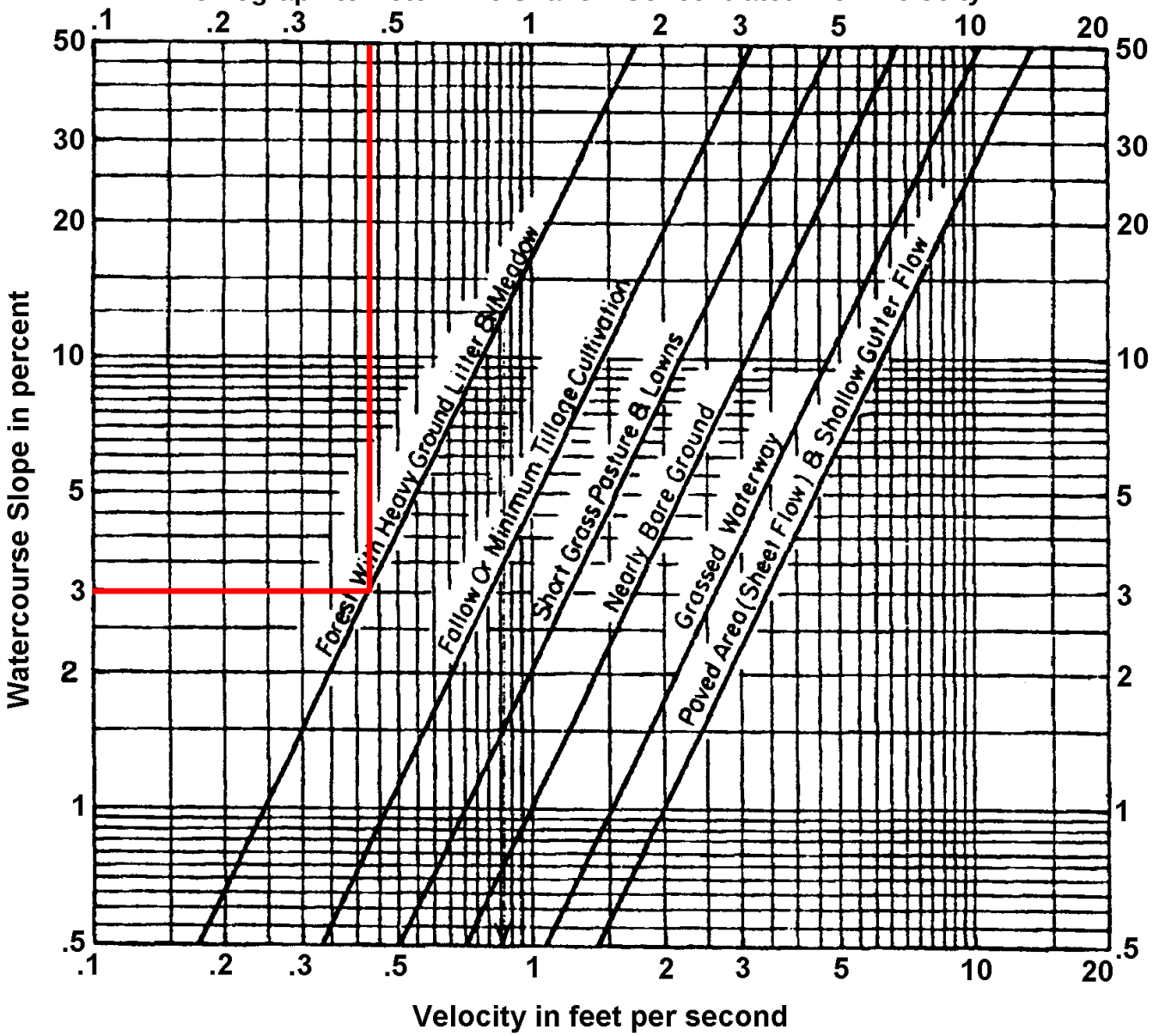
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ Total Channel Depth, whichever is greater.
5. Permissible velocity lining design method is not acceptable for channels with a bed slope of 10% or greater. Shear stress lining design method is required for channels with a bed slope of 10% or greater. Shear stress lining design method may be used for any channel bed slope.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_76.25_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

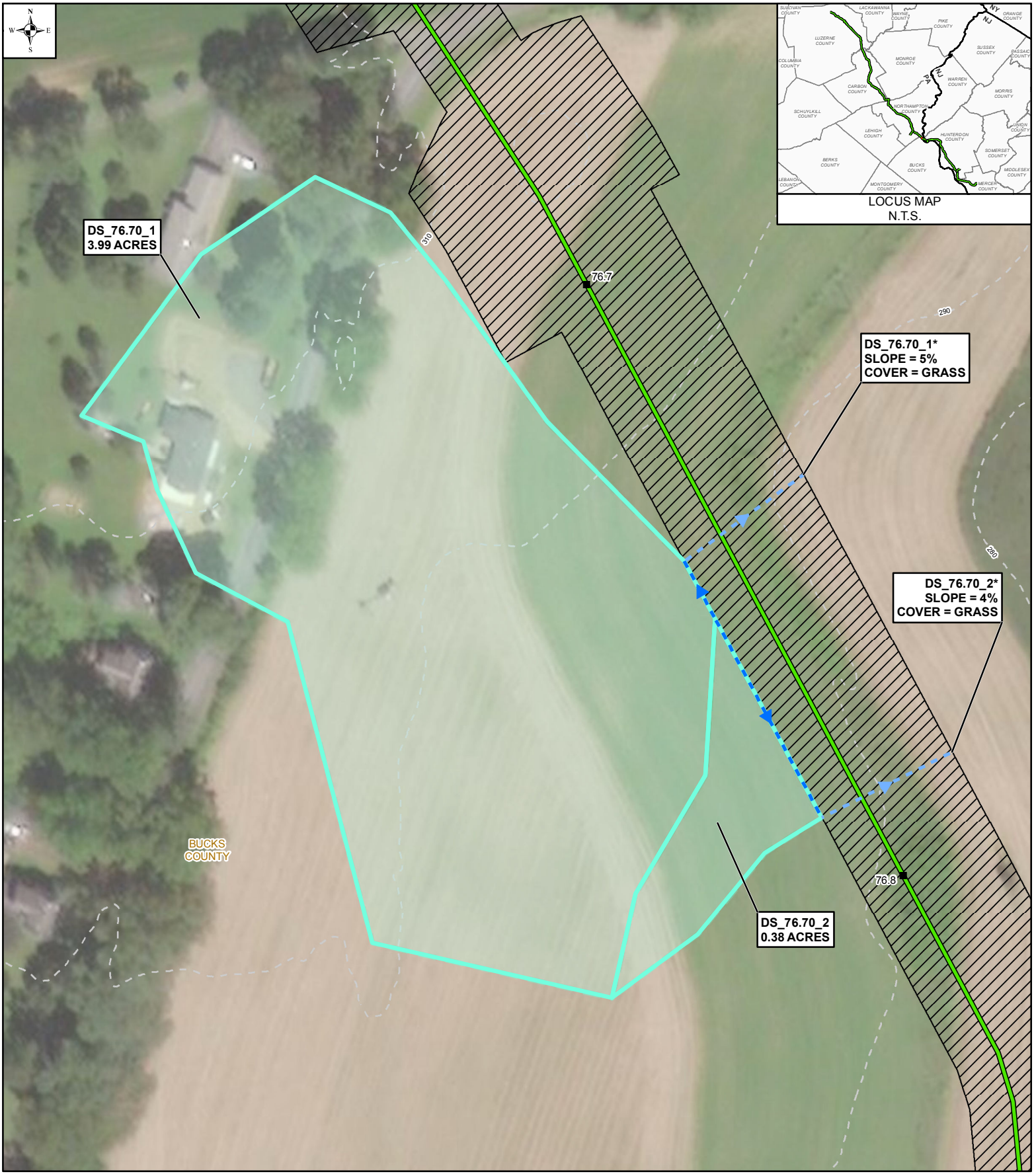


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 3%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.4 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.4 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R — MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_76.70

BUCKS COUNTY, PENNSYLVANIA

DRAWN BY: SNP 10/2018	**APPROVED BY:** MJD 10/2019	**SCALE:** 1 INCH = 100 FEET
CHECKED BY: JMB 10/2019	**REV. DATE:** 10/2019	**REV.:** 1

0 50 100 FEET

PennEast PIPELINE

DWG NO: PAGE 101 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_76.70_1
3.99 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 76.70_1	100	0.4	0.030	10.52

$$T_{c\,(sheet\ flow)} = \left[\frac{2(\quad)(n)}{3(\quad)^{0.5}}\right]^{0.4673}$$

n	Type of Cover
0.02	smooth pavement
0.1	bare parched soil
0.3	poor grass cover
0.4	average grass cover
0.8	dense grass cover

(L = 150' maximum)

SHALLOW CONCENTRATED FLOW:

PATH NUMBER	LENGTH (ft)	TYPE OF COVER	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 76.70_1	326	SHORT GRASS	0.052	1.59	3.42

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
13.95

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 76.70_1	1	PASTURE	0.50	3.16	1.58	0.48
	2	OPEN SPACE	0.28	0.59	0.17	
	3	INDUSTRIAL	0.69	0.24	0.17	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	13.95	3.43	4.10	4.60	3.43	4.10	4.60

DETERMINE PEAK RUNOFF RATES (Q = C x I x A)

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.48	3.43	3.99	6.55	7.83	8.79

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: BUCKS COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_76.70_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	3.99		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	6.55		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	16.80		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	3.63		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.59		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	37.04 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	37.04		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	18.52		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	4.63		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.019		
S_C (CRITICAL SLOPE)	(FT/FT)	0.012		
$.7S_c$	(FT/FT)	0.008		
$1.3S_c$	(FT/FT)	0.015		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

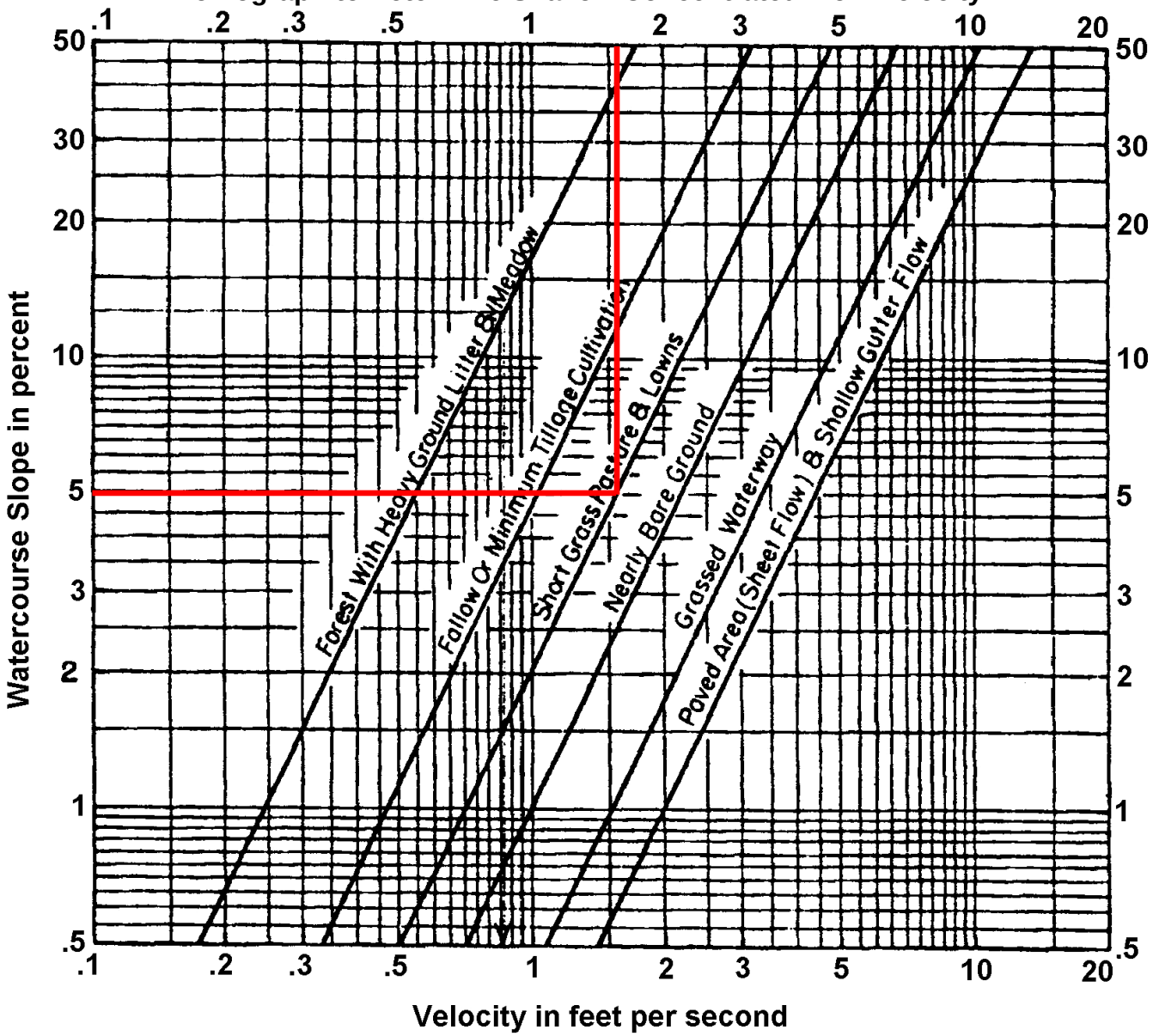
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ Total Channel Depth, whichever is greater.
5. Permissible velocity lining design method is not acceptable for channels with a bed slope of 10% or greater. Shear stress lining design method is required for channels with a bed slope of 10% or greater. Shear stress lining design method may be used for any channel bed slope.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_76.70_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 5%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.6 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.6 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_76.70_2
0.38 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 76.70_2	100	0.4	0.020	11.57

$$T_{c\,(sheet\ flow)} = \left[\frac{2(\quad)(n)}{3(\quad)^{0.5}}\right]^{0.4673}$$

n	Type of Cover
0.02	smooth pavement
0.1	bare parched soil
0.3	poor grass cover
0.4	average grass cover
0.8	dense grass cover

(L = 150' maximum)

SHALLOW CONCENTRATED FLOW:

PATH NUMBER	LENGTH (ft)	TYPE OF COVER	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 76.70_2	216	SHORT GRASS	0.014	0.82	4.37

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
15.94

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 76.70_2	1	PASTURE	0.40	0.38	0.15	0.40

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	15.94	3.22	3.86	4.37	3.22	3.86	4.37

DETERMINE PEAK RUNOFF RATES (Q = C x I x A)

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	3.22	0.38	0.49	0.59	0.66

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: BUCKS COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_76.70_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	0.38		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.49		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	0.65		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.27		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.10		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	37.04 / 0		
D (TOTAL DEPTH)	(FT)	0.67		
CHANNEL TOP WIDTH @ D	(FT)	24.69		
d (CALCULATED FLOW DEPTH)	(FT)	0.17		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.17		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.51		
R (HYDRAULIC RADIUS)		0.08		
S (BED SLOPE)[3, 7]	(FT/FT)	0.01		
S_C (CRITICAL SLOPE)	(FT/FT)	0.017		
$.7S_c$	(FT/FT)	0.012		
$1.3S_c$	(FT/FT)	0.022		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

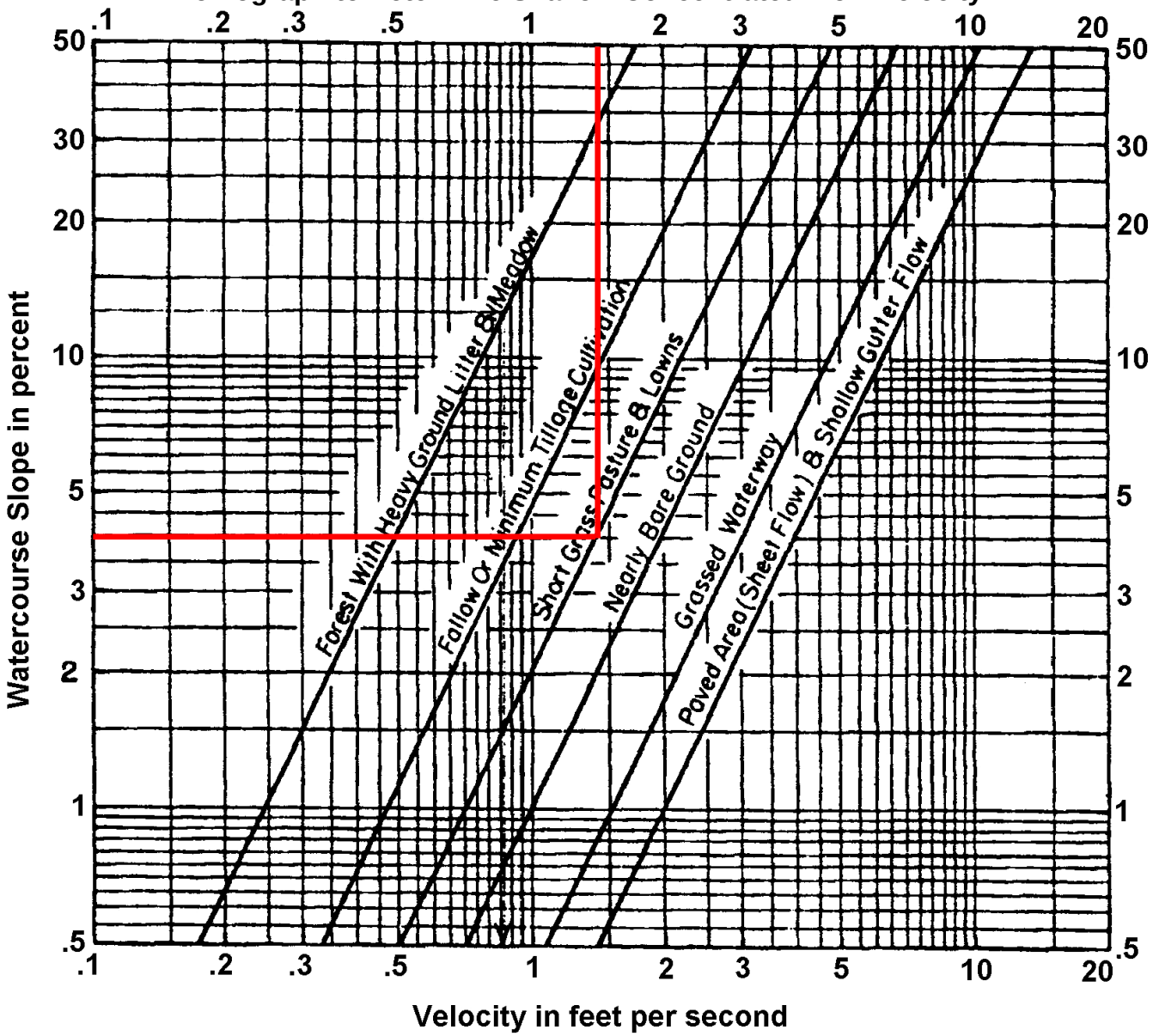
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ Total Channel Depth, whichever is greater.
5. Permissible velocity lining design method is not acceptable for channels with a bed slope of 10% or greater. Shear stress lining design method is required for channels with a bed slope of 10% or greater. Shear stress lining design method may be used for any channel bed slope.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_76.70_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

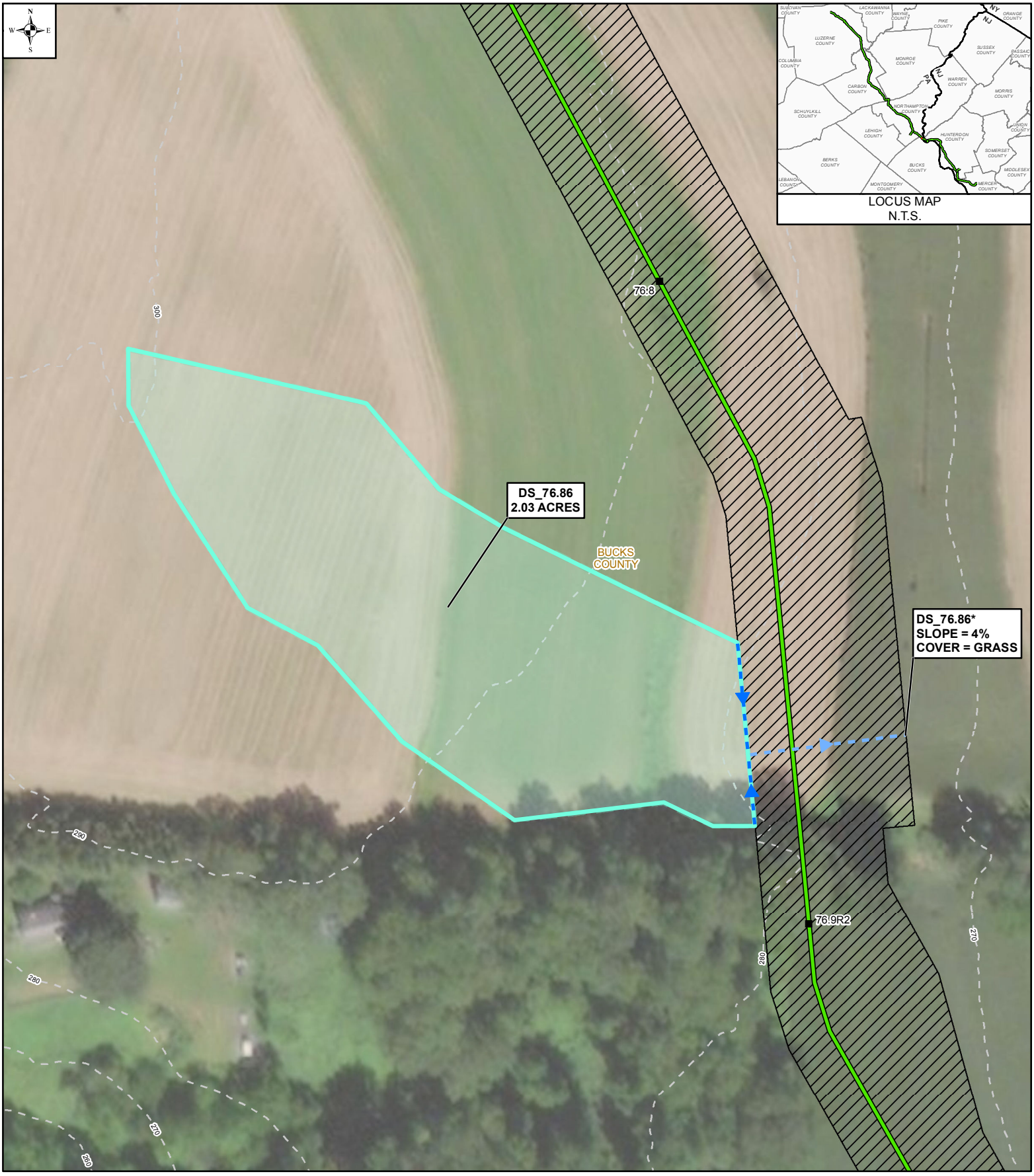


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 4%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.4 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.4 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R — MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_76.86

BUCKS COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY: SNP 10/2018	**APPROVED BY:** MJD 10/2019	**SCALE:** 1 INCH = 100 FEET
CHECKED BY: JMB 10/2019	**REV. DATE:** 10/2019	**REV.:** 1

DWG NO: PAGE 102 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 76.86	100	0.4	0.020	11.57

$$T_{c\,(sheet\ flow)} = \left[\frac{2(\quad)(n)}{3(\quad)^{0.5}}\right]^{0.4673}$$

n	Type of Cover
0.02	smooth pavement
0.1	bare parched soil
0.3	poor grass cover
0.4	average grass cover
0.8	dense grass cover

(L = 150' maximum)

SHALLOW CONCENTRATED FLOW:

PATH NUMBER	LENGTH (ft)	TYPE OF COVER	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 76.86	596	SHORT GRASS	0.030	1.21	8.24

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
19.81

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: BUCKS COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 76.86	1	PASTURE	0.40	2.03	0.81	0.40

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	19.81	2.88	3.48	3.97	2.88	3.48	3.97

DETERMINE PEAK RUNOFF RATES (Q = C x I x A)

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	2.88	2.03	2.34	2.82	3.22

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: BUCKS COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_76.86		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	2.03		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.34		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.48		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.36		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.87		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	20.41 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	20.41		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	10.20		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	2.55		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.028		
S_C (CRITICAL SLOPE)	(FT/FT)	0.121		
$.7S_c$	(FT/FT)	0.085		
$1.3S_c$	(FT/FT)	0.157		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ Total Channel Depth, whichever is greater.
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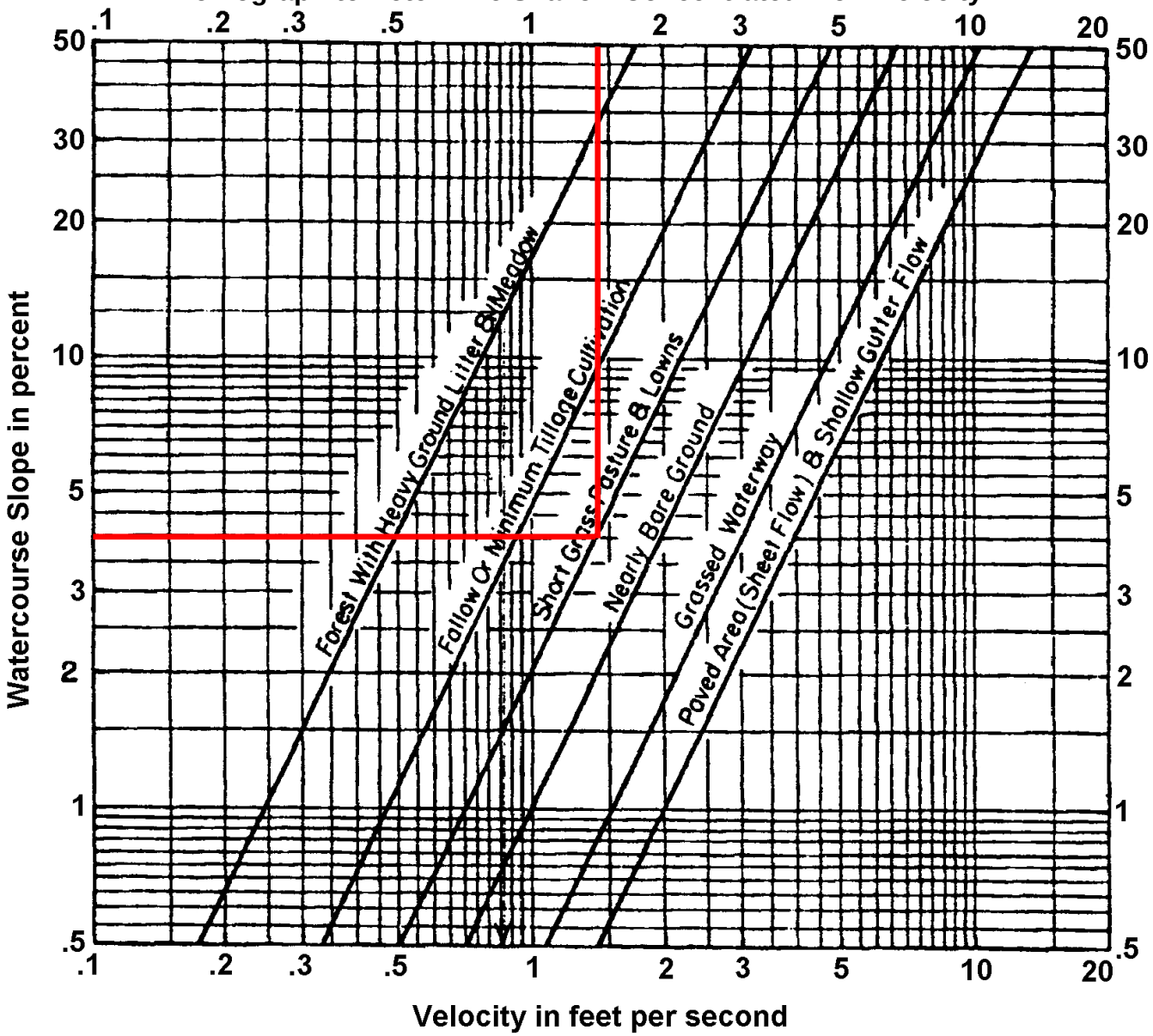
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_76.86

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 4%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.4 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.4 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.