GRASSED WATERWAY UNDERDRAINS

This EFM supplement has been developed to provide guidance in applying the concept of and designing underdrains for grassed waterways.

Background

Many grassed waterways in Indiana are constructed in areas where geologic or hydrologic conditions result in seepage or prolonged base flow. This nearly continuous, small flow results in waterways that are difficult to establish and maintain. Some type of surface inlet and underdrain are frequently installed to deal with the situation.

In the past, waterway underdrains have been designed in two ways. One approach is where the drain was sized only large enough to remove the soil moisture from the waterway area itself. This usually resulted in a minimum size drain with inadequate capacity when a surface inlet was installed. The other approach was based on the amount of soils needing drainage to produce agricultural commodities in the entire contributing drainage area. This approach frequently resulted in drains larger than practical with respect to what drainage installation may have been expected.

A method is described here where hydrologic soil groupings of the contributing drainage area are used as an indicator of what seepage or base flow quantity may be expected to design underdrains for grassed waterways.

Procedure

Group the soils of the contributing drainage area into hydrologic soil groups (HSG). Use the following guideline to establish the appropriate design discharge for the drain.

Use 1.0 csm[1] for watersheds where soils are predominantly (85% or more) HSG B. The remaining portion could be either HSG A or C.

Use 1.5 csm for watersheds that are predominantly an even mix of HSG B and C soils. The remaining portion could be either HSG A or D.

Use 2.5 csm for watersheds where soils are predominantly an even mix of HSG C and D soils.

[1]The abbreviation csm stands for cubic feet per second per square mile or cfs/sq mi.

Use 3.5 csm for watersheds where soils are predominantly HSG D or the watershed has significant seepage or spring fed baseflow.[2]

Example: A watershed has a contributing drainage area of 340 acres. Soils are approximately 50% HSG B and 50% HSG C. The design drain discharge would be established by:

$$\frac{1.5 \text{ csm} * 340 \text{ acres}}{640 \text{ acres/ sq mi}} = 0.8 \text{ cfs}$$

Once the required discharge is computed, the drain can be sized using Exhibit IN 7-9 or IN 7-10 for plastic tubing or rigid tile, respectively.

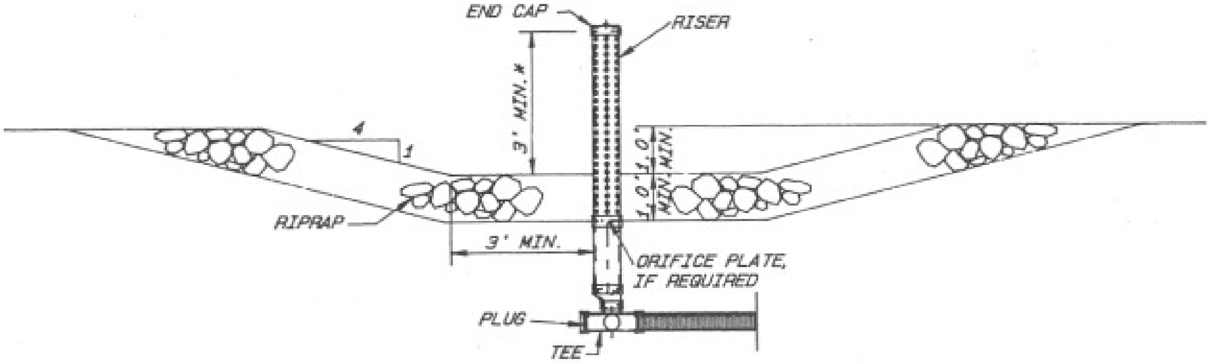
The most critical consideration in this type of installation is the inlet to the drain. The design discharge must be able to pass through the inlet for the drain to be fully effective. The inlet must also be designed so as to not overload the drain which could result in operation and maintenance problems. The inlet should have a design capacity less than the gravity flow drain capacity unless provisions are made for pressure flow.

In situations where the waterway underdrain will connect to an existing tile main or a new main in a system, it is extremely important that the capacity of the inlet be limited to a rate that will not overload the system. In these instances the design procedure may be used in reverse. The design Q required for the inlet may be considered to be the currently unused portion of the tile capacity. Inlet capacity may be limited by the open area of the inlet, an orifice plate in the riser, or by reducing the size of the connecting pipe from the riser to the tile main. Lengths of non-perforated conduit, breathers, and relief wells may also be incorporated in the design of the underdrain system to effectively deal with pressure flow conditions.

The inlet to the drain should be constructed by installing a shallow, rock lined basin with a surface inlet pipe in the center. The surface inlet pipe may be either cut flush with the ground and installed with a trash guard or it may consist of a standard riser that might be used in a wascob or terrace. If the pipe is installed flush with the surface of the basin bottom, the pipe capacity should be computed using the orifice flow equation and a design head of the basin depth plus one-quarter of the waterway design depth. If a standard riser is installed, the effective opening area should be established using the depth of the basin plus one-quarter of the waterway depth. The design

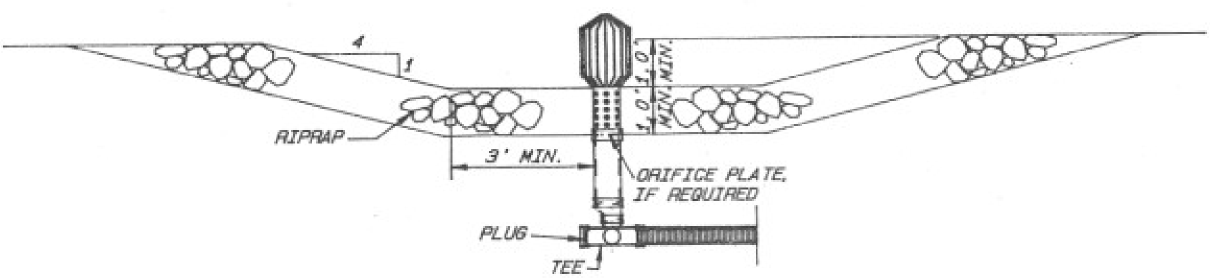
[2] Unless the spring flow quantity can be measured or estimated more accurately.

head for use in the orifice flow equation should be equal to 0.5 times the depth used for the effective opening area. In either case, maintenance, removing debris from the inlet, removing sediment, etc. will be a major factor in the successful operation of the installation.



TYPICAL CROSS SECTION OF BASIN

*MINIMUM LENGTH IS BASIN DEPTH (1' MIN.) PLUS WATERWAY DEPTH OR 3 FEET WHICHEVER IS GREATER.



TYPICAL CROSS SECTION OF BASIN

*MINIMUM LENGTH IS BASIN DEPTH (1' MIN.) PLUS WATERWAY DEPTH OR 3 FEET WHICHEVER IS GREATER.

<u>Example</u>: A 6 inch diameter riser having 24, 1 inch holes per foot of riser has an effective open area of 0.131 sq ft/ft (See Exhibit IN 7-11). Assume the grassed waterway design process resulted in a design depth of 1.2 feet. If a 1 foot deep basin is constructed, the total effective riser open area is (1 foot + 1.2 feet/4)(0.131 sq ft/ft) = 0.17 sq ft.

The design capacity of the riser is

$$Q=Ca(2gH)^{1/2} =(0.6)(0.17)[64.4(1.3)(0.5)]^{1/2}= 0.66 \text{ cfs, Too small}$$

Try an 8 inch riser, open area is (1.3 feet)(0.196 sq ft/ft) = 0.26 sq ft.

The design capacity of this riser is

$$Q=Ca(2gH)^{1/2}=(0.6)(0.26)[64.4(1.3)(0.5)]^{1/2}= 1.0 \text{ cfs, OK}$$

<u>Example</u>: A 6 inch diameter riser is sized for the same channel and basin. It will be installed flush with the bottom of the basin. The inlet open area is

$$A= r^2 = (3.14)(6 \text{ inches}/(2)12 \text{ inches/ft})^2 = 0.20 \text{ ft}$$

$$Q= 0.6\ (0.20)\ [64.4(1.3)]^{1/2} = 1.1 \text{ cfs, OK}$$

<u>Example</u>: The same 340 acre watershed in the examples above has a subsurface drainage system draining approximately 75 acres with a 10 inch plastic tile main laid on a 1% grade to the outlet. The planned waterway is located where the 10 inch main can be used as the underdrain. Assuming a 3/8" drainage co-efficient (for good agricultural drainage), the 10 inch main is currently carrying approximately 1.2 cfs discharge from the subsurface drainage system. (From exhibit IN 7-9) Its total capacity flowing full is approximately 1.7 cfs. The capacity that is available for the surface inlet would be 0.5 cfs.

Try a 6 inch diameter riser with 24, 3/4 inch holes per foot. From exhibit IN 7-11, the hole area is 0.074 sq.ft./ft. The effective riser height computed in the earlier example was

1 foot basin depth + 1.2 feet design waterway depth/4 = 1.3 feet

Total effective opening area = 1.3 (0.074) = 0.10 sq.ft.

Head on orifice(s) = 0.5 (1.3) = 0.65 feet

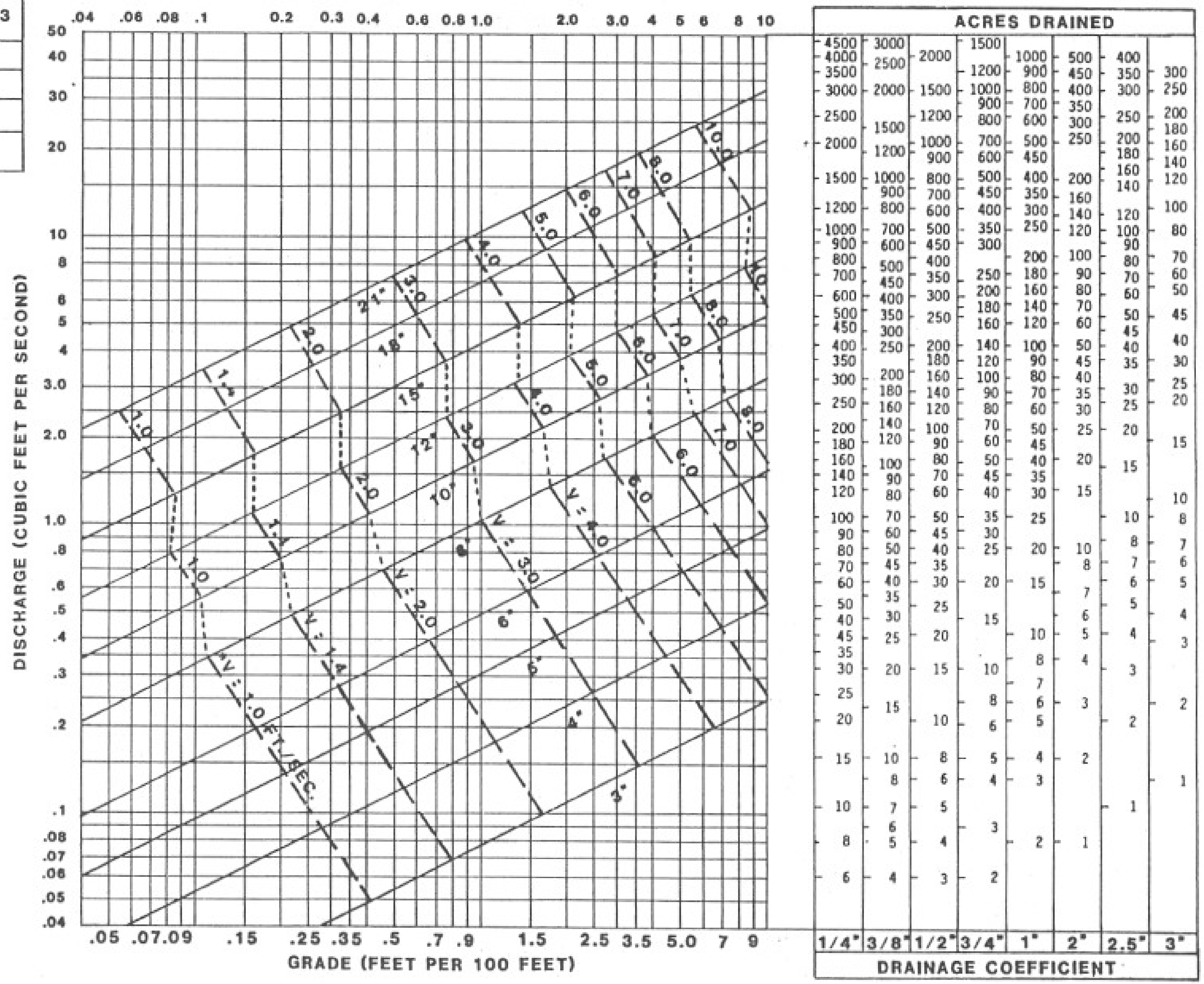
$$Q = 0.6\ (0.10)\ [64.4\ (0.65)]^{1/2} = 0.39 \text{ cfs} \quad \text{OK}$$

REFERENCE

MANNING'S ROUGHNESS BASED ON ASAE EP 260.3

SIZE (DIA.)	"n"
3" - 8"	0.015
10" - 12"	0.017
> 12"	0.020

* V equals velocity in feet per second



(EFM Notice IN-56, December 1990)

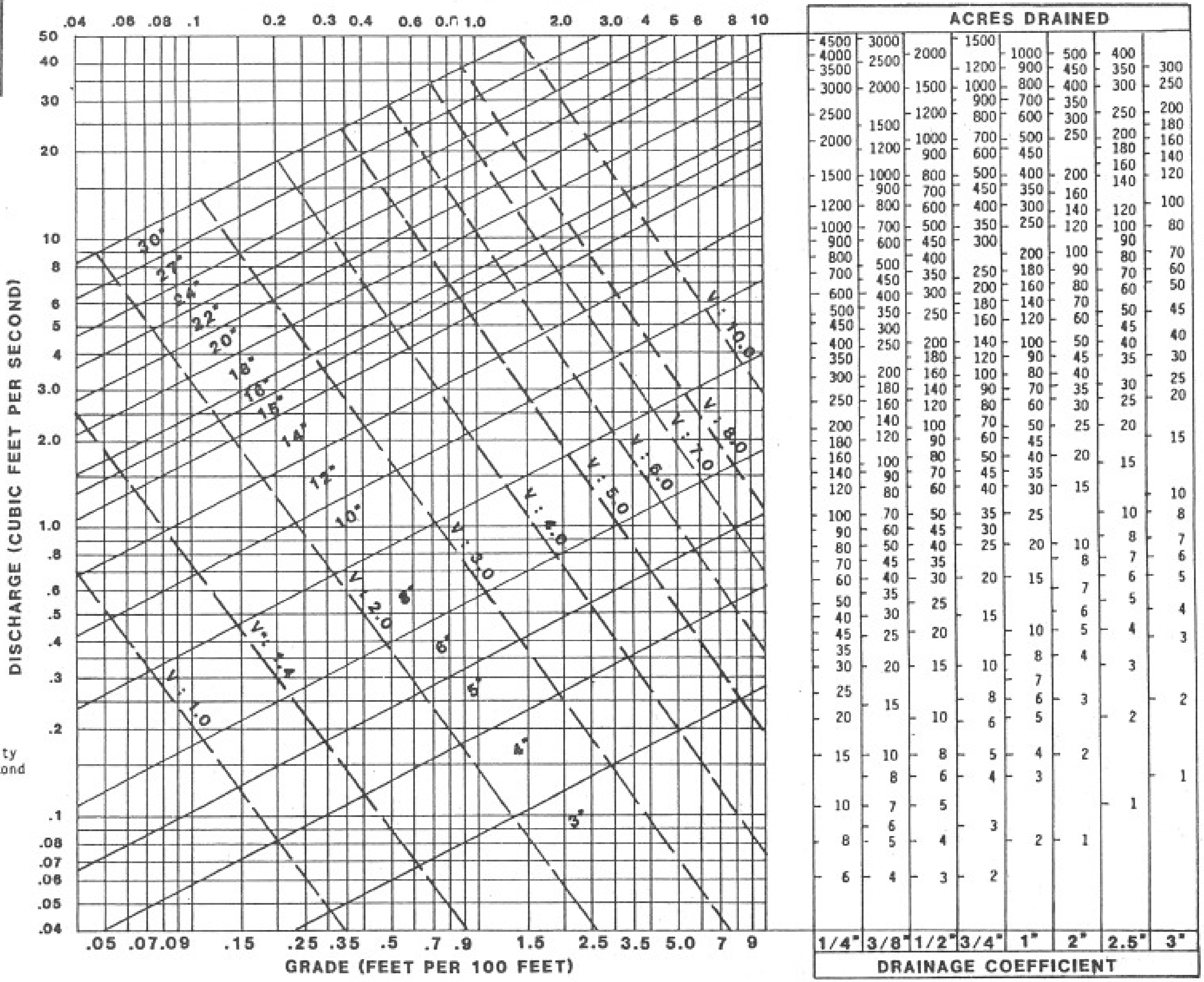
Exhibit IN 7-9

CHART FOR DETERMINING REQUIRED SIZE OF CORRUGATED PLASTIC DRAINAGE TUBING

REFERENCE

MANNING'S ROUGHNESS

"n" = 0.013



* V equals velocity in feet per second

Exhibit IN 7-10

CHART FOR DETERMINING REQUIRED SIZE OF SMOOTH RIGID DRAINAGE TILE

Inlet Diameter	Rows of Slots	Slot Area (sq ft/ft)[1]	Holes per foot	Hole Area (sq ft/ft) 3/4 inch dia.	1inch dia.
6	4	0.128	24	0.074	0.131
8	6	0.201	36	0.110	0.196
10	8	0.268	45	0.138	0.245
12	10	0.336	54	0.167	0.295

[1] Slots are 3/4 inch by 4 inches spaced vertically 7 inches center to center. If one inch slots are used, multiply the slot area for 3/4 inch holes by 1.33.

Exhibit IN 7-11

	Effective Open Area, sq ft							
Head, ft	0.1	0.2	0.3	0.4	0.5	1	1.5	2
0.1	0.15	0.30	0.46	0.61	0.76	1.52	2.28	3.05
0.5	0.34	0.68	1.02	1.36	1.70	3.40	5.11	6.81
1	0.48	0.96	1.44	1.93	2.41	4.81	7.22	
1.5	0.59	1.18	1.77	2.36	2.95	5.90		
2	0.68	1.36	2.04	2.72	3.40	6.81		
2.5	0.76	1.52	2.28	3.05	3.81	7.61		

Exhibit IN 7-12 Orifice Flow Capacity of Open Riser, cfs

UNDERGROUND DRAINAGE FOR GRASSED WATERWAYS
WITH OPEN SURFACE INLETS ; PLASTIC TUBING

			Maximum Capacity Expressed in Drainage Area, Acres									
Drain Grade in Percent =			0.10	0.25	0.50	0.75	1.00	1.25	1.50	2.00	2.50	3.00
Tubing	CSM =	1.0	33	53	75	91	105	118	129	149	167	183
Diam. =	CSM =	1.5	22	35	50	61	70	79	86	99	111	122
4	CSM =	2.5	13	21	30	37	42	47	52	60	67	73
inches	CSM =	3.5	10	15	21	26	30	34	37	43	48	52
n =	Cap, cfs		0.05	0.08	0.12	0.14	0.16	0.18	0.20	0.23	0.26	0.29
0.015	Vel, fps		0.60	0.94	1.34	1.64	1.89	2.11	2.31	2.67	2.99	3.27
Tubing	CSM =	1.0	60	96	135	166	191	214	234	270	302	331
Diam. =	CSM =	1.5	22	35	50	61	70	79	86	99	111	122
5	CSM =	2.5	13	21	30	37	42	47	52	60	67	73
inches	CSM =	3.5	10	15	21	26	30	34	37	43	48	52
n =	Cap, cfs		0.09	0.15	0.21	0.26	0.30	0.33	0.37	0.42	0.47	0.52
0.015	Vel, fps		0.69	1.10	1.55	1.90	2.19	2.45	2.68	3.10	3.47	3.80
Tubing	CSM =	1.0	98	156	220	269	311	348	381	440	492	539
Diam. =	CSM =	1.5	66	104	147	180	207	232	254	293	328	359
6	CSM =	2.5	39	62	88	108	124	139	152	176	197	215
inches	CSM =	3.5	28	44	63	77	89	99	109	126	141	154
n =	Cap, cfs		0.15	0.24	0.34	0.42	0.49	0.54	0.60	0.69	0.77	0.84
0.015	Vel, fps		0.78	1.24	1.75	2.14	2.47	2.77	3.03	3.50	3.91	4.29
Tubing	CSM =	1.0	212	335	474	580	670	749	820	947	1059	1160
Diam. =	CSM =	1.5	141	223	316	387	447	499	547	632	706	774
8	CSM =	2.5	85	134	189	232	268	300	329	379	424	464
inches	CSM =	3.5	61	96	135	166	191	214	234	271	303	332
n =	Cap, cfs		0.33	0.52	0.74	0.91	1.05	1.17	1.28	1.48	1.65	1.81
0.015	Vel, fps		0.95	1.50	2.12	2.60	3.00	3.35	3.67	4.24	4.74	5.19
Tubing	CSM =	1.0	339	536	758	928	1072	1198	***	***	***	***
Diam. =	CSM =	1.5	226	357	505	619	715	799	875	1010	1130	***
10	CSM =	2.5	136	214	303	371	429	479	525	606	678	743
inches	CSM =	3.5	97	153	217	265	306	342	375	433	484	530
n =	Cap, cfs		0.53	0.84	1.18	1.45	1.67	1.87	2.05	2.37	2.65	2.90
0.017	Vel, fps		0.97	1.54	2.17	2.66	3.07	3.43	3.76	4.34	4.85	5.32
Tubing	CSM =	1.0	551	871	***	***	***	***	***	***	***	***
Diam. =	CSM =	1.5	367	581	822	1006	1162	***	***	***	***	***
12	CSM =	2.5	220	349	493	604	697	779	854	***	***	***
inches	CSM =	3.5	157	249	352	431	498	557	610	704	787	863
n =	Cap, cfs		0.86	1.36	1.93	2.36	2.72	3.04	3.34	3.85	4.31	4.72
0.017	Vel, fps		1.10	1.73	2.45	3.00	3.47	3.88	4.25	4.90	5.48	6.01
Tubing	CSM =	1.0	849	***	***	***	***	***	***	***	***	***
Diam. =	CSM =	1.5	566	895	***	***	***	***	***	***	***	***
15	CSM =	2.5	340	537	760	931	***	***	***	***	***	***
inches	CSM =	3.5	243	384	543	665	768	***	***	***	***	***
n =	Cap, cfs		1.33	2.10	2.97	3.64	4.20	4.69	5.14	5.94	6.64	7.27
0.020	Vel, fps		1.08	1.71	2.42	2.96	3.42	3.82	4.19	4.84	5.41	5.92
Tubing	CSM =	1.0	***	***	***	***	***	***	***	***	***	***
Diam. =	CSM =	1.5	921	***	***	***	***	***	***	***	***	***
18	CSM =	2.5	553	874	***	***	***	***	***	***	***	***
inches	CSM =	3.5	395	624	***	***	***	***	***	***	***	***
n =	Cap, cfs		2.16	3.41	4.83	5.91	6.83	7.63	8.36	9.65	10.79	11.82
0.020	Vel, fps		1.22	1.93	2.73	3.35	3.86	4.32	4.73	5.46	6.11	6.69

Exhibit IN 7-13