2024 Onsite Wastewater Mega-Conference

Evaluation of a Potential Pressure Drop Estimation Tool

Hydraulic Properties of Drip Tubing

John R. Buchanan, Ph.D., P.E.

Professor and Extension Specialist

Water and Wastewater Engineering

Biosystems Engineering and Soil Science Department

Evaluation of a Potential Pressure Drop Estimation Tool

- Determining the pressure-drop due to pipe friction is not a straight-forward task
  - not a single outlet pipe
    - it is a lateral with multiple outlets
    - velocity (flow) changes along length

Traditional Method

- For dripline
  - we use the manufacturer's design guide for determining the maximum tubing length that maintains minimum pressure requirement at distal end
    - during dose, zero flow at distal end
    - during flush, flow that provides velocity of 2 fps

For Example, a 2-fps Flush

BIOLINE DOSING CHART **Maximum Length** *(feet)* **of a Single Lateral** *(1.5 & 2.0 fps)*

Dripper Spacing		12"			18"			24"		
Dripper Flow Rate *(GPH)*		**0.4**	**0.6**	**0.9**	**0.4**	**0.6**	**0.9**	**0.4**	**0.6**	**0.9**
Flushing Velocity *(fps)*		1.5 / 2.0	1.5 / 2.0	1.5 / 2.0	1.5 / 2.0	1.5 / 2.0	1.5 / 2.0	1.5 / 2.0	1.5 / 2.0	1.5 / 2.0
Inlet Pressure *(psi)*	**15**	201 / 161	171 / 141	140 / 119	275 / 217	235 / 191	194 / 164	337 / 263	289 / 233	241 / 201
	25	266 / 221	222 / 190	179 / 157	366 / 302	308 / 261	251 / 218	453 / 369	383 / 321	313 / 270
	35	316 / 269	262 / 229	210 / 187	437 / 370	365 / 316	295 / 260	543 / 455	455 / 391	369 / 324
	40	337 / 290	280 / 246	223 / 200	469 / 399	391 / 340	313 / 278	583 / 493	487 / 421	393 / 347
	45	358 / 310	296 / 261	235 / 212	497 / 427	413 / 362	331 / 296	619 / 527	517 / 449	415 / 369
Flow per 100' *(GPM/GPH)*		0.67 / 40	1.02 / 61	1.53 / 92	0.44 / 26.67	0.68 / 41	1.02 / 61	0.34 / 20	0.51 / 31	0.77 / 46

Additional flow of 1.2 GPM required per lateral to achieve 1.5 fps.
Additional flow of 1.6 GPM required per lateral to achieve 2.0 fps.

Wastewater Reuse and Drip Dispersal Design Guide
Wastewater Division, Netafim. www.netafimuse.com

Dose, No Flush

BIOLINE DOSING CHART **Maximum Length** *(feet)* **of a Single Lateral**

Dripper Spacing		12"			18"			24"		
Dripper Flow Rate (GPH)		**0.4**	**0.6**	**0.9**	**0.4**	**0.6**	**0.9**	**0.4**	**0.6**	**0.9**
Inlet Pressure (psi)	**15**	292	233	175	410	322	247	510	405	308
	25	397	312	238	558	438	335	660	550	423
	35	460	365	260	656	514	394	760	649	497
	45	505	407	295	732	574	429	880	725	555

Lateral lengths are calculated for operation while dosing, and allow for the pressure at the end of the dripperline to be 7 psi or greater. Their data does not take scouring velocity into account.

Wastewater Reuse and Drip Dispersal Design Guide
Wastewater Division, Netafim. www.netafimuse.com

On Level Ground….

- Using 24-inch spacing and 0.6 gph emitters
  - maximum length is 449 feet if a 45-psi inlet pressure is provided
  - total flow is 3.81 gpm
    - 224 emitters – 2.28 gpm
    - 0.56-in diameter – 1.53 gpm for 2 fps

As an Engineer…..

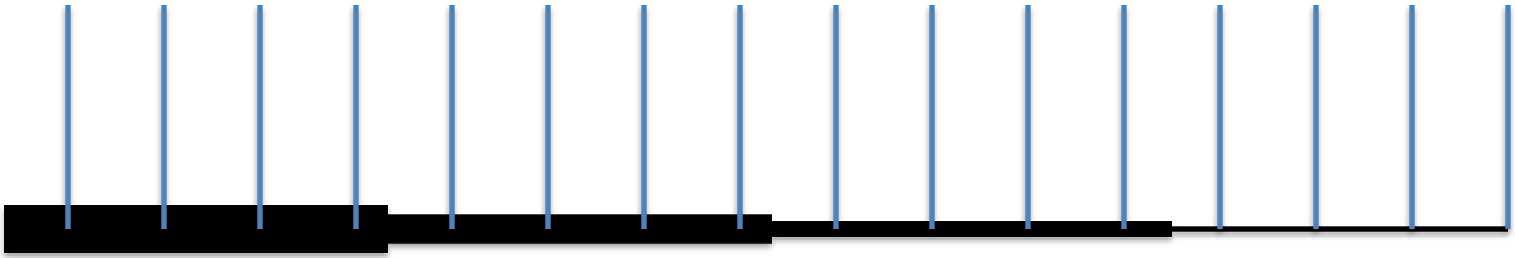
- I am given the maximums
  - and left to assume that shorter lengths should work fine
- But I don't work in flat country
  - elevation changes are part of the equation
  - individual laterals on contour, but inlet pressures vary

The Real Problem…

- Parallel pipes
  - I need to know the pressure drop across each lateral to ensure the flush velocity

Engineering of Laterals

- Sprinkler irrigation
  - sprayers are not pressure compensated
  - must minimize head loss so sprayers are equal

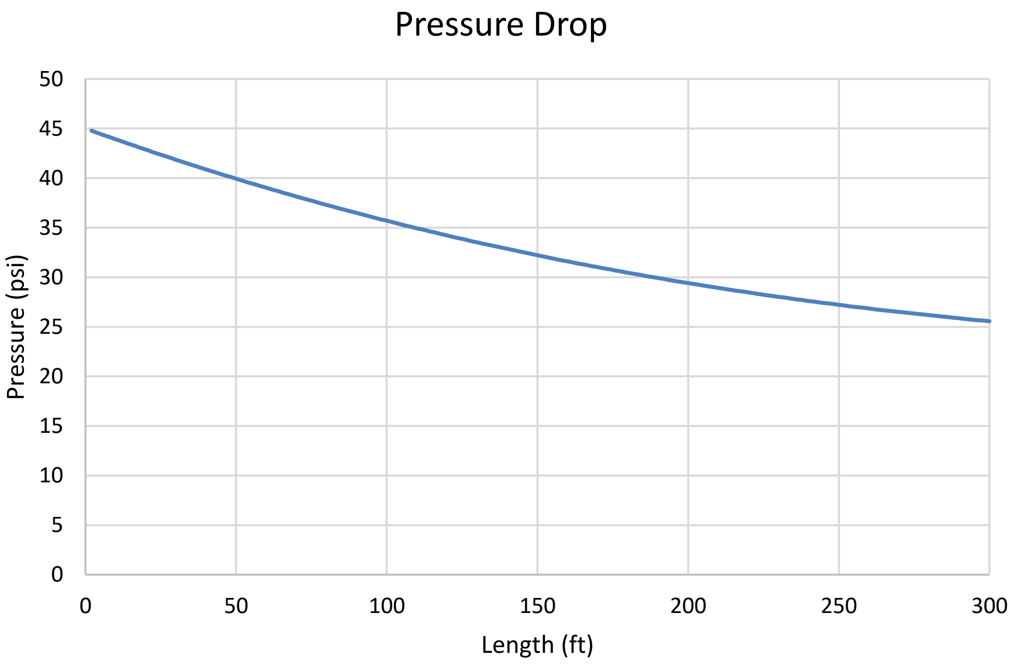


Pressure Compensated

- So much easier to design a lateral
  - allows same diameter pipe to be used along length
  - upper limit to length is inlet and distal pressures
    - cannot over pressurize near-end.
    - must have manufacturer's minimum to operate last emitter

Thus….

- It is desirable to have an algorithm to estimate the head loss due to friction along a drip lateral
- Need pressure to return flush to primary



Major Head Loss

- Pipe friction, function of pipe material
  - Hazen-Williams Equation
  - empirical, commonly used
  - C-factor describes material, 150 for plastic

$$Hf_{major} = 10.44 \left(\frac{Q}{C}\right)^{1.852} L\, d^{-4.866}$$

Back to Original Problem

- Equation is for single-outlet pipe
  - acceptable solution
    - break the pipe into a section per outlet
    - use new flow rate per section
    - sum friction calculated for each of the sections
  - 300 feet of pipe, that’s 150 sections
    - Holy Sh*t

Chill Out – Use a Spreadsheet

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	Dose Only																
	Spacing=	24	Emitter Rate=	0.61		Q=	3		Em Section=	0.00076	C=	150	K=	0	Inlet P=	45	
	Emitter	Length (ft)	Cumulative (ft)	Flow (gpm)	Cum Flow	C	Diameter (in)	Constant	Velocity-1	Velocity-2	K	Fitting Loss (ft)	Headloss (ft)	Total Hf	Total psi	Cum psi	est dist P
	0	2	2	3	0.01	150	0.56	10.46	3.91	7.04	0	0.000	0.253	0.253	0.109	0.109	44.891
	1	2	4	2.99	0.02	150	0.56	10.46	3.90	7.01	0	0.000	0.251	0.251	0.109	0.218	44.782
	2	2	6	2.98	0.03	150	0.56	10.46	3.88	6.99	0	0.000	0.249	0.249	0.108	0.326	44.674
	3	2	8	2.97	0.04	150	0.56	10.46	3.87	6.97	0	0.000	0.248	0.248	0.107	0.433	44.567
	4	2	10	2.96	0.05	150	0.56	10.46	3.86	6.94	0	0.000	0.246	0.246	0.107	0.540	44.460
	5	2	12	2.95	0.06	150	0.56	10.46	3.84	6.92	0	0.000	0.245	0.245	0.106	0.646	44.354
	6	2	14	2.94	0.07	150	0.56	10.46	3.83	6.90	0	0.000	0.243	0.243	0.105	0.751	44.249
	7	2	16	2.93	0.08	150	0.56	10.46	3.82	6.87	0	0.000	0.242	0.242	0.105	0.856	44.144
	8	2	18	2.92	0.09	150	0.56	10.46	3.80	6.85	0	0.000	0.240	0.240	0.104	0.960	44.040
	9	2	20	2.91	0.10	150	0.56	10.46	3.79	6.82	0	0.000	0.239	0.239	0.103	1.063	43.937
	10	2	22	2.90	0.11	150	0.56	10.46	3.78	6.80	0	0.000	0.237	0.237	0.103	1.166	43.834
	11	2	24	2.89	0.12	150	0.56	10.46	3.76	6.78	0	0.000	0.236	0.236	0.102	1.268	43.732
	12	2	26	2.88	0.13	150	0.56	10.46	3.75	6.75	0	0.000	0.234	0.234	0.101	1.369	43.631
	13	2	28	2.87	0.14	150	0.56	10.46	3.74	6.73	0	0.000	0.232	0.232	0.101	1.470	43.530
	14	2	30	2.86	0.15	150	0.56	10.46	3.72	6.70	0	0.000	0.231	0.231	0.100	1.570	43.430
	15	2	32	2.85	0.16	150	0.56	10.46	3.71	6.68	0	0.000	0.229	0.229	0.099	1.669	43.331
	16	2	34	2.84	0.17	150	0.56	10.46	3.70	6.66	0	0.000	0.228	0.228	0.099	1.768	43.232
	17	2	36	2.83	0.18	150	0.56	10.46	3.68	6.63	0	0.000	0.226	0.226	0.098	1.866	43.134
	18	2	38	2.82	0.19	150	0.56	10.46	3.67	6.61	0	0.000	0.225	0.225	0.097	1.963	43.037
	19	2	40	2.81	0.20	150	0.56	10.46	3.66	6.59	0	0.000	0.223	0.223	0.097	2.060	42.940
	20	2	42	2.80	0.21	150	0.56	10.46	3.64	6.56	0	0.000	0.222	0.222	0.096	2.156	42.844
	21	2	44	2.79	0.22	150	0.56	10.46	3.63	6.54	0	0.000	0.220	0.220	0.095	2.251	42.749
	22	2	46	2.78	0.23	150	0.56	10.46	3.62	6.51	0	0.000	0.219	0.219	0.095	2.346	42.654
	23	2	48	2.77	0.24	150	0.56	10.46	3.60	6.49	0	0.000	0.217	0.217	0.094	2.440	42.560
	24	2	50	2.76	0.25	150	0.56	10.46	3.59	6.47	0	0.000	0.216	0.216	0.093	2.534	42.466

Question

- Can C-factor incorporate the friction due to the embedded emitter bodies?
- On a theorical basis → No
  - Hazen Williams is a surface effect model
  - emitters cause regionalized changes in velocity

Minor Head Loss

- Pipe fittings
  - additional turbulence
  - changes in cross-sectional area
- Two methods
  - equivalent lengths of pipe
  - velocity head method

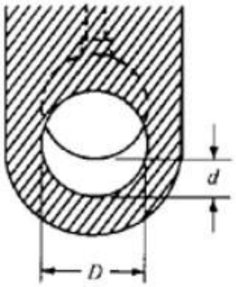
Velocity Head Method

$$Hf_{minor} = K\frac{V^2}{2g}$$

v = velocity in small section

K = coefficient

Cause of minor loss	K value or loss expression
Gate valve	



D, mm	in	d/D 1/8	1/4	3/8	1/2	3/4	1
50	2	140	20	6.5	3.0	0.68	0.16
100	4	91	16	5.6	2.6	0.55	0.14
150	6	74	14	5.3	2.4	0.49	0.12
200	8	66	13	5.2	2.3	0.47	0.10
300	12	56	12	5.1	2.2	0.47	0.07

For larger sizes, values for 300-mm valve may be used.

Flow Cross-Section at Emitter

- Tubing cross-section
  - 0.25 in^2
- Emitter cross-section
  - 0.109 in^2
- Difference
  - 0.141 in^2

Quesstimating the K-coefficient

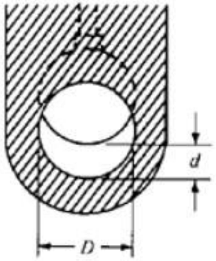
- Assuming a gate valve

  d/D = 0.44

  – starting point

  K ≈ 0.16 to 3

Cause of minor loss	K value or loss expression
Gate valve	



D, mm	in	d/D ⅛	¼	⅜	½	¾	1
50	2	140	20	6.5	3.0	0.68	0.16
100	4	91	16	5.6	2.6	0.55	0.14
150	6	74	14	5.3	2.4	0.49	0.12
200	8	66	13	5.2	2.3	0.47	0.10
300	12	56	12	5.1	2.2	0.47	0.07

For larger sizes, values for 300-mm valve may be used.

Model

$$Total\ Head\ Loss\ per\ section = 10.44 \left(\frac{Q}{C}\right)^{1.852} L\, d^{-4.866} + K\frac{V^2}{2g}$$

$$\sum_{1}^{n}(major\ loss + minor\ loss)$$

- where

  n = number of pipe sections

- For each section
  - different flow
  - different velocity
    - in tubing
    - along emitter

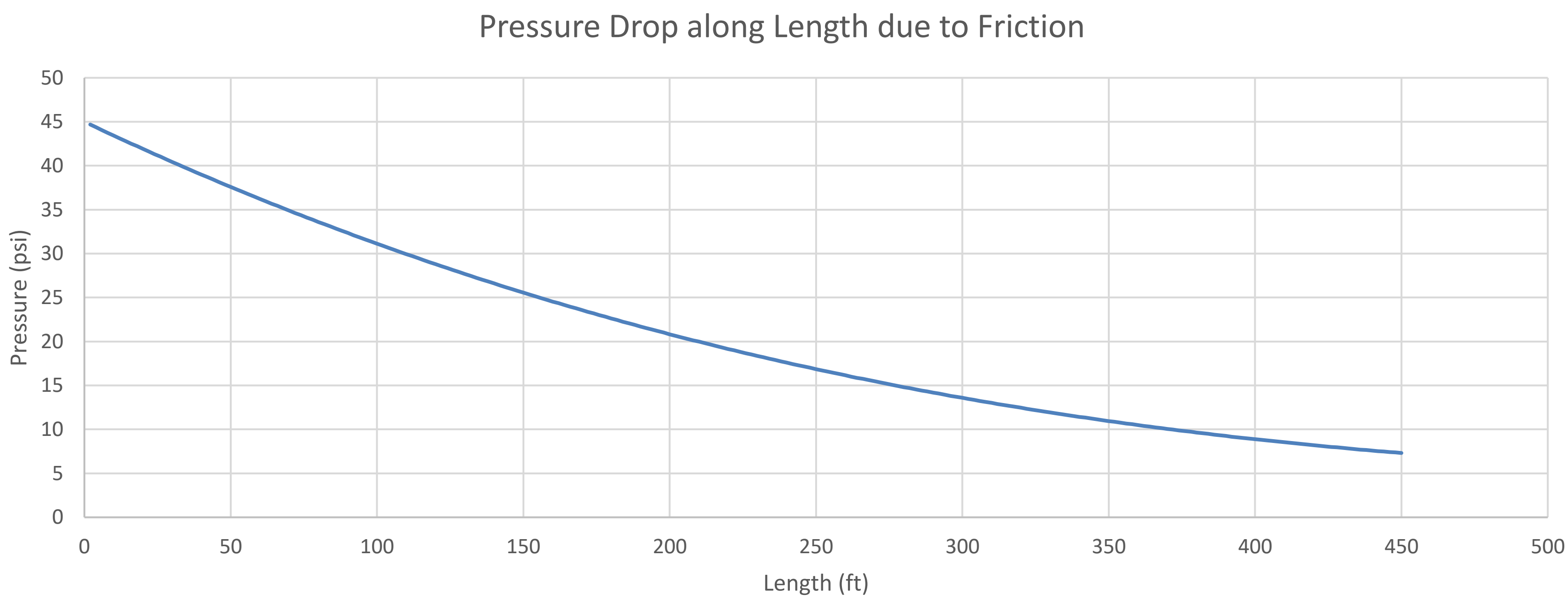
Spreadsheet

- Built to allow easy changes for
  - C, K, Q, L
  - cross-sections
  - inlet pressure
- Results compared to Manufacturer's Design Manual

Assumption!

- The manufacturer's allowable length is based on having 7 psi available at distal end
  - difference between inlet pressure and 7 psi is the pressure drop due to pipe friction
    - 45 psi – 7 psi = 38 psi
    - friction for 449 feet, Q = 3.81 gpm, 24-in spacing, 0.6 gph emitters
      - per manufacturer's Design Guide

After Some Adjustments: K = 0.25

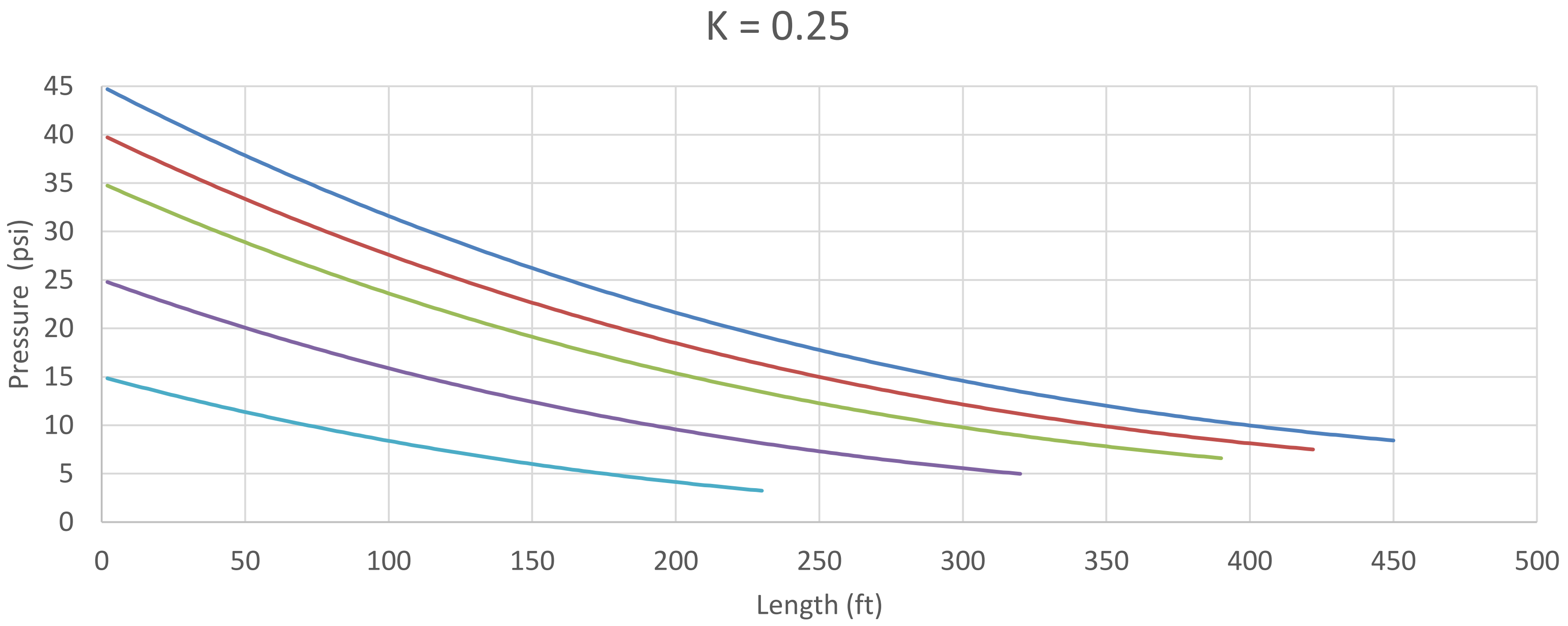


So, Yeah….

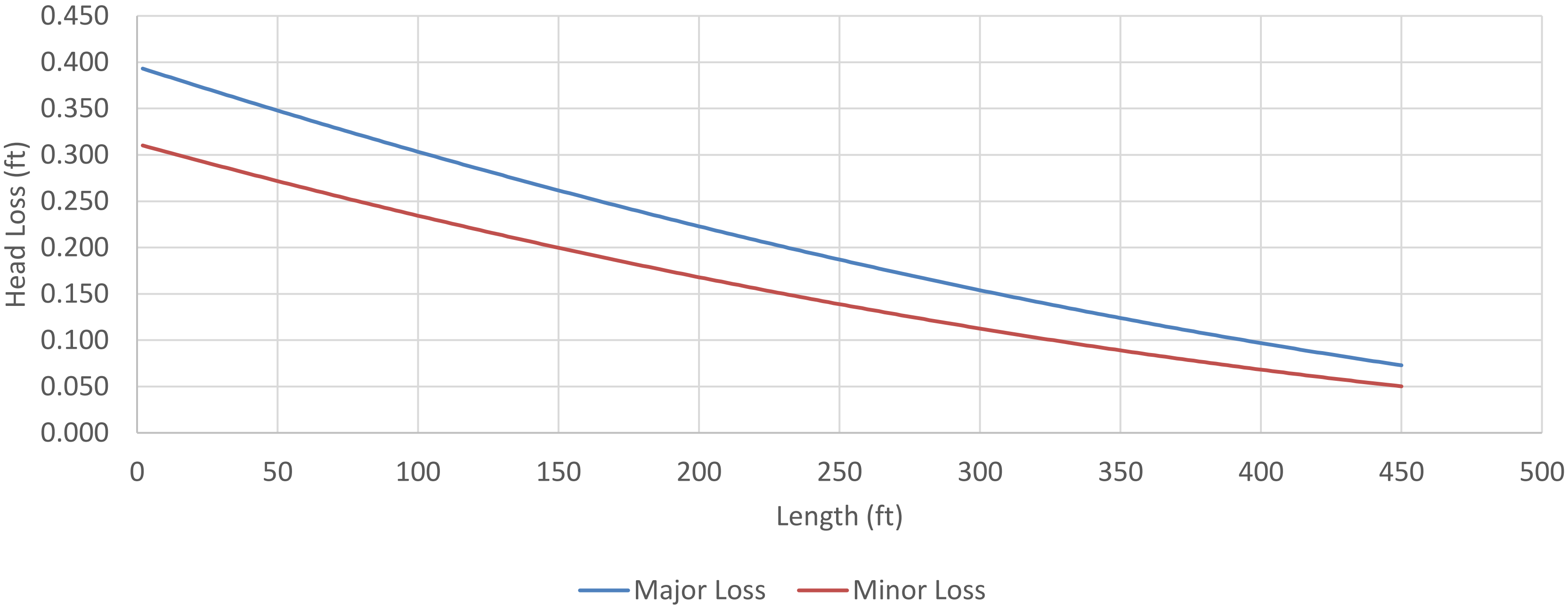
- I can make a model work for one set of data
  - how does it perform for other data sets?
- For shorter lengths,
  - it seems to over predict head loss

Additional Results

Each Curve Should End at 7 psi



Major and Minor Losses Along Length



Thinking About the Model

- Overpredicts pressure loss with shorter lengths
  - could increase C-factor to 160
    - the research literature provides some precedence for polyethylene pipe being "smoother than smooth"
    - investigate "sudden contraction & sudden enlargement" as a minor loss model

Thinking About the Model

- Overpredicts pressure loss with shorter lengths
  - Darcy-Weisbach may be a better major loss model
    - still have to determine a friction-factor
    - iterative process
      - nobody has time to do that

Next Steps

- Collect real data
  - hoped to accomplish before this meeting
- Pressure transducers
  - every 50 feet
  - can control flow and pressure input
  - can measure flush flow

Disclosure and Acknowledgements

- Mention of Brand Names is not an endorsement by the University of Tennessee
- Funding for this project was/is provided by the Tennessee Extension Service
- Tubing provided by
  - David Morgan, Geoflow
  - Glenn Marcum, Ecostruct Group, LLC

Questions

UTEXTENSION
INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE