



# West Linn

## Water Main Thrust Restraints

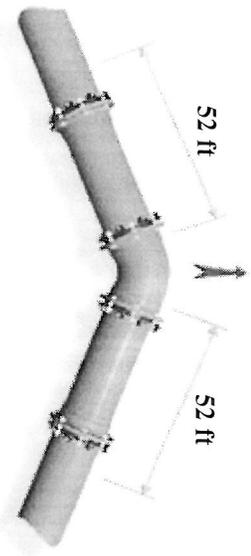
1. Please refer to attached tables for water main thrust restraint lengths. Pipe sizes, scenarios, or field conditions not shown in tables are subject to thrust restraint calculation by the City Engineer.
2. At connections to existing pipe, thrust blocks will be required per City of West Linn Public Works Standards.
3. Where minimum thrust restraint length cannot be achieved by field loks due to insufficient pipe length, thrust blocks will be required.
4. City Engineer reserves the right to adjust field lok restraint lengths and/or require thrust blocks depending on field conditions.

# Project Name: City Water Project

Fitting Type	Pipe Material	Soil Type	Safety Factor	Trench Type	Depth Of Bury	Test Pressure	Nominal Size	Bend Angle	Branch Size	Length Along Run	Small Size	Lowside Depth	Restraint Length	Restraint Length 2
Horizontal Bend	Ductile Iron	ML	2.0 to 1	3	3	200	8	90°					52 ft	

Site Location: City Water Project

Notes:



### Defined Variables

- H = 3 Depth of Bury
  - SF = 2.0 Safety Factor
  - P = 200 Internal Pressure
  - θ = 90 Bend Angle
- ### Pipe Derived Variables
- A = 64.330 Cross Sec. Area of Pipe
  - D = 0.750 Outside Pipe Diameter
  - Wp = 26.000 Weight of Pipe
  - Ww = 24.000 Weight of Water in Pipe

### Soil Derived Variables

- fc = 0.000 Cohesion Modifier Coefficient
- c = 0.000 Cohesion of Soil
- fp = 1.000 Friction Angle Modifier
- φ = 29.000 Internal Friction Angle of Soil
- F = 100.000 Soil Density
- Kn = 0.600 Trench Compaction Modifier

### Calculations for Horizontal Bend

$$We = F \cdot D \cdot H = 225.000 \text{ Normal Force Due to Soil}$$

$$W = 2W_e + W_p + W_w = 500.000 \text{ Normal Force Acting on Pipeline}$$

$$Kp = \tan^2(\pi/180) \cdot (45 + (\pi/2)) = 2.882 \text{ Rankin Passive Pressure Coeff.}$$

$$He = H + (D/2) = 3.375 \text{ Depth from Surface to Pipe Center}$$

$$\Delta h = F \cdot He \cdot Kp + 2c \cdot \sqrt{Kp} = 972.695 \text{ Horizontal Passive Soil Pressure}$$

$$Ap = \pi \cdot (D/2) = 1.178 \text{ Area Based on Half of Circum.}$$

$$Rs = Kn \cdot \Delta h \cdot D = 437.713 \text{ Bearing Resistance on Pipelines}$$

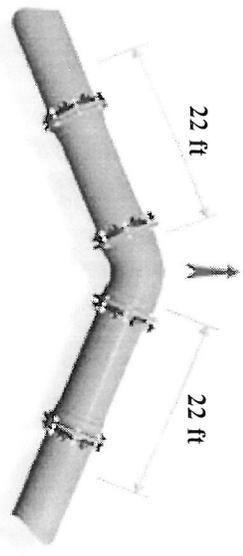
$$Fs = Ap \cdot fc \cdot c + W \cdot \tan(\pi/180) \cdot fp \cdot \phi = 277.155 \text{ Frictional Resistance}$$

$$L = (SF \cdot P \cdot A \cdot \tan(\pi/180) \cdot (\theta/2)) / (Fs + (Rs/2)) = 51.878 \text{ Minimum Restraint Length}$$

# Project Name: City Water Project

Fitting Type	Pipe Material	Soil Type	Safety Factor	Trench Type	Depth Of Bury	Test Pressure	Nominal Size	Bend Angle	Branch Size	Length Along Run	Small Size	Lowside Depth	Restraint Length	Restraint Length 2
Horizontal Bend	Ductile Iron	ML	2.0 to 1	3	3	200	8	45°					22 ft	

Site Location: City Water Project



### Defined Variables

- H = 3 Depth of Bury
  - SF = 2.0 Safety Factor
  - P = 200 Internal Pressure
  - θ = 45 Bend Angle
- Pipe Derived Variables**
- A = 64.330 Cross Sec. Area of Pipe
  - D = 0.750 Outside Pipe Diameter
  - Wp = 26.000 Weight of Pipe
  - Ww = 24.000 Weight of Water in Pipe

### Soil Derived Variables

- fc = 0.000 Cohesion Modifier Coefficient
- c = 0.000 Cohesion of Soil
- fp = 1.000 Friction Angle Modifier
- φ = 29.000 Internal Friction Angle of Soil
- Γ = 100.000 Soil Density
- Kn = 0.600 Trench Compaction Modifier

### Calculations for Horizontal Bend

$$We = \Gamma \cdot D \cdot H = 225.000 \text{ Normal Force Due to Soil}$$

$$W = 2We + Wp + Ww = 500.000 \text{ Normal Force Acting on Pipeline}$$

$$Kp = \tan^2(\pi/180) \cdot (45 + (\pi/2)) = 2.882 \text{ Rankin Passive Pressure Coeff.}$$

$$Hc = H + (D/2) = 3.375 \text{ Depth from Surface to Pipe Center}$$

$$\Delta h = \Gamma \cdot Hc \cdot Kp + 2c \cdot \sqrt{Kp} = 972.695 \text{ Horizontal Passive Soil Pressure}$$

$$Ap = \pi \cdot (D/2) = 1.178 \text{ Area Based on Half of Circum.}$$

$$Rs = Kn \cdot \Delta h \cdot D = 437.713 \text{ Bearing Resistance on Pipelines}$$

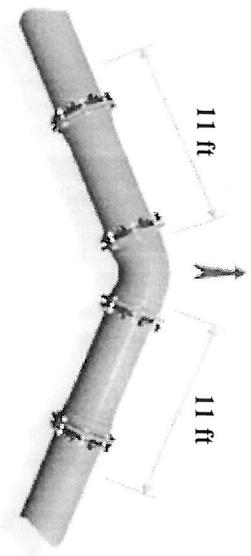
$$Fs = Ap \cdot fc \cdot c + W \cdot \tan(\pi/180) \cdot fp \cdot \phi = 277.155 \text{ Frictional Resistance}$$

$$L = (SF \cdot P \cdot A \cdot \tan(\pi/180) \cdot (\theta/2)) / (Fs + (Rs/2)) = 21.489 \text{ Minimum Restrained Length}$$

# Project Name: City Water Project

Fitting Type	Pipe Material	Soil Type	Safety Factor	Trench Type	Depth Of Bury	Test Pressure	Nominal Size	Bend Angle	Branch Size	Length Along Run	Small Size	Lowside Depth	Restraint Length	Restraint Length 2
Horizontal Bend	Ductile Iron	ML	2.0 to 1	3	3	200	8	22° ½					11 ft	

Site Location: City Water Project



### Defined Variables

- H = 3 Depth of Bury
  - SF = 2.0 Safety Factor
  - P = 200 Internal Pressure
  - θ = 23 Bend Angle
- ### Pipe Derived Variables
- A = 64.330 Cross Sec. Area of Pipe
  - D = 0.750 Outside Pipe Diameter
  - Wp = 26.000 Weight of Pipe
  - Ww = 24.000 Weight of Water in Pipe

### Soil Derived Variables

- fc = 0.000 Cohesion Modifier Coefficient
- c = 0.000 Cohesion of Soil
- fp = 1.000 Friction Angle Modifier
- φ = 29.000 Internal Friction Angle of Soil
- T = 100.000 Soil Density
- Kn = 0.600 Trench Compaction Modifier

### Calculations for Horizontal Bend

$$We = T \cdot D \cdot H = 225.000 \text{ Normal Force Due to Soil}$$

$$W = 2We + Wp + Ww = 500.000 \text{ Normal Force Acting on Pipeline}$$

$$Kp = \tan^2(\pi/180) \cdot (45 + (\pi/2)) = 2.882 \text{ Rankin Passive Pressure Coeff.}$$

$$He = H + (D/2) = 3.375 \text{ Depth from Surface to Pipe Center}$$

$$\Delta h = T \cdot He \cdot Kp + 2c \cdot \sqrt{Kp} = 972.695 \text{ Horizontal Passive Soil Pressure}$$

$$Ap = \pi \cdot (D/2) = 1.178 \text{ Area Based on Half of Circum.}$$

$$Rs = Kn \cdot \Delta h \cdot D = 437.713 \text{ Bearing Resistance on Pipelines}$$

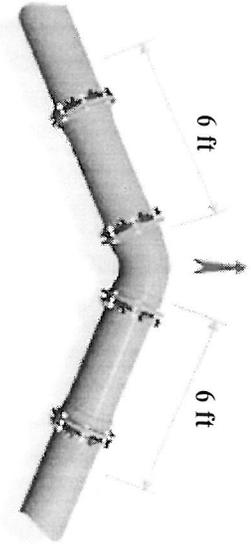
$$Fs = Ap \cdot fc \cdot c + W \cdot \tan(\pi/180) \cdot fp \cdot \phi = 277.155 \text{ Frictional Resistance}$$

$$L = (SF \cdot P \cdot A \cdot \tan(\pi/180) \cdot (\theta/2)) / (Fs + (Rs/2)) = 10.319 \text{ Minimum Restrained Length}$$

# Project Name: City Water Project

Fitting Type	Pipe Material	Soil Type	Safety Factor	Trench Type	Depth Of Bury	Test Pressure	Nominal Size	Bend Angle	Branch Size	Length Along Run	Small Size	Lowside Depth	Restraint Length	Restraint Length 2
Horizontal Bend	Ductile Iron	ML	2.0 to 1	3	3	200	8	11° ¼					6 ft	

Site Location: City Water Project



### Defined Variables

- H = 3 Depth of Bury
  - SF = 2.0 Safety Factor
  - P = 200 Internal Pressure
  - θ = 11 Bend Angle
- ### Pipe Derived Variables
- A = 64.330 Cross Sec. Area of Pipe
  - D = 0.750 Outside Pipe Diameter
  - Wp = 26.000 Weight of Pipe
  - Ww = 24.000 Weight of Water in Pipe

### Soil Derived Variables

- fc = 0.000 Cohesion Modifier Coefficient
- c = 0.000 Cohesion of Soil
- fp = 1.000 Friction Angle Modifier
- Φ = 29.000 Internal Friction Angle of Soil
- Γ = 100.000 Soil Density
- Kn = 0.600 Trench Compaction Modifier

### Calculations for Horizontal Bend

$$W_e = \Gamma \cdot D \cdot H = 225.000 \text{ Normal Force Due to Soil}$$

$$W = 2W_e + W_p + W_w = 500.000 \text{ Normal Force Acting on Pipeline}$$

$$K_p = \tan^2((\pi/180)(45 + (\pi/2))) = 2.882 \text{ Rankin Passive Pressure Coeff.}$$

$$H_e = H + (D/2) = 3.375 \text{ Depth from Surface to Pipe Center}$$

$$\Sigma H = \Gamma \cdot H_e \cdot K_p + 2c \cdot \sqrt{K_p} = 972.695 \text{ Horizontal Passive Soil Pressure}$$

$$A_p = \pi \cdot (D/2) = 1.178 \text{ Area Based on Half of Circum.}$$

$$R_s = K_n \cdot \Sigma H \cdot D = 437.713 \text{ Bearing Resistance on Pipelines}$$

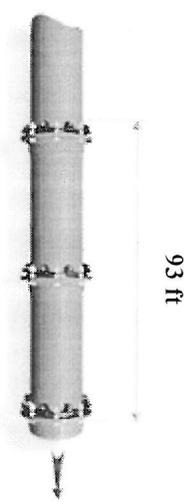
$$F_s = A_p \cdot f_c \cdot c + W \cdot \tan((\pi/180) \cdot f_p \cdot \Phi) = 277.155 \text{ Frictional Resistance}$$

$$L = (SF \cdot P \cdot A \cdot \tan((\pi/180)(\theta/2))) / (F_s + (R_s/2)) = 5.110 \text{ Minimum Restrained Length}$$

**Project Name: City Water Project**

Fitting Type	Pipe Material	Soil Type	Safety Factor	Trench Type	Depth Of Bury	Test Pressure	Nominal Size	Bend Angle	Branch Size	Length Along Run	Small Size	Lowside Depth	Restraint Length	Restraint Length 2
Dead End	Ductile Iron	ML	2.0 to 1	3	3	200	8						93 ft	

Site Location: City Water Project



**Defined Variables**

H = 3 Depth of Bury  
 SF = 2.0 Safety Factor  
 P = 200 Internal Pressure

**Pipe Derived Variables**

A = 64.330 Cross Sec. Area of Pipe  
 D = 0.750 Outside Pipe Diameter  
 Wp = 26.000 Weight of Pipe  
 Ww = 24.000 Weight of Water in Pipe

**Soil Derived Variables**

fc = 0.000 Cohesion Modifier Coefficient  
 c = 0.000 Cohesion of Soil  
 fp = 1.000 Friction Angle Modifier Coeff.  
 φ = 29.000 Internal Friction Angle of Soil  
 Γ = 100.000 Soil Density

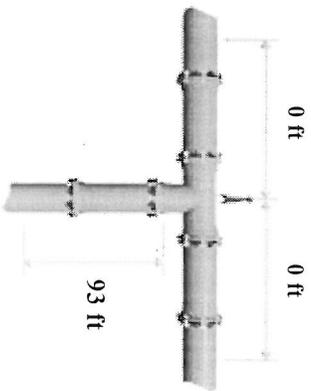
**Calculations for Dead End**

$W_e = \Gamma \cdot D \cdot H = 225.000$  Normal Force Due to Soil  
 $W = 2W_e + W_p + W_w = 500.000$  Normal Force Acting on Pipeline  
 $(A \cdot p) / b = \pi \cdot D = 2.356$  Area Based on Full Circum.  
 $F_{sb} = (A \cdot p) / b \cdot f_c + W \cdot \tan((\pi / 180) \cdot f_p \cdot \phi) = 277.155$  Frictional Resistance  
 $L = (S \cdot F \cdot A) / F_{sb} = 92.844$  Minimum Restraint Length

# Project Name: City Water Project

Fitting Type	Pipe Material	Soil Type	Safety Factor	Trench Type	Depth Of Bury	Test Pressure	Nominal Size	Bend Angle	Branch Size	Length Along Run	Small Size	Lowside Depth	Restraint Length	Restraint Length 2
Tee	Ductile Iron	ML	2.0 to 1	3	3	200	8		8	0			93 ft	

Site Location: City Water Project



### Defined Variables

- H = 3 Depth of Bury
- SF = 2.0 Safety Factor
- P = 200 Internal Pressure
- Lr = 0 Retained Length along run

### Pipe Derived Variables

- Ab = 64.330 Cross Sec. Area of Branch
- D = 0.750 Outside Pipe Diameter
- d = 0.750 Outside Pipe Dia. of Branch
- Wp = 26.000 Weight of Pipe
- Ww = 24.000 Weight of Water in Pipe

### Soil Derived Variables

- fc = 0.000 Cohesion Modifier Coefficient
- c = 0.000 Cohesion of Soil
- fp = 1.000 Friction Angle Modifier
- Phi = 29.000 Internal Friction Angle of Soil
- F = 100.000 Soil Density
- Kn = 0.600 Trench Compaction Modifier

### Calculations for Tee

$$We = F \cdot d \cdot H = 225.000 \text{ Normal Force Due to Soil}$$

$$W = 2We + Wp + Ww = 500.000 \text{ Normal Force Acting on Pipeline}$$

$$Kp = \tan^2((\pi/180)(45 + (\pi/2))) = 2.882 \text{ Rankin Passive Pressure Coeff.}$$

$$Hc = H + (D/2) = 3.375 \text{ Depth from Surface to Pipe Center}$$

$$\Delta h = F \cdot Hc \cdot Kp + 2c \cdot \sqrt{Kp} = 972.695 \text{ Horizontal Passive Soil Pressure}$$

$$Rs = Kn \cdot \Delta h \cdot D = 2.356 \text{ Area Based on Full Circum.}$$

$$Fsb = (Ap) \cdot b \cdot fc \cdot c + W \cdot \tan((\pi/180) \cdot fp \cdot \Phi) = 437.713 \text{ Bearing Resistance on Pipelines}$$

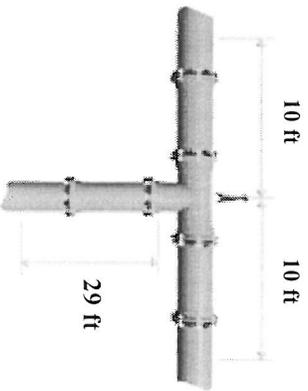
$$Lb = (SF) \cdot ((P \cdot Ab) - (Rs \cdot Lr)) / Fsb = 277.15 \text{ Frictional Resistance}$$

$$92.844 \text{ Minimum Restrained Length}$$

# Project Name: City Water Project

Fitting Type	Pipe Material	Soil Type	Safety Factor	Trench Type	Depth Of Bury	Test Pressure	Nominal Size	Bend Angle	Branch Size	Length Along Run	Small Size	Lowside Depth	Restraint Length	Restraint Length 2
Tee	Ductile Iron	ML	2.0 to 1	3	3	200	8		6	10			29 ft	

Site Location: City Water Project



### Defined Variables

- H = 3 Depth of Bury
- Sf = 2.0 Safety Factor
- P = 200 Internal Pressure
- Lr = 10 Retained Length along run

### Pipe Derived Variables

- Ab = 37.390 Cross Sec. Area of Branch
- D = 0.750 Outside Pipe Diameter
- d = 0.580 Outside Pipe Dia. of Branch
- Wp = 26.000 Weight of Pipe
- Ww = 24.000 Weight of Water in Pipe

### Soil Derived Variables

- fc = 0.000 Cohesion Modifier Coefficient
- c = 0.000 Cohesion of Soil
- fp = 1.000 Friction Angle Modifier
- φ = 29.000 Internal Friction Angle of Soil
- F = 100.000 Soil Density
- Kn = 0.600 Trench Compaction Modifier

### Calculations for Tee

$$We = F \cdot d \cdot H = 174.000 \text{ Normal Force Due to Soil}$$

$$W = 2We + Wp + Ww = 398.000 \text{ Normal Force Acting on Pipeline}$$

$$Kp = \tan^2(\pi/180)(45 + (\pi/2)) = 2.882 \text{ Rankin Passive Pressure Coeff.}$$

$$He = H + (D/2) = 3.375 \text{ Depth from Surface to Pipe Center}$$

$$\Delta h = F \cdot He \cdot Kp + 2c \cdot \sqrt{Kp} = 972.695 \text{ Horizontal Passive Soil Pressure}$$

$$(Ap)b = \pi \cdot D = 2.356 \text{ Area Based on Full Circum.}$$

$$Rs = Kn \cdot \Delta h \cdot D = 437.713 \text{ Bearing Resistance on Pipelines}$$

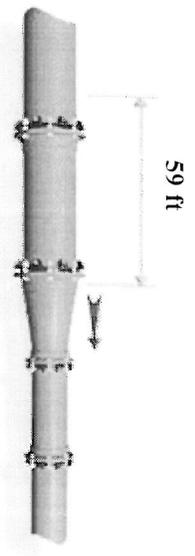
$$Fsb = (Ap)b \cdot fc \cdot c + W \cdot \tan(\pi/180) \cdot fp \cdot \phi = 220.62 \text{ Frictional Resistance}$$

$$Lb = (Sf)((P \cdot Ab) - (Rs \cdot Lr)) / Fsb = 28.111 \text{ Minimum Restraint Length}$$

# Project Name: City Water Project

Fitting Type	Pipe Material	Soil Type	Safety Factor	Trench Type	Depth Of Bury	Test Pressure	Nominal Size	Bend Angle	Branch Size	Length Along Run	Small Size	Lowside Depth	Restraint Length	Restraint Length 2
Reducer	Ductile Iron	ML	3.0 to 1	3	3	200	8				6		59 ft	

Site Location: City Water Project



### Defined Variables

H = 3 Depth of Bury  
 Sf = 3.0 Safety Factor  
 P = 200 Internal Pressure

### Pipe Derived Variables

AI = 64.330 Cross Sec. Area of Pipe (lg)  
 Assx = 37.390 Cross Sec. Area of Pipe (sm)  
 D = 0.750 Outside Pipe (lg) Diameter  
 d = 0.580 Outside Pipe (sm) Diameter  
 Wp = 26.000 Weight of Pipe  
 Ww = 24.000 Weight of Water in Pipe

### Soil Derived Variables

fc = 0.000 Cohesion Modifier Coefficient  
 c = 0.000 Cohesion of Soil  
 fp = 1.000 Friction Angle Modifier  
 Φ = 29.000 Internal Friction Angle of Soil  
 Γ = 100.000 Soil Density

### Calculations for Reducer

We = Γ · D · H = 225.000 Normal Force Due to Soil  
 W = 2We + Wp + Ww = 500.000 Normal Force Acting on Pipeline  
 (Ap)b = π · D = 2.356 Area Based on Full Circum.  
 Fsb1 = (Ap)b · fc · c + W · tan(π/180) · fp · Φ = 277.155 Frictional Resistance  
 LI = (SFP · (AI - Assx)) / Fsb = 58.321 Minimum Restrained Length

Project Notes: