# Burris Basin GWRS Turnout Project

Draft Preliminary Design Report

Prepared for:
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# Executive Summary

Orange County Water District (OCWD) currently owns and operates approximately 1,200 acres of recharge spreading facilities in and adjacent to the Santa Ana River, Carbon Creek, and Santiago Creek. A significant part of the operations entails the pumping of purified water from the Ground Water Replenishment System (GWRS) water treatment plant in Fountain Valley northward to a series of four recharge basins (Miller, Kraemer, Miraloma and La Palma Basins) located in Anaheim via the GWRS pipeline. The GWRS plant is currently undergoing a "Final Expansion" which, when completed in 2023, will allow OCWD to produce up to 130 MGD of purified water. Of the 130 MGD produced, approximately 100 MGD will be delivered to the northern recharge basins with the balance of purified water used for the Mid Basin Injection (MBI) Turnout and Talbert seawater intrusion barrier.

With increased GWRS production, and the desire for additional operational flexibility, OCWD has determined a turnout from the GWRS pipeline to Burris Basin is warranted. The new turnout will allow OCWD to divert flows to Burris Basin ranging from 7 MGD up to a maximum of 100 MGD. During maximum flow diversions of 100 MGD, OCWD will be able to take three of the northerly recharge basins offline for maintenance during this operational scenario (Miller, Kraemer and Miraloma Basins).

The following items will be discussed in more detail in this PDR:

1. Introduction – Project background and proposed improvements / objectives.

2. Existing Conditions – Summarizes the existing conditions at the project site and surrounding area. Project constraints are discussed including center levee requirements, basin improvements, basin operations and existing utilities.

3. Basis of Design – Establishes the design criteria to be used for the final design of the various proposed improvements. Also includes hydraulic modeling results for the GWRS system.

4. Alternatives – Summarizes advantages / disadvantages of the alternative designs developed for the proposed project.

5. Project Administration – Summarizes the permits required for construction of the proposed improvements and a listing of the recommended technical specifications required for the bid construction documents.

6. References

Also included in the attached Appendix are schematic designs, supporting calculations, catalogue cut sheets with quotes for the various materials / instrumentation / devices, hydraulic modeling data, and preliminary opinion of probable costs.

# 1.0 INTRODUCTION

## 1.1 BACKGROUND

The proposed Burris Basin turnout is located at the southern end of Burris Basin, north of Ball Road and west of the Santa Ana River. Burris Basin provides some recharge but is primarily a reservoir for storing water that is pumped to the Santiago Basins. Burris basin is separated from the Santa Ana River by the existing Santa Ana River Levee, commonly referred to as the "center levee". The existing GWRS pipeline is located within the center levee and all proposed work within or influenced by the center levee is under Army Corps of Engineers (ACOE) jurisdiction and subject to their review. The GWRS line is located within property owned by Orange County Flood Control District (OCFCD) and all proposed work within OCFCD property will also need to be reviewed / approved by OCFCD.

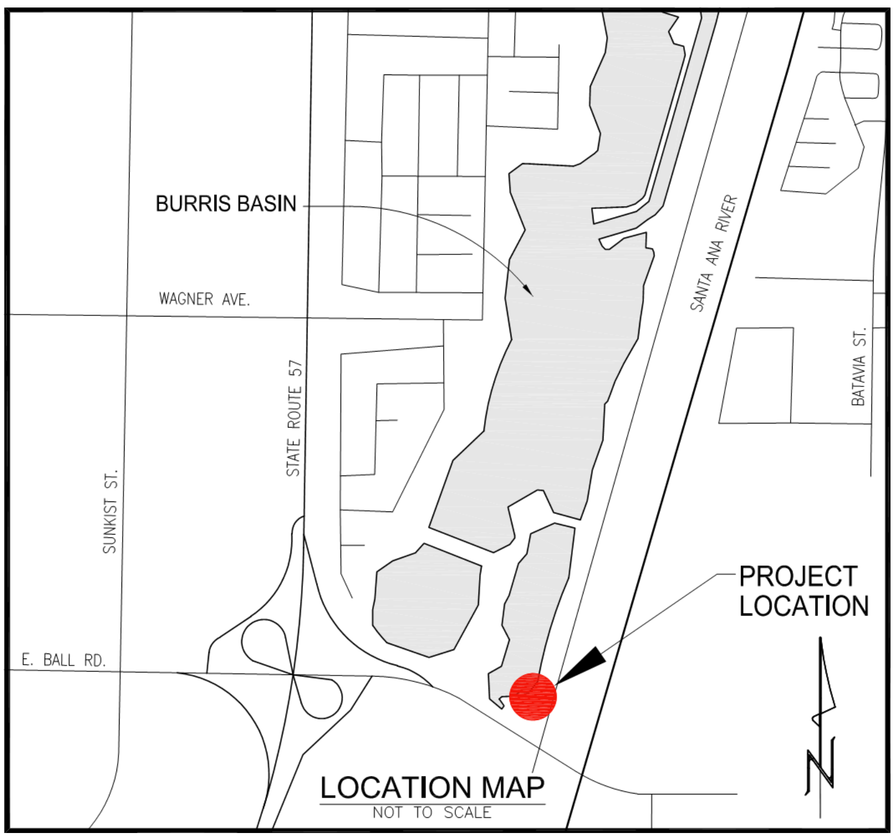


**Figure 1 Location Map**

# 1.2 PROPOSED IMPROVEMENTS

Proposed improvements include grading, pipes, valves, meters and structures. The improvements, and associated objectives are summarized below:

**Grading**

- Provide a graded pad area that will allow for OCWD operations and maintenance access to the proposed facilities;
- Balance site from an earthwork standpoint (materials will be generated from the Burris Basin floor and per the Geotech's recommended offset from the center levee);
- Graded slopes at ratio per geotechnical recommendations;
- Graded ramp that will allow ingress and egress to the basin floor; and
- Improvements that do not impact the center levee and in conformance with Corps requirements.

**Pipeline**

- Provide a pipe configuration that will allow for the diversion of GWRS water into Burris Basin given the variable flow scenarios ranging from about 7 MGD to 100 MGD;
- Consider use of parallel piping to reduce valve and meter sizes and increase operational /maintenance flexibility; and
- Use of steel pipe with cement coating and epoxy lined to resist corrosion;

**Appurtenances**

- Provide a manual isolation valve between the GWRS pipeline and turnout assembly;
- Motor operated valves for "throttling" flow rates to the basin;
- Meters to track quantity of water delivered; and
- Water level sensor in air gap structure for back-up flow measurement.

**Structures**

- Air-gap structure designed to prevent siphoning of basin water into GWRS pipeline; and
- Dissipation structure designed to prevent basin shore erosion.

**Electrical and Instrumentation**

- Provide power needed to operate and monitor proposed devices / instrumentation;
- Provide remote monitoring and control of various facility devices including motor operated valves, flow meters, and water level sensors; and
- Ensure new devices are integrated into the District's existing SCADA system.

# 2.0 EXISTING CONDITIONS

## 2.1 PROJECT SITE

The project site is located near the southeasterly corner of Burris Basin and is bounded by Ball Road to the south and the Santa Ana River to the east. The site is separated from the Santa Ana River by a levee (center levee). Additional information as follows:

- the existing GWRS pipeline is located within the center levee;
- a fiber optic run for GWRS signal / control is located adjacent to the mainline pipe;
- the GWRS pipeline is a 66" diameter CMC&CL pipe which reduces to a 60" diameter followed by a 60" tee located at the proposed turnout location;
- there is an existing 60" mainline BFV just downstream of the tee which when closed allows for mainline draining via a 12" pipe to Burris Basin;
- above ground equipment includes meter pedestal / power distribution panel and RTU
- earthen access ramp from the center levee to bottom of Burris Basin;
- 16" crude oil line (not anticipated to be a conflict); and
- abandoned 36" CMP SD line that runs perpendicular to the GWRS line (to be removed if there's a conflict with the proposed improvements).

Burris Basin is operated at a normal water surface elevation of 165.0 and has an overflow spillway located at the southwesterly corner of the basin at elevation 174.0.

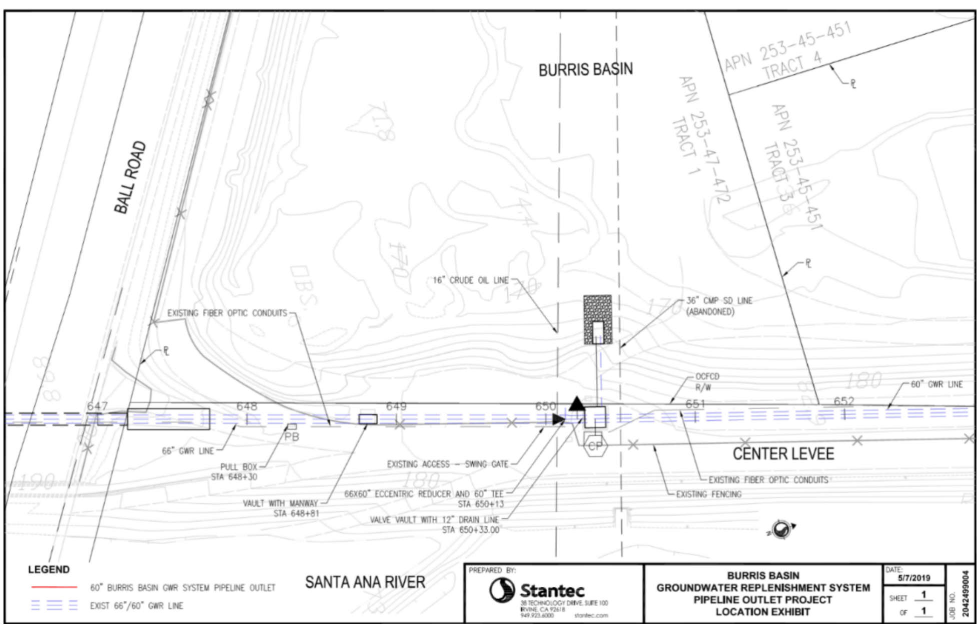


**Figure 2 Existing Site Map**

## 2.2 PROPERTY OWNERSHIP

Burris Basin is owned and operated by OCWD. Burris Basin is adjacent to the Santa Ana River which is owned and operated by Orange County Flood Control District (OCFCD). Within the center levee, OCWD has an easement over the GWRS pipeline granted by OCFCD.

## 2.3 SITE TOPOGRAPHY

The existing site and surrounding terrain have been mapped by generating an aerial topo compiled at a 2-foot contour interval. OCWD has provided the topo and it has been used previously to construct the Burris and Lincoln Basins Reconfiguration Project (circa 2010) and more recently the Burris Basin Pump Station Project.

The project vertical and horizontal control are based on the following:

**BASIS OF BEARINGS**

THE BEARINGS SHOWN HEREON ARE BASED ON THE GRID BEARING "**N 01°05'12" E**" BETWEEN O.C.S. HORIZONTAL CONTROL STATION GPS NO. **3282** AND GPS NO. **5247R1** PER RECORDS ON FILE IN THE OFFICE OF THE ORANGE COUNTY SURVEYOR.

**DATUM STATEMENT**

COORDINATES ARE BASED ON THE CALIFORNIA COORDINATE SYSTEM (CCS83) ZONE VI, NAD 83 (2007.00 EPOCH ADJUSTMENT), AS PER RECORDS ON FILE IN THE OFFICE OF THE ORANGE COUNTY SURVEYOR.

**BENCHMARK**

THE ELEVATIONS SHOWN ARE BASED ON O.C.S. BENCHMARK 1L-57-82, USING NAVD88 ELEVATION OF 190.113', PER RECORDS ON FILE IN THE OFFICE OF THE ORANGE COUNTY SURVEYOR.

**FIELD SURVEYS**

Supplemental topography will be generated by Stantec field survey crews to verify the existing topography and obtain precise information at specific key features and join points. Surveyors will also be on-site when potholing occurs to capture horizontal and vertical location of potholed items.

Stantec's mapping specialist will research existing record maps / monumentation prior to field crews visiting the site. The survey crew will locate the monuments and confirm the basis of bearing calculated is accurate. The mapping base will be oriented / adjusted to match the field verified data.

## 2.4 UTILITIES

Existing utilities located within the project site have been identified on the schematic design. A DigAlert search was conducted resulting in a list of potential purveyors with utilities in the local vicinity of the project. The purveyors were contacted, and record information requested. The only utility known at this time to be in close proximity of the proposed improvements is included in the table below:

**Table 2.1 Existing Utilities**

| Agency/Utility | Contact | Email | Phone Number |
|---|---|---|---|
| 16" Crude Oil Line | Cole Wright | cole.wright@dominionenergy.com | (307) 352-7115 |
| 12" GWRS Drain Line | Fernando Almario | falmario@ocwd.com | (714) 378-8220 |

## 2.5 CONSTRAINTS

Known project constraints that may affect the project design features include the following:

- Center levee
- Burris Basin operations
- OCFCD operations
- Existing GWRS pipeline and associated appurtenances

# 3.0 BASIS OF DESIGN

## 3.1 DESIGN CRITERIA

The following subsections detail the design criteria to be used for the proposed improvements design.

### 3.1.1 Basin Grading

- 2:1 slopes minimum;
- positive drainage;
- 0.3% minimum slope for basin floor; and
- adherence to geotechnical recommendations.

### 3.1.2 Site Grading

- Adequate pad area for operations and maintenance;
- earthen ramps to basin floor at 15 feet wide;
- minimum inside turning radius of 30 feet;
- maximum slope of 10% for ramps; and
- fill material excavated from basin floor.

### 3.1.3 Mechanical Design Criteria

**Pipeline design criteria:**

- Material: steel with cement mortar coating and epoxy lining;
- corrosion protection commensurate with Geotech findings;
- Minimum cover: 48";
- Minimum slope: 0.0% for pressure lines;
- Steel wall thickness based on AWWA M11 5th edition (see Appendix for preliminary pipe wall thickness calculations):
  - internal pressure,
  - deflection, and
  - buckling
- Pipe diameter based on:
  - maximum design flow rate of about 155 cfs;
  - maximum velocity of 8 fps
  - Hazen Williams Equation and roughness coefficient C = 130

**Valve design criteria:**

Butterfly Valves

- worm gear operators;
- electric motor and manual actuators; and
- Pratt or Dezurik BFVs and AUMA actuators or approved equal.

A single 60" isolation BFV is proposed at the existing GWRS pipeline 60" tee. This valve will be manually operated and buried.

Ball Valves

- Metal seated; and
- Pratt or Dezurik dependent upon available sizes.

Ball valves are proposed for all schematic design alternatives (see Section 4) for control of flow rates through the turnout structure. In alternatives 1 & 2, both ball valves will be controlled in tandem to achieve desired flow rate.

**Meter design criteria:**

- magnetic type with forward and reverse flow measurement capability;
- no bends, valves etc. within five pipe diameters upstream and three pipe diameters downstream (or per selected manufacturer's recommendations); and
- Khrone Tidaflux 4000 Series or approved equal.

Two mag meters are proposed for the 36" & 48" pipes in schematic design alternatives 1 & 2 (see Section 4), or a single mag meter for the 60" pipe in alternative 3.

**Level sensor design criteria:**

- Pressure transducer type (Druck) and / or ultrasonic type (Siemens AG) dependent upon installation location.

Water level sensors are proposed within the air gap structure (ultrasonic) and Burris Basin near the proposed dissipator structure (transducer).

### 3.1.4 Structural Design Criteria

Structures will include an air-gap and dissipator and will be designed to meet the following current edition criteria:

- California Building Code; and
- ACI 318-11 Building Code Requirements for Structural Concrete

Material properties will meet the following:

- Concrete strength, f'c = 4,000 psi;
- Concrete cement type per project's Geotech Report corrosivity test results (Type II or V cement);
- Reinforcing steel, ASTM 615, Gr. 60, fy = 60,000 psi;
- Seismic Design Criteria obtained from USGS and the project's Geotechnical Report; and
- Soil design parameters obtained from the project's Geotechnical Report.

### 3.1.5 Electrical, Instrumentation and SCADA Design Criteria

**Electrical design criteria:**

- Comply with edition of the NEC recognized by the Authority Having Jurisdiction.
- Utilize the existing 100A, 277Y/480V electric service. The serving electric utility company is the City of Anaheim. The electric utility meter number is 58S422NKS.
- Expand the power distribution system that emanates from the existing electric service. The existing system consists of a 100A, 277Y/480 panelboard and a 10kVA, 480V:120/240V single phase transformer with 40A, 120/240V panelboard in the form of an integrated unit. A second similar integrated unit will be added if enough spare 120V circuits do not exist.

**Instrumentation design criteria:**

<u>Control Panel</u>

- Comply with edition of the NEC recognized by the Authority Having Jurisdiction.
- Expand the existing system Control Panel CPC-003 (GWRS Pipeline Valve Vault #3 Panel) to provide for additional level, flow and valve monitoring and control.
- The existing Phoenix Contact Inline Bus Coupler FL IL 24 BK-PAC – 2862314 has since reached obsolescence and will need to be replaced. Existing modular I/O modules shall be reviewed for reuse.

<u>Flow Control Ball Valves</u>

- Provide I/O and connections for monitoring and control of two electric actuators associated with the flow control ball valves - valve control, position, limits and alerts etc.

<u>Flow Meters</u>

- Khrone Tidaflux 4000 Series or approved equal magnetic type with forward and reverse flow measurement capability; (Two FM's Design Alt. 1 & 2 or one FM for Design Alt. 3).

<u>Level Measurement</u>

- One Pressure transducer type (Druck) and / or ultrasonic type (Siemens AG) dependent upon final installation location.

**SCADA design criteria:**

- Communications between the project site and the District's Central SCADA system located at the District's Field Headquarters is existing and makes use of fiber optic;
- Local PLCs will be Phoenix Contact InLine Series, Ethernet capable with standard PLC I/O and communication to level sensors, flow meters and motor operated valves;
- Data acquisition through the SCADA system to include air-gap structure water level, basin water level, flow rates, valve motor on/off and valve positioning;
- Remote control of valve motor on/off and valve positioning; and
- Automatic valve motor on/off in relationship to water level in the basin.

## 3.2 HYDRAULIC MODELING

Hydraulic modeling was conducted to determine water distribution effects due to the proposed Burris Basin turnout. Utilizing Innovyze InfoWater, the GWRS pipeline network model was updated to run the following scenarios:

- Scenario 1 – The proposed Burris Basin turnout is closed and not being utilized.
- Scenarios 2A & 2B – Considered "typical" operational ranges for the various basins, except for Kraemer Basin, which is closed under Scenarios 2A & 2B.
- Scenario 3 – Assumes MET imports to Kraemer and Miller Basins and therefore no GWRS water to these basins.
- Scenario 4 – This scenario delivers 100 mgd to Burris Basin and allows for Miraloma, Kraemer, and Miller to be placed offline for maintenance. La Palma Basin is allowed to flow at 13 mgd. This scenario would also apply if the groundwater producers stop pumping from the basin and are purchasing "in-lieu" water from MET (groundwater elevations in the basin would rise, thus Talbert Barrier injection would be ramped down).

The table below summarizes actual water delivery flow rates analyzed.

### Table 3.1 GWRS Operational Scenarios

| | GWRS FLOW SCENARIOS (MGD) | | | | |
|---|---|---|---|---|---|
| | 1 | 2A | 2B | 3 | 4 |
| **MBI Turnout** | 8 | 8 | 8 | 8 | 8 |
| **Burris** | 0 | 7 | 10 | 25 | 100 |
| **La Palma** | 65 | 65 | 65 | 65 | 13 |
| **Miraloma** | 13 | 13 | 13 | 13 | 0 |
| **Kraemer** | 25 | 0 | 0 | 0 | 0 |
| **Miller** | 0 | 20 | 15 | 0 | 0 |
| **Total GWRS Pumped Flow*** | 111 | 113 | 111 | 111 | 121 |
| **Talbert Seawater Barrier** | 19 | 17 | 19 | 19 | 9 |
| **TOTAL** | 130 | 130 | 130 | 130 | 130 |

**Note: Total GWRS Pumped Flow assumes an additional water source from the proposed Huntington Beach Desalination Plant. A total of 100 MGD will be the maximum GWRS Water Purification Plant output after final expansion.*

Variable Speed Pump Control was added to the pumps in the model to simulate the existing variable frequency drive (VFD) system and to adjust the downstream pressure setting. In this analysis, the downstream pressure was set to 130 psi. The roughness coefficient was set at 130 for the transmission mains in the hydraulic model. In addition, the following weir heights were entered into the model.

La Palma: 231
Miraloma: 231
Miller: 234
Kraemer: 229

Appendix A.1 includes a hydraulic model exhibit and a representative pump curve. Since the total GWRS pumped flows do not vary much from one scenario to another, pump curves for a single scenario is included in Appendix A.1 and is intended to be representative of all provided scenarios.

In each of the five scenarios described in Table 3.1, the resulting pressures at Burris Basin, at the proposed elevations of 184 feet and 194 feet, were verified and summarized in Table 3.2 below. The analysis also verified that there would be sufficient pressure (i.e. positive pressure) for water to flow over the weir at each of the four existing basins. Model results in Table 3.2 below indicate the existing GWRS system will function as desired under the various flow scenarios. These results assume head needed to pump to the upper basins is available; however, the District understands a booster pump would be necessary to achieve the desired flow rates. Currently the booster pump is envisioned to reside at Burris Basin and would tie into the proposed GWRS Turnout infrastructure.

**Table 3.2 Model Results**

| Scenario | Meets GWRS Flow Scenarios* | Pressure (psi) | | Head Loss at Burris Basin Turnout | Burris Basin Turnout 60" CMC&EL Pipeline Velocity (ft/s) |
|---|---|---|---|---|---|
| | | at 194 msel | at 184 msel | | |
| 1 | Yes | 19 | 24 | - | - |
| 2A | Yes | 18 | 22 | 0.02 ft/1000ft | 0.55 |
| 2B | Yes | 19 | 24 | 0.04 ft/1000ft | 0.79 |
| 3 | Yes | 19 | 24 | 0.20 ft/1000ft | 1.97 |
| 4 | Yes | 9 | 14 | 2.57 ft/1000ft | 7.88 |

**Note: "Yes" in this category indicates that the GWRS system has adequate pressure to deliver water per the flow scenarios defined in Table 3.1 above.*

## 3.3 GEOTECHNICAL INVESTIGATION

Stantec subconsultant, Ninyo & Moore (N&M), will conduct a geotechnical investigation. A "Drilling Program Plan" will be prepared for Corps of Engineers review prior to conducting the field work. The geotechnical recommendations will be incorporated into design criteria.

# 4.0 ALTERNATIVES

## 4.1 ALTERNATIVES OVERVIEW

Stantec has developed two alternatives for OCWD consideration, a summary of which is presented below

**Table 4.1 Alternatives**

| Alternative Number | Description |
|---|---|
| 1 | • Graded pad on Burris side of center levee large enough to allow access around turnout structure and air-gap structure.<br>• Earthen ramp allowing access to basin floor.<br>• 60" CMC&EL line and 60" butterfly valve connects to existing flange.<br>• 60" line runs northward and flanges into underground 60"x36" tee.<br>  o 48" CMC&El steel pipe on tee run.<br>  o 36" CMC&EL steel pipe on tee branch.<br>• 36" and 48" line bend vertically out of ground.<br>• 48" & 36" lines outlet into Air Gap structure with 15' wide weir 10'± above graded pad. Level sensor within Air Gap.<br>• Air Gap structure outlets to dissipation structure. |
| 2 | • Graded pad on Burris side of center levee large enough to allow access around turnout structure and air-gap structure.<br>• Earthen ramp allowing access to basin floor.<br>• 60" CMC&EL line and 60" butterfly valve connects to existing flange.<br>• 60" line runs northward and is entirely underground.<br>• Metering and valving on 60" line within vaults.<br>• 60" lines outlet into Air Gap structure with 15' wide weir 10'± above graded pad. Level sensor within Air Gap.<br>• Air Gap structure outlets to dissipation structure. |

Additionally, an "option" is presented for OCWD's consideration. This option may apply to one or more above alternative:

- For both alternatives, an option to provide a blind flanged tee for future pump station connection is available to OCWD.

## 4.2 ALTERNATIVES ANALYSIS

OCWD operational needs and cost will be considered in this decision. A matrix of considerations is presented below in Table 4.2.

**Table 4.2 Alternatives Analysis**

| | **Alternative 1** 36" & 48" parallel lines | **Alternative 2** Single 60" line |
|---|---|---|
| Design Objectives Met | 3 | 3 |
| Site Constraints Met | 3 | 3 |
| Cost | TBD | TBD |
| OCWD Operational Flexibility | 3 | 2 |
| Total Score | 9 | 8 |

Note: "1" – Least Ideal, "2" – Sufficient and "3" – Most Ideal

Alternative 1 ranks the highest and is the recommended alternative for final design. This is primarily due to the greater operational flexibility it provides OCWD. Pipes in parallel act as bypasses if maintenance on either line is needed. Also, above ground assembly prevents the need for OCWD to work in a confined space. Preliminary Opinions of Probable Costs for each alternative have been prepared and are summarized below (see Appendix for line item costs):

- Alternative 1 - $xxx
- Alternative 2 - $xxx

# 5.0 PROJECT ADMINISTRATION

## 5.1 PERMITS

A summary of anticipated permits required for the project are included Table 5.1 below.

**Table 5.1 Permits**

| Permit Type | Description |
|---|---|
| OCFCD Property Encroachment Permit | An encroachment permit is necessary for the proposed improvements considering the existing tee falls within OC property. |
| Army Corps 408 Permit | A 408 Permit will be required considering the proposed improvements fall with the center levee and therefor subject to Corps review. |
| 401 / 404 Permit | TBD |
| 1600 Permit | TBD |

## 5.2 TECHNICAL SPECIFICATIONS

The following is a preliminary list of anticipated technical specifications to be developed for the project construction documents:

**Table 5.2 Technical Specifications**

| Section | Description |
|---|---|
| Division 1 – General Project Provisions | |
| 01000 | General Safety Requirements |
| 01045 | Existing Facilities |
| 01150 | Measurement and Payment |
| 01300 | Submittals |
| 01310 | Project Control Schedule |
| 01430 | Maintenance Manual Requirements |
| Division 2 – Construction/Installation Provisions | |
| 02100 | Site Preparation |
| 02140 | Dewatering and Drainage |
| 02201 | Earthwork |
| 02220 | Structure Backfill |
| 02221 | Demolition and Salvage |
| 02223 | Trenching, Backfilling, and Compacting |

| Section | Description |
|---|---|
| 02271 | Rip-Rap |
| 02433 | Reinforced Concrete Pipe |
| 02444 | Fencing |
| 02718 | Installation of Water Pipeline |
| Division 3 – Concrete Provisions | |
| 03150 | Formwork for Cast-in-place Concrete |
| 03200 | Reinforcing |
| 03260 | Concrete Joints and Waterstops |
| 03300 | Cast-in-Place Concrete |
| 03345 | Concrete Finishing, Curing and Waterproofing |
| 03462 | Precast Concrete Vaults and Meter Boxes |
| Division 5 - Metals | |
| 05120 | Structural Steel |
| 05125 | Miscellaneous Metals |
| Division 9 – Finishes (Coatings) | |
| 09900 | Painting and Protective Coatings |
| 09960 | Protective Coating for Concrete Structures |
| Division 11 – Equipment | |
| 11005 | General Mechanical and Equipment Provisions |
| 11293 | Motor Operators |
| 11300 | Meters |
| 11400 | Level Sensors |
| 11500 | Equipment House |
| Division 15 – Mechanical | |
| 15042 | Hydrostatic Testing of Pressure Pipelines |
| 15043 | Leakage and Infiltration Testing of Non-Pressure Pipelines |
| 15051 | Installation of Pressure Pipelines |
| 15076 | Epoxy Lined and Cement Coated Steel Pipe |
| 15089 | Air Valves |
| 15100 | Butterfly Valves |
| 15101 | Motor Operators |
| 15151 | Water Facilities Identification |
| 15180 | Flow Meters |
| Division 16 – Electrical | |
| 16010 | General Electrical Requirements |
| 16111 | Metal Conduit and Fittings |
| 16112 | Plastic Conduit and Fittings |
| 16121 | Low Voltage Wire and Cable |
| 16130 | Boxes |
| 16190 | Supports and Fasteners |
| 16195 | Identification |
| 16450 | Grounding |
| 16461 | Dry-Type Transformers |
| 16470 | Panelboards |

| Section | Description |
|---|---|
| 16475 | Molded Case Circuit Breakers |
| Division 17 – Programmable System Provisions | |
| 17000 | General Instrumentation Control Requirements |
| 17110 | Identification Tags |
| 17200 | Miscellaneous Instrumentation Equipment |
| 17300 | PLCs and Programmable Operator Interfaces |
| 17330 | SCADA System Hardware and Software |

# 6.0 REFERENCES

1. Record Drawings for "Groundwater Replenishment Pipeline Unit III, Contract No. GWRS-2003-03", dated April 2003, prepared by Tetra Tech Inc.

# Appendix A

## A.1 GWRS HYDRAULIC MODELING RESULTS

GWR Model Layout Exhibit

Typical Flow Scenario – GWR Pump Curves

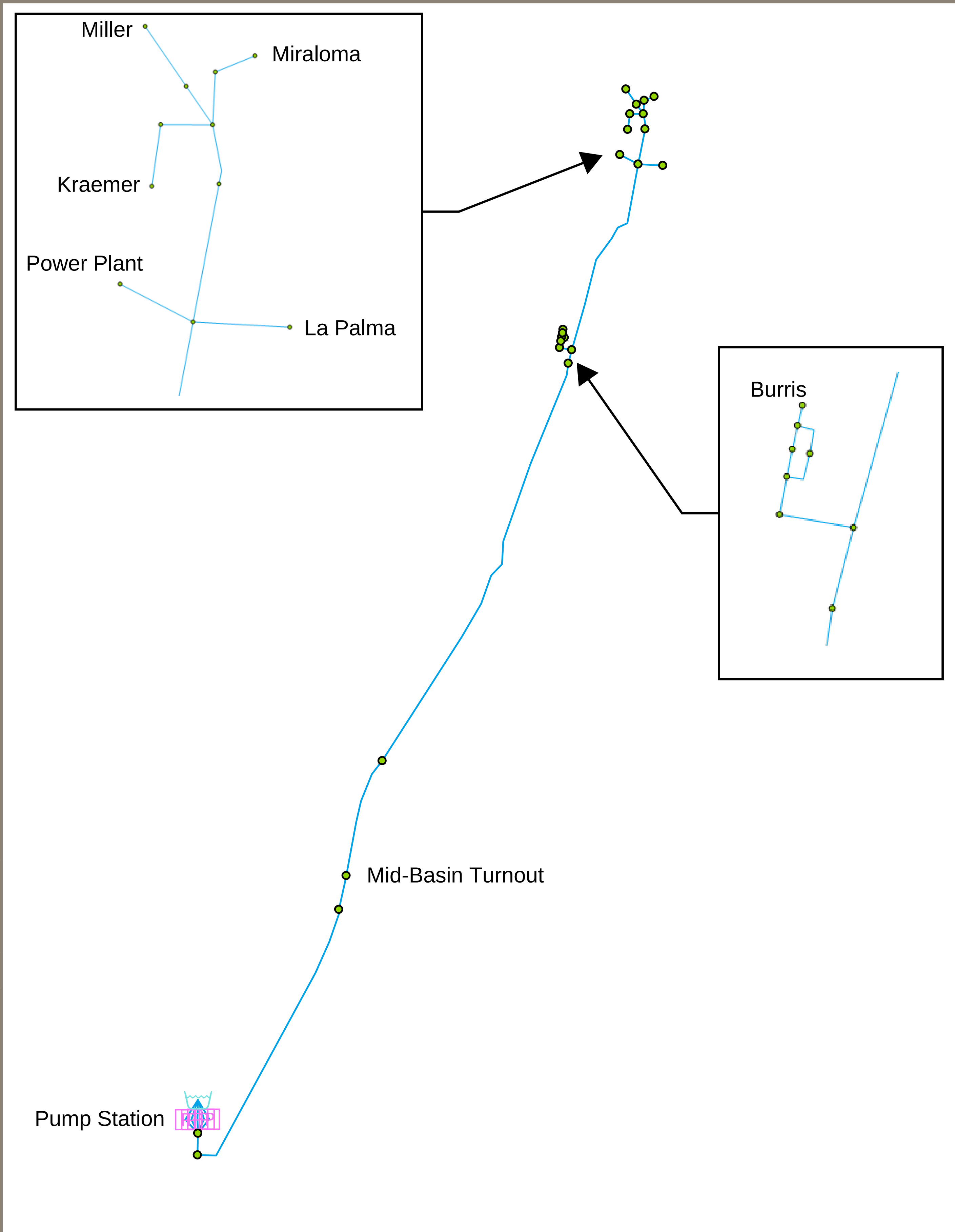


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Exhibit Path: V:\2042\active\2042499000\design\analysis\Burris Basin Analysis\Figures\Figure 3-1 Hydraulic Model.pdf

*Geographic Information Systems*

GIS Analyst: ML Date: 07/01/2019

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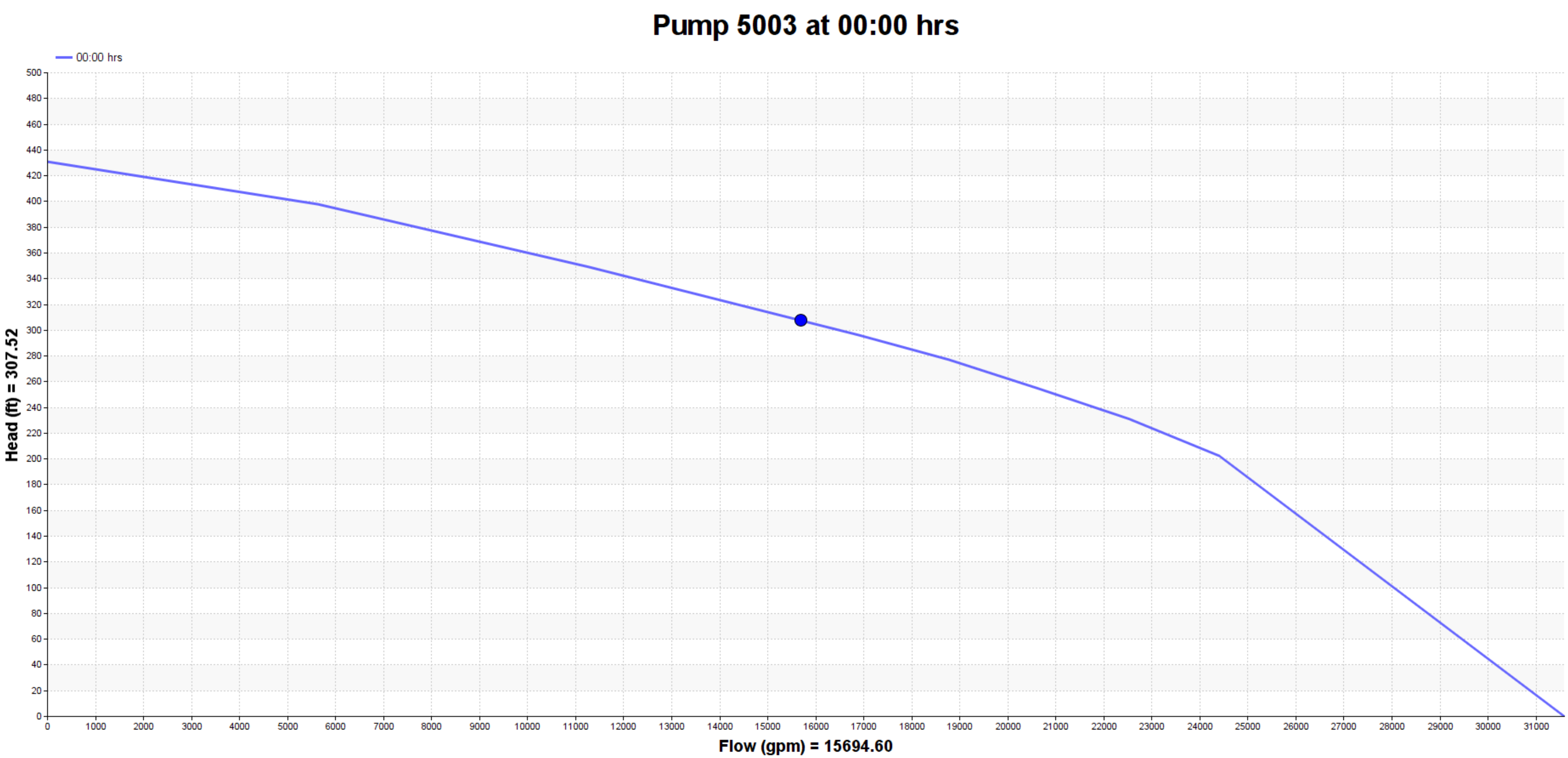
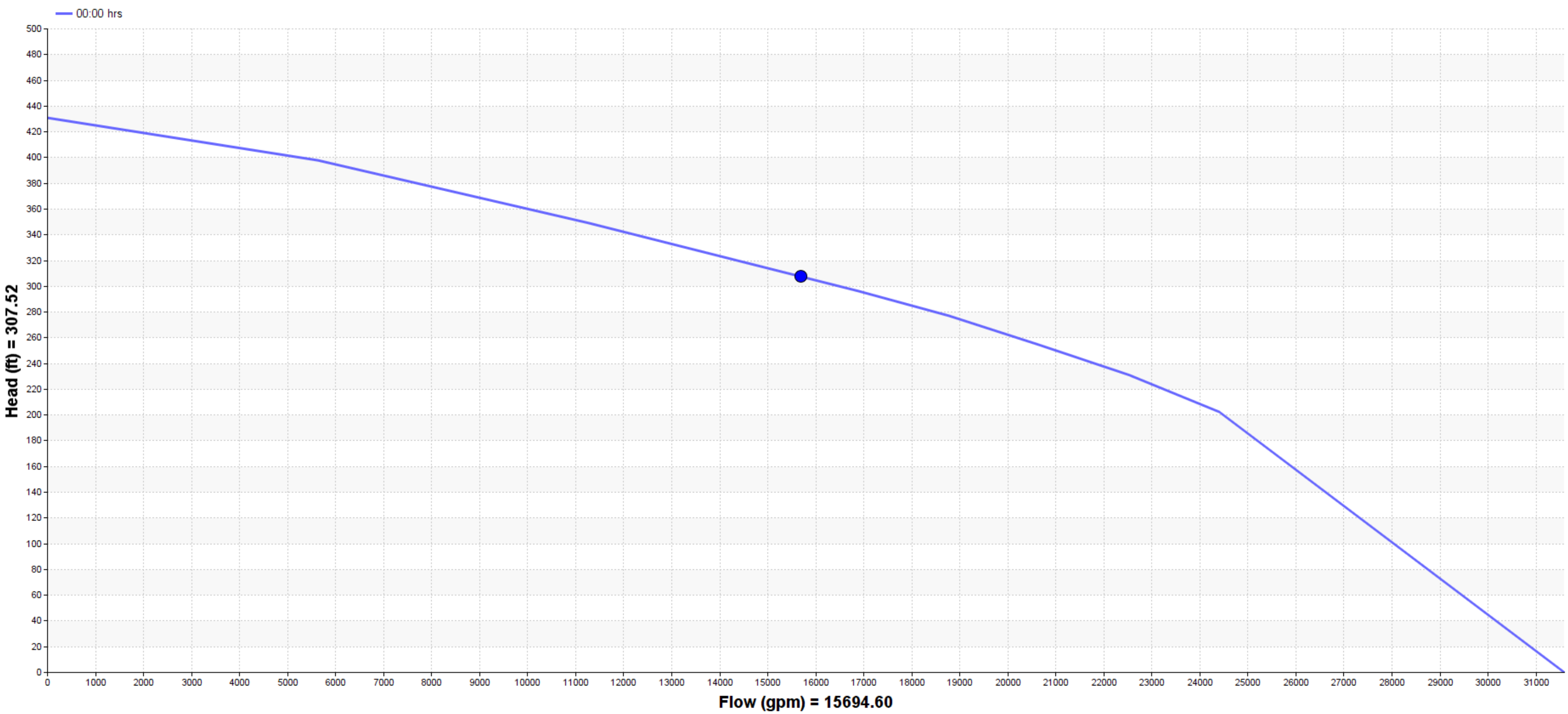
38 Technology Drive, Irvine, CA 92618
Phone 949.923.6000 www.stantec.com

# Hydraulic Model

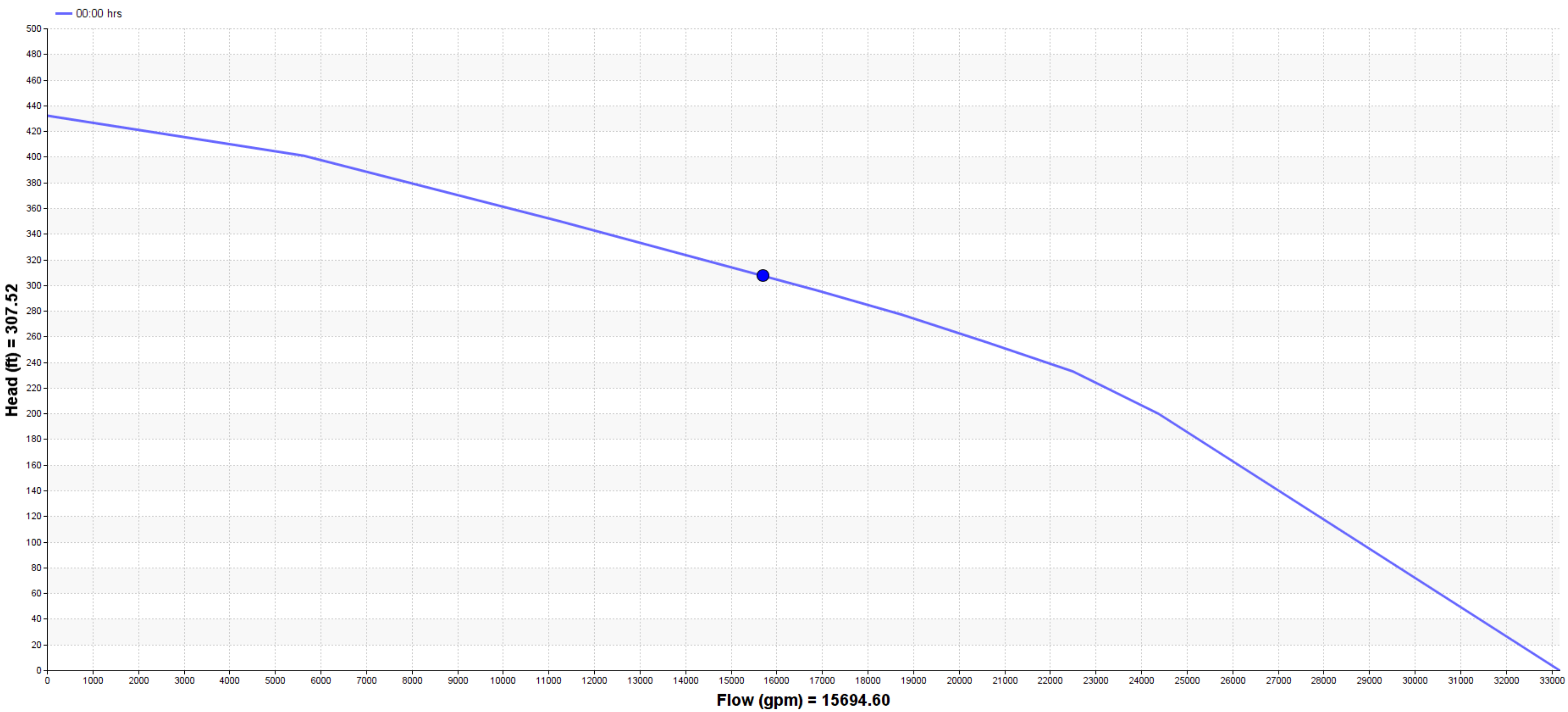
## *Burris Basin GWRS Turnout Project*


Pump 5003 at 00:00 hrs
00:00 hrs
Head (ft) = 307.52
Flow (gpm) = 15694.60

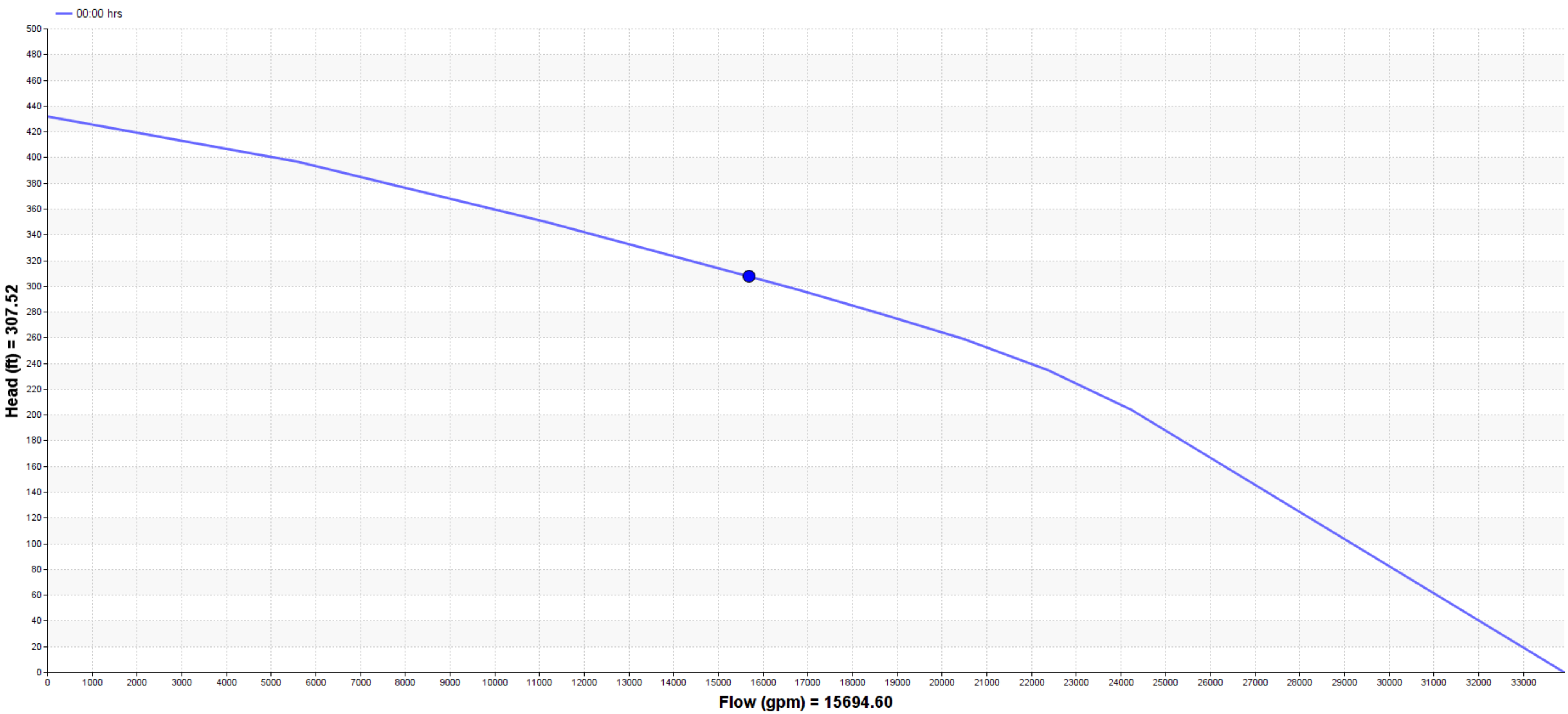
# Pump 5009 at 00:00 hrs

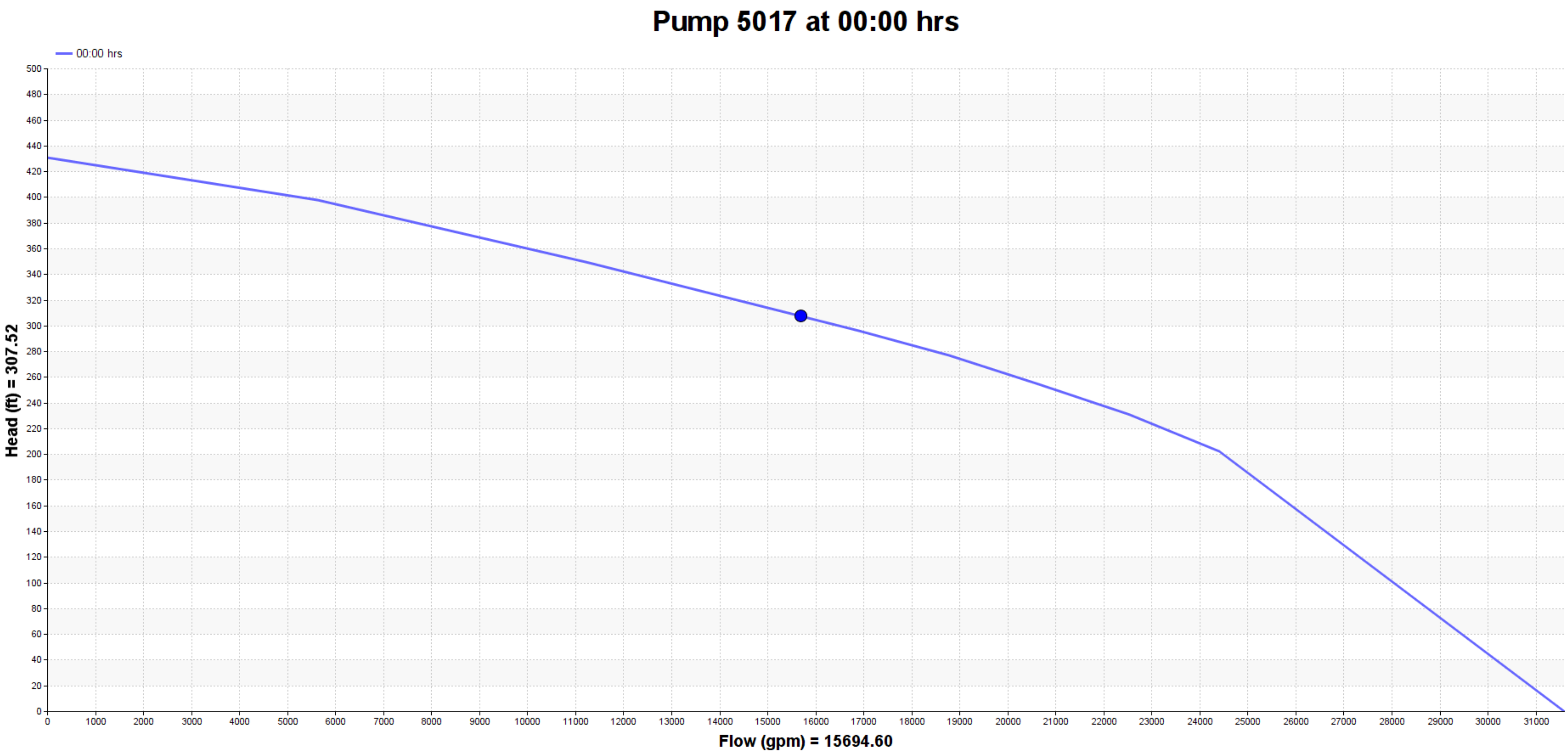


# Pump 5013 at 00:00 hrs



# Pump 5015 at 00:00 hrs




Pump 5017 at 00:00 hrs
00:00 hrs
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
1000
2000
3000
4000
5000
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7000
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10000
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17000
18000
19000
20000
21000
22000
23000
24000
25000
26000
27000
28000
29000
30000
31000
Head (ft) = 307.52
Flow (gpm) = 15694.60

# Appendix B

## B.1 PRELIMARY OPINION OF PROBABLE COSTS

Alternative 1 OPC

Alternative 2 OPC

Alternative 3 OPC

# Appendix C

## C.1 PIPE WALL THICKNESS DESIGN

| | | | |
|---|---|---|---|
| **Client:** | (Client Name here) | **Sheet:** | of |
| **Project:** | (Project Name Here) | **Date:** | mm/dd/yy |
| **Description:** | (Description of what is being calculated, specific building, system, discipline, etc…) | **Job No:** | xxxxxx |
| | | **By:** (Author) | **Chkd By:** xxx |

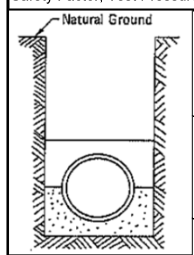
## Steel Pipe Wall Design - Trench Condition

**Steel Cylinder Structural Calculations per AWWA M11 - Fourth Edition (2004)**

| *Legend* | |
|---|---|
| *Red Numbers =* | Input required |

### Minimum Thickness for Internal Pressure (Eqn 4-1, AWWA M11)

| Input Section | | Output Section | |
|---|---|---|---|
| Nominal Diameter of Pipe (DN, in.) = | 48.000 | | |
| Select type of Lining = | Epoxy | Allowable Stress, Working ($s_w$, psi), $Y_s/SF_w$ = | 16,500 |
| Internal Working Pressure ($p_w$, psi) = | 24.00 | Allowable Stress, Transient ($s_s$, psi), $Y_s/SF_s$ = | 22,000 |
| Test Pressure- ($p_t$, psi) = | 150.00 | Allowable Stress, Test/Shutoff ($s_t$, psi), $Y_s/SF_t$ = | 22,000 |
| Transient Pressure ($p_s$, psi) [Limit to 1.33$p_w$] (See note 1) = | 31.92 | | |
| Pump Shutoff Pressure ($p_o$, psi) = | 300.00 | | |
| Specified Minimum Yield Point of Steel ($Y_s$, psi) (See note 2) = | 33,000 | Mortar Lining Thickness ($t_L$, in.) = | 0.000 |
| Safety Factor, Working ($SF_w$) = | 2.0 | Internal Diameter (ID, in.) = | 48.00 |
| Safety Factor, Transient Pressure (SFs )= | 1.5 | ID requirement based on (see note 2A) = | MWH |
| Safety Factor, Test Pressure/Pump Shutoff ($SF_t$) = | 1.5 | | |




| | |
|---|---|
| **Pipe Wall Thickness due to Pressure:** | |
| Min Steel Thickness from Working Pressure Calc ($t_w$, in), $p_wOD/(2s_w)$ = | 0.0356 |
| Min Steel Thickness from Test Pressure Calc ($t_t$, in), $p_tOD/(2s_t)$ = | 0.1670 |
| Min Steel Thickness from Transient Pressure Calc ($t_s$,in), $p_sOD/(2s_s)$ = | 0.0355 |
| Min Steel Thickness from Shutoff Pressure Calc ($t_o$,in), $p_oOD/(2s_t)$ = | 0.3341 |
| **Pipe Wall Thickness due to Handling/Constructability:** **User Defined OD/t =** | 200 |
| Min Steel Thickness for Handling (OD/t ≤ 240, mortar lining) (see note 3) = | 0.2042 |
| Min Steel Thickness for Handling (OD/t ≤ 288, flexible lining) (see note 4) = | 0.1701 |
| Min Steel Thickness for Constructibility (from 'Min. Pipe Can' table) = | 0.2000 |
| Min Steel Thickness for User Specified Handling (OD/t ≤ 200) = | 0.2450 |
| **Pipe Wall Thickness Results:** Min Pipe Wall Thickness Required ($t_{min}$, in) (see note 5) = | 0.3341 |
| Standard Pipe Wall Thickness per AWWA M11 Table A-1 ($t_{std}$, in) = | 0.3750 |
| **Design OD/t =** | **98** |

### Deflection Calculation, (Eqn. 6-5, AWWA M11)

| Input Section | | Output Section | |
|---|---|---|---|
| Wall thickness to use in design ($t_s$, in) = | 0.5000 | Mean Dia (D, in), OD - $t_s$ - $t_L$ = | 48.50 |
| Mortar Coating Thickness ($t_c$, in) (See note 7) = | 1.00 | Cylinder Outside Dia (OD, in), ID + 2$t_L$ + 2$t_s$ = | 49.00 |
| Soil backfill type | Sand & gravel | Pipe Outside Dia ($B_c$, ft), OD + 2$t_c$ = | 4.250 |
| Depth of soil cover (H, ft) = | 5.50 | Wall stiffness (EI, $in^4/in$), $30E10^6.I_s+4E10^6(I_L+I_c)$ = | 645,833 |
| Distance beyond pipe OD to trench wall (m, ft) = | 1.00 | Steel moment of inertia ($I_s$, $in^4$/linear in), $t_s^3/12$ = | 0.0104 |
| Trench width at top of the pipe ($B_d$, ft) = $B_c$ + 2m | 6.25 | Lining moment of inertia ($I_L$, $in^4$/linear in), $t_L^3/12$ = | 0.0000 |
| Transition width ($B_{dt}$, ft) (**Go to "transition" tab to calculate $B_{dt}$**) | 7.05 | Coating moment of inertia ($I_c$, $in^4$/linear in), $t_c^3/12$ = | 0.0833 |
| | | Mean radius (r, in), D/2 = | 24.25 |
| Included additional load to apply to pipe | distributed load | $B_d/B_c$ = | 1.47 |
| Load, (Y, lbs) | 67,500.0 | ------------------------> Distributed load impact factor, I = | 1.00 |
| Length of loaded surface area, a (ft) | 3.40 | | |
| Width of loaded surface area, b (ft) | 2.01 | Surcharge load (Wy, psf), Y.I/[(a+H)(b+H)] = | 1,010 |
| Unit weight of soil (w, pcf) = | 120.00 | Lane loading (LL, psf) = | 0 |
| Height of water surface above top of pipe ($h_w$, ft) = | 0.00 | Wheel load spread width (A, ft), 5.67+fH = | 0.00 |
| Include saturated soil weight in deflection calc (Y/N) (see note 10) = | No | Wheel load spread length (B, ft), 0.83+fH = | 0.00 |
| Live load (HS-20 Single/HS-20 ALT./E80/NA)= | NA | Alternate live load backfill factor (f) = | 0.00 |
| Modulus of soil reaction, E' | Per AWWA M11 | Govn dimension parallel to long axis of pipe (L, ft) = | 0.00 |
| Modulus of the soil reaction (E', psi) (See table 6-1 and note 8) = | 500.00 | $E'_n/E'_b$ = | NA |
| Native soil modulus ($E'_n$, psi) (See table 5-6) = | 0.00 | Modulus of soil reaction (E', psi) = | 500.00 |
| Modulus of the backfill soil ($E'_b$, psi) (See table 6-1 and note 8) = | 0.00 | Bedding constant (K) = | 0.110 |
| Soil support combining factor (Sc) (See table 5-5) = | 0.00 | | |
| Deflection lag factor ($D_L$, 1.0-1.5) (See note 9) = | 1.50 | | |
| Select bedding angle (ϴ, degree) = | 0 | | |

**Determination of External Load and Deflection for Trench Condition**

| | |
|---|---|
| **Earth load** | |
| Earth load for trench condition ($W_c$, lb/linear in.), Non-saturated soil: $HwB_c/12$ -or- Saturated soil: $0.0361h_wB_c + R_wHwB_c/12$ = | 233.75 |
| **Determination of Live Load for HS-20 wheel Or Cooper E-80 Railroad Loading** | |
| **Highway loading per AWWA M11** | |
| Single HS-20 truck live load on pipe from table 6-3 ($P_L$, psf) = | 0.00 |
| Single HS-20 truck live load on pipe ($W_L$,lb/linear in.), $P_LBc/12$ = | 0.00 |
| **Alternate Highway loading per AASHTO** | |
| Impact factor for highway ($I_f$, %), 33*(1-0.125H))/100 = | 0% |
| Total wheel load applied at the surface (P,lbs) = | 0 |
| Total live load assuming truck travel transverse to pipe centerline ($W_T$, lbs), $[P(1+I_f)/(AB)+LL].A.Min(B,B_c)$ = | 0 |
| Total live load assuming truck travel parallel to pipe centerline ($W_P$, lbs), $[P(1+I_f)/(AB)+LL].B.Min(A,B_c)$ = | 0 |
| HS-20 ALT,Maximum AASHTO HS-20 Passing truck live load on pipe ($W_L$, lb/linear in.), $\{Max(W_T,W_P) / [L+1.75(0.75B_c)]\} / 12$ = | 0.00 |
| **Railroad loading per AWWA M11** | |
| Railroad loading on pipe from table 6-3 ($W_L$, lb/linear in.) = | 0.00 |
| **Surcharge loading** | |
| Surcharge loading on pipe (Wy, lb/linear in.) = | 357.67 |
| **Total External Load** | |
| Total external load on pipe (W, lb/linear in.) = | 591.42 |
| **Deflection Results (Eqn 6-5, AWWA M11)** | |
| Vertical/Horizontal deflection of the pipe (ΔX, in), $D_L [KWr^3/(EI+0.061E'r^3)]$ = | 1.29 |
| Percent deflection, Δx/D = | 2.65% |
| This is not a standard type of pipe | |

### Buckling Results (Eqns. 6-7, 6-8, 6-9, AWWA M11)

| Input Section | | Output Section | |
|---|---|---|---|
| Include internal vacuum pressure | Yes | Water bouyancy factor ($R_w$), $1-(0.33(h_w/H))$ = | 1.00 |
| Internal vacuum pressure ($P_v$, psi) = | 14.70 | Elastic support coefficient, (B'), $1 / (1+4e^{-0.065H})$ = | 0.26 |
| Buckling factor of safety based on AWWA M-11 (3rd Ed/4th Ed) | 4th Ed (2004) | $H/B_c$ = | 1.29 |
| | | Buckling factor of safety, FS (See note 13) = | 2.0 |

| | |
|---|---|
| Allowable buckling pressure ($q_a$, psi), $(1/FS) [32 R_wB'E'(EI/B_c^3)]^{0.5}$ = | 71.61 |
| Total Negative Pressure, live load condition (psi), $0.0361h_w + R_wW_{c(dry)}/B_c + W_L/B_c$ (See note 14) = | 4.58 |
| Total Negative Pressure, vacuum condition (psi), $0.0361h_w + R_wW_{c(dry)}/B_c + P_v$ (See note 14) = | 19.28 |

### Sheet Notes:

1. MWH surge allowance is limited to 1.33 $p_w$ - Use actual surge value if higher. (See Hydraulic Lead/Surge report for surge values)

2. Yield Stress -$Y_s$ limited to:
   33,000 psi - Mortar Lined and Coated pipe
   42,000 psi - Mortar Lined - Flexible Coated pipe
   50,000 psi - Flexible Lined and Coated pipe

2A. MWH ID requirement is based on ID for 14" dia and larger.

3. Use OD/t = 240 for handling, unless justified otherwise, for mortar lined pipe.

4. Use OD/t ≤ 288 for OD up to 54" (M11 Eq 4-5).
   For OD ≥ 54", use t≥ (OD+20)/400 (M11 Eq 4-6).

5. Use the maximum of the wall thicknesses calculated by pressure, handling or the minimum thickness shown for the pipe or fitting.

6. Minimum allowable pressure to avoid vapor pressure of fluid and associated cavitation is -5.00 psi

### Notes for Designer:

7. Limit Mortar Coating to 1" max in Δx Calculations

8. Selection of E' value from Table 6-1 shall be limited to 85% relative compaction effort, unless otherwise approved by Geotechnical Engineer. Coordinate with Geotechnical Report for suitable E' value for pipeline design.

9. The deflection Lag factor is 1.0 for a pressurized pipe, however, if the pipe will sit empty for periods of time the value would be greater than 1.0.

10. Saturated soil weight is accounted for using bouyancy reduction factor ($R_w$).

Non-saturated soil

11. Allowable deflections used herein are set at 75% of allowable deflections shown in AWWA M11, consistent with MWH standards.

**Deflection Result : Deflection is Within Allowable Limits**

12. Where internal vacuum occurs with cover depth less than 4 ft but not less than 2 ft care should be exercised in defining allowable buckling pressure. (AWWA M11 buckling footnote)

13. Design factor FS=2.0 is recommended by AWWA M11 4th Ed for all depths in buckling calculation. AWWA M11 3rd Ed recommended FS=3.0 for $H/B_c$<2.0 and FS=2.5 for $H/B_c$≥2.

14. Total negative pressure does not include surcharge load.

**Buckling Result : Pipe stiffness acceptable**

### Pipe Reference Data

**Bedding Constant K**

| Bedding Angle (degree) | Bedding Constant |
|---|---|
| 0 | 0.11 |
| 30 | 0.108 |
| 45 | 0.105 |
| 60 | 0.102 |
| 90 | 0.096 |
| 120 | 0.090 |
| 180 | 0.083 |

**MWH Min. Wall Thickness Requirements — Fittings and Specials - Thickness**

| | |
|---|---|
| 24" Dia. & under - 3/16" = | 0.1875 |
| 25" to 48" Dia. - 1/4" = | 0.2500 |
| Over 48" Dia. - 5/16" = | 0.3125 |

**Min. Pipe Can - Thickness**

| ND, (in) | Min. t, (in) |
|---|---|
| 6 | 0.1345 |
| 12 | 0.1345 |
| 18 | 0.1345 |
| 24 | 0.1345 |
| 30 | 0.1345 |
| 36 | 0.1500 |
| 42 | 0.1750 |
| 48 | 0.2000 |
| 54 | 0.2250 |
| 60 | 0.2500 |
| 66 | 0.2750 |
| 72 | 0.3000 |
| 78 | 0.3250 |
| 84 | 0.3500 |
| 90 | 0.3750 |
| 96 | 0.4000 |
| 102 | 0.4250 |
| 108 | 0.4500 |
| 114 | 0.4750 |
| 120 | 0.5000 |

**Mortar Lining Thickness — MWH**

| Diameter (in) | Lining Thickness (in) | Diameter (in) | Lining Thickness (in) |
|---|---|---|---|
| 4 | 0.25 | 60 | 0.5 |
| 6 | 0.25 | 66 | 0.5 |
| 8 | 0.25 | 72 | 0.5 |
| 10 | 0.25 | 78 | 0.5 |
| 12 | 0.313 | 84 | 0.5 |
| 14 | 0.313 | 90 | 0.5 |
| 16 | 0.313 | 96 | 0.5 |
| 18 | 0.313 | 102 | 0.5 |
| 20 | 0.313 | 108 | 0.5 |
| 24 | 0.375 | 114 | 0.5 |
| 26 | 0.375 | 120 | 0.5 |
| 28 | 0.375 | 126 | 0.5 |
| 30 | 0.375 | 132 | 0.5 |
| 32 | 0.375 | 138 | 0.5 |
| 34 | 0.375 | 144 | 0.5 |
| 36 | 0.375 | | |
| 38 | 0.5 | | |
| 40 | 0.5 | | |
| 42 | 0.5 | | |
| 44 | 0.5 | | |
| 46 | 0.5 | | |
| 48 | 0.5 | | |
| 50 | 0.5 | | |
| 52 | 0.5 | | |
| 54 | 0.5 | | |
| 56 | 0.5 | | |
| 58 | 0.5 | | |

**Backfill Materials**:

Table 6-1 Values* of modulus of soil reaction, E (psi) based on depth of cover, type of soil, and relative compaction

| Type of Soil† | Depth of Cover ft | (m) | 85% psi | (kPa) | 90% psi | (kPa) | 95% psi | (kPa) | 100% psi | (kPa) |
|---|---|---|---|---|---|---|---|---|---|---|
| Fine-grained soils with less than 25% sand content (CL, ML, CL-ML) | 2–5 | (0.6–1.5) | 500 | (3,450) | 700 | (4,830) | 1,000 | (6,895) | 1,500 | (10,340) |
| | 5–10 | (1.5–3.1) | 600 | (4,140) | 1,000 | (6,895) | 1,400 | (9,655) | 2,000 | (13,790) |
| | 10–15 | (3.1–4.6) | 700 | (4,830) | 1,200 | (8,275) | 1,600 | (11,030) | 2,300 | (15,860) |
| | 15–20 | (4.6–6.1) | 800 | (5,520) | 1,300 | (8,965) | 1,800 | (12,410) | 2,600 | (17,930) |
| Coarse-grained soils with fines (SM, SC) | 2–5 | (0.6–1.5) | 600 | (4,140) | 1,000 | (6,895) | 1,200 | (8,275) | 1,900 | (13,100) |
| | 5–10 | (1.5–3.1) | 900 | (6,205) | 1,400 | (9,655) | 1,800 | (12,410) | 2,700 | (18,615) |
| | 10–15 | (3.1–4.6) | 1,000 | (6,895) | 1,500 | (10,340) | 2,100 | (14,480) | 3,200 | (22,065) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,600 | (11,030) | 2,400 | (16,545) | 3,700 | (25,510) |
| Coarse-grained soils with little or no fines (SP, SM, GP, GW) | 2–5 | (0.6–1.5) | 700 | (4,830) | 1,000 | (6,895) | 1,600 | (11,030) | 2,500 | (17,235) |
| | 5–10 | (1.5–3.1) | 1,000 | (6,895) | 1,500 | (10,340) | 2,200 | (15,170) | 3,300 | (22,750) |
| | 10–15 | (3.1–4.6) | 1,050 | (7,240) | 1,600 | (11,030) | 2,400 | (16,545) | 3,600 | (24,820) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,700 | (11,720) | 2,500 | (17,235) | 3,800 | (26,200) |

(Standard AASHTO relative compaction‡)

**Native Soils**:

Table 5-6 Values for the modulus of soil reaction $E'_n$ for the native soil at pipe zone elevation

| Granular Blows/ft† | Granular Description | Cohesive $q_u$(Tons/sf) | Cohesive Description | $E'_n$ (psi) |
|---|---|---|---|---|
| >0–1 | very, very loose | >0–0.125 | very, very soft | 50 |
| 1–2 | very loose | 0.125–0.25 | very soft | 200 |
| 2–4 | | 0.25–0.50 | soft | 700 |
| 4–8 | loose | 0.50–1.0 | medium | 1,500 |
| 8–15 | slightly compact | 1.0–2.0 | stiff | 3,000 |
| 15–30 | compact | 2.0–4.0 | very stiff | 5,000 |
| 30–50 | dense | 4.0–6.0 | hard | 10,000 |
| >50 | very dense | >6.0 | very hard | 20,000 |

(Native in Situ Soils*)

**Composite E' Coefficients**:

Table 5-5 Values for the soil support combining factor $S_c$

| $M_{sn}/M_{sb}$ | $B_d/D$ = 1.25 | $B_d/D$ = 1.5 | $B_d/D$ = 1.75 | $B_d/D$ = 2 | $B_d/D$ = 2.5 | $B_d/D$ = 3 | $B_d/D$ = 4 | $B_d/D$ = 5 |
|---|---|---|---|---|---|---|---|---|
| 0.005 | 0.02 | 0.05 | 0.08 | 0.12 | 0.23 | 0.43 | 0.72 | 1.00 |
| 0.01 | 0.03 | 0.07 | 0.11 | 0.15 | 0.27 | 0.47 | 0.74 | 1.00 |
| 0.02 | 0.05 | 0.10 | 0.15 | 0.20 | 0.32 | 0.52 | 0.77 | 1.00 |
| 0.05 | 0.10 | 0.15 | 0.20 | 0.27 | 0.38 | 0.58 | 0.80 | 1.00 |
| 0.1 | 0.15 | 0.20 | 0.27 | 0.35 | 0.46 | 0.65 | 0.84 | 1.00 |
| 0.2 | 0.25 | 0.30 | 0.38 | 0.47 | 0.58 | 0.75 | 0.88 | 1.00 |
| 0.4 | 0.45 | 0.50 | 0.56 | 0.64 | 0.75 | 0.85 | 0.93 | 1.00 |
| 0.6 | 0.65 | 0.70 | 0.75 | 0.81 | 0.87 | 0.94 | 0.98 | 1.00 |
| 0.8 | 0.84 | 0.87 | 0.90 | 0.93 | 0.96 | 0.98 | 1.00 | 1.00 |
| 1 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1.5 | 1.40 | 1.30 | 1.20 | 1.12 | 1.06 | 1.03 | 1.00 | 1.00 |
| 2 | 1.70 | 1.50 | 1.40 | 1.30 | 1.20 | 1.10 | 1.05 | 1.00 |
| 3 | 2.20 | 1.80 | 1.65 | 1.50 | 1.35 | 1.20 | 1.10 | 1.00 |
| ≥5 | 3.00 | 2.20 | 1.90 | 1.70 | 1.50 | 1.30 | 1.15 | 1.00 |

NOTE: In-between values of $S_c$ may be determined by straight-line interpolation from adjacent values.

**Table 6-3; AWWA M11**

| Highway HS-20 Load Soil Cover (ft) | Highway HS-20 Load Load (psf) | Railroad E-80 Load Soil Cover (ft) | Railroad E-80 Load Load (psf) |
|---|---|---|---|
| 1 | 1800 | 2 | 3800 |
| 2 | 800 | 5 | 2400 |
| 3 | 600 | 8 | 1600 |
| 4 | 400 | 10 | 1100 |
| 5 | 250 | 12 | 800 |
| 6 | 200 | 15 | 600 |
| 7 | 176 | 20 | 300 |
| 8 | 100 | 30 | 100 |

Note: Neglect live load when less than 100 psf; use dead load only.

**Typical Trench Section**

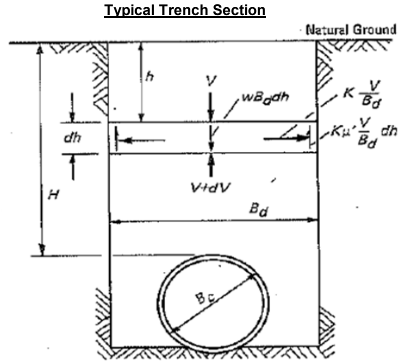



**Figure 4.3.** Trench Condition.

## Steel Pipe Wall Design - Trench Condition

Steel Pipe Wall Design - Trench Condition

### Equations used

**Barlow Formula - Hoop Stress**

$$t = \frac{pd}{2s}$$

Where:

$t$ = minimum pipe wall thickness for the specified internal design pressure, in. (mm)
$p$ = internal design pressure, psi (kPa)
$d$ = outside diameter of pipe steel cylinder (not including coatings), in. (mm)
$s$ = allowable design stress, psi (kPa)

**Buckling Equations**

Allowable Buckling Pressure

$$q_a = \left(\frac{1}{FS}\right)\left(32R_w B' E' \frac{EI}{D^3}\right)^{1/2}$$

Vacuum Pres: Live Load Pressure

$$\gamma_w h_w + R_w \frac{W_c}{D} + \frac{W_L}{D} \leq \quad \gamma_w h_w + R_w \frac{W_c}{D} + P_v \leq q_a$$

Where:

$h_w$ = height of water above conduit in in. (mm)
$\gamma_w$ = specific weight of water = 0.0361 lb/cu in. (0.0098 kPa/mm$^3$)
$P_v$ = internal vacuum pressure in psi (kPa) = atmospheric pressure less absolute pressure inside pipe, in psi (kPa)
$W_c$ = vertical soil load on pipe per unit length, in lb/in. (kPa/mm)

**EARTH LOADING**

**Embankment Condition**

$$W_c = C_c w B_c^2$$

Where:

$C_c$ = coefficient for embankment conditions, a function of soil properties.

For flexible pipe, the settlement ratio (Spangler 1947) is assumed to be zero, in which case

Where:

$H_c$ = height of fill above top of pipe in ft (m)

Then:

$$W_c = \frac{H_c}{B_c} w B_c^2 = w H_c B_c$$

**PIPE DEFLECTION**

$$\text{Deflx} = \frac{D_L\, K\, W\, r^3}{EI + 0.0614E'r3}$$

**Where:**

**Deflx = Vertical deflection of pipe in inches, (not to exceed 0.015 times the nominal diameter for mortar-lined and coated pipe, 0.025 times the nominal diameter for mortar-lined and dielectric coated pipe and 0.05 times the nominal diameter for dielectric lined and coated pipe.)**

**DL = Deflection lag factor.**
**K = Bedding constant**
**W = Vertical load on pipe, lb/in.**
**r = Mean radius of pipe shell, inches**
**EI = Pipe stiffness, lb in.**
**E' = Modulus of soil reaction, lb/in2 A specific, rational method must be used to develop this number for soils at the site. The method must be reviewed.**

Stantec

Burris Basin - 36" Line

$ID = 36"$
$OD = 36.5"$
$D_c = 38.5"$
$D = ID + t_L + t_s = 36.25"$
$t_s = .25"$
$t_c = 1"$
$t_L = 0"$
$r = .5D = 18.125"$
$r_o = .5OD = 18.25"$
$H_c = 5.5'$
$H_w = 0'$
$w = 120\ lb/ft^2$
$D_l = 1.5$
$K = .1$
$I_x = t_x^3/12$
$E_s = 30 \times 10^6$
$E_c = 4 \times 10^6$
$EI = E_s I_s + E_c(I_L + I_c) \longrightarrow 30 \times 10^6 \left(\frac{.25^3}{12}\right) + 4 \times 10^6 \left(\frac{1^3}{12}\right) \rightarrow 372396$
*$E' = 500$
$C_n = .55$
$\varphi_s = .9$
$K_v = .74$
$FS_B = 2$
$\gamma_w = 62.4\ lb/ft^3$
$P_v = 14.7\ lb/in^2$

*Note: E' taken from table 5-3. Assume most conservative SC@90% compaction. Apply a F.S. of 2 (1/2).

Designed by:

Checked by:

Stantec

Earth Load & Live Load

$W_c = w H_c \left(\frac{D_c}{12}\right)$ (Eq. 5.3)

$= (120)(5.5)\left(\frac{38.5}{12}\right) \longrightarrow 2117.5\ ^{lb}/_{ft}$ or $176.46\ ^{lb}/_{in}$

Live Load — Cat 657

$P = 135{,}000$ (axle load)

$\frac{P}{2} = 67{,}500$ (single tire)

tire dimension = 40.8" × 24.12"

Surface Area = $(40.8 \times 24.12)/144 \longrightarrow 6.834\ ft^2$

Surface Pressure = $(67{,}500/6.834) \longrightarrow 9877.09\ ^{lb}/_{ft^2}$

$A_T = .5(40.8/12) \longrightarrow 1.7$

$B_T = .5(24.12/12) \longrightarrow 1.0$

$m = A_T/H_c \longrightarrow 1.7/5.5 \longrightarrow .31$

$n = B_T/H_c \longrightarrow 1/5.5 \longrightarrow .18$

Use table 5-2 for Newmark Vertical influence Coefficients

= .026

$W_L = (4)(.026)(9877.09) \longrightarrow 1027.21\ ^{lb}/_{ft^2}$

$W_y = W_L\left(\frac{D_c}{12}\right) \longrightarrow 1027.21\left(\frac{~~36.25~~\ 38.5}{12}\right) \longrightarrow 3{,}295.63\ ^{lb}/_{ft}$ or $274.64\ ^{lb}/_{in}$

$W = W_c + W_L \longrightarrow 176.46 + 274.64 \longrightarrow$ **451.~~096~~ 10 lb/in**

Designed by: Checked by:

Stantec

Deflection

$$\Delta x = \left(\frac{D_l K W r^3}{EI + .61E' r^3}\right) \quad \text{(Eq. 5.4)}$$

$$= \left[\frac{(1.5)(.1)(451.10)(18.125)^3}{(372396) + (.061(500)(18.125)^3)}\right] \longrightarrow \ldots$$

$$\ldots \longrightarrow \left(\frac{402900.80}{554003.54}\right) \longrightarrow .73 \text{ in}$$

$$\% \text{ Deflection} = \frac{\Delta x}{OD} \longrightarrow \frac{.73}{36.5} \longrightarrow 2.0\%$$

Designed by: Checked by:

Stantec

Buckling

$$q_a = \frac{(1.2 C_n)(EI)^{.33}(\varphi_s E' K_v)^{.67} R_H}{(FS_B) r_o}$$

$$= \frac{(1.2(.55))(372396)^{.33}((.9)(500)(.74))^{.67} R_H}{(2)(18.25)} \text{ ———...}$$

$$\text{...} \longrightarrow \frac{2228.50\, R_H}{36.5} \longrightarrow 61.05 R_H \longrightarrow \boxed{60.26\ lb/in^2}$$

$$R_H = \frac{11.4}{11 + \left(\frac{2r}{H_c}\right)} \longrightarrow \frac{11.4}{11 + \left(\frac{2(18.125)}{(5.5 \times 12)}\right)} \longrightarrow .987$$

$$q_a \geq \frac{\gamma_w}{1728} H_w + R_w \frac{W_c}{12 D_o} + P_v$$

$$\geq \frac{(62.4)}{1728}(0) + R_w \frac{(176.46 \times 12)}{12 \times (36.5)} + (14.7) \text{ ———...}$$

$$\text{...} \longrightarrow 4.83 R_w + 14.7 \longrightarrow \boxed{19.53\ lb/in^2}$$

$$R_w = 1 - .33\left(\frac{H_w}{H_c}\right) \longrightarrow 1 - .33\left(\frac{0}{5.5}\right) \longrightarrow 1$$

$$60.26 \geq 19.53 \checkmark$$

Table 6-4 Influence coefficients for rectangular areas

| $m = A/H$ or $n = B/H$ | $n = B/H$ or $m = A/H$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| 0.1 | 0.005 | 0.009 | 0.013 | 0.017 | 0.020 | 0.022 | 0.024 | 0.026 | 0.027 |
| 0.2 | 0.009 | 0.018 | 0.026 | 0.033 | 0.039 | 0.043 | 0.047 | 0.050 | 0.053 |
| 0.3 | 0.013 | 0.026 | 0.037 | 0.047 | 0.056 | 0.063 | 0.069 | 0.073 | 0.077 |
| 0.4 | 0.017 | 0.033 | 0.047 | 0.060 | 0.071 | 0.080 | 0.087 | 0.093 | 0.098 |
| 0.5 | 0.020 | 0.039 | 0.056 | 0.071 | 0.084 | 0.095 | 0.103 | 0.110 | 0.116 |
| 0.6 | 0.022 | 0.043 | 0.063 | 0.080 | 0.095 | 0.107 | 0.117 | 0.125 | 0.131 |
| 0.7 | 0.024 | 0.047 | 0.069 | 0.087 | 0.103 | 0.117 | 0.128 | 0.137 | 0.144 |
| 0.8 | 0.026 | 0.050 | 0.073 | 0.093 | 0.110 | 0.125 | 0.137 | 0.146 | 0.154 |
| 0.9 | 0.027 | 0.053 | 0.077 | 0.098 | 0.116 | 0.131 | 0.144 | 0.154 | 0.162 |
| 1.0 | 0.028 | 0.055 | 0.079 | 0.101 | 0.120 | 0.136 | 0.149 | 0.160 | 0.168 |
| 1.2 | 0.029 | 0.057 | 0.083 | 0.106 | 0.126 | 0.143 | 0.157 | 0.168 | 0.178 |
| 1.5 | 0.030 | 0.059 | 0.086 | 0.110 | 0.131 | 0.149 | 0.164 | 0.176 | 0.186 |
| 2.0 | 0.031 | 0.061 | 0.089 | 0.113 | 0.135 | 0.153 | 0.169 | 0.181 | 0.192 |
| 2.5 | 0.031 | 0.062 | 0.090 | 0.115 | 0.137 | 0.155 | 0.170 | 0.183 | 0.194 |
| 3.0 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.171 | 0.184 | 0.195 |
| 5.0 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 |
| 10.0 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 |
| ∞ | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 |

| | 1.0 | 1.2 | 1.5 | 2.0 | 2.5 | 3.0 | 5.0 | 10.0 | ∞ |
|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 0.028 | 0.029 | 0.030 | 0.031 | 0.031 | 0.032 | 0.032 | 0.032 | 0.032 |
| 0.2 | 0.055 | 0.057 | 0.059 | 0.061 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 |
| 0.3 | 0.079 | 0.083 | 0.086 | 0.089 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 |
| 0.4 | 0.101 | 0.106 | 0.110 | 0.113 | 0.115 | 0.115 | 0.115 | 0.115 | 0.115 |
| 0.5 | 0.120 | 0.126 | 0.131 | 0.135 | 0.137 | 0.137 | 0.137 | 0.137 | 0.137 |
| 0.6 | 0.136 | 0.143 | 0.149 | 0.153 | 0.155 | 0.156 | 0.156 | 0.156 | 0.156 |
| 0.7 | 0.149 | 0.157 | 0.164 | 0.169 | 0.170 | 0.171 | 0.172 | 0.172 | 0.172 |
| 0.8 | 0.160 | 0.168 | 0.176 | 0.181 | 0.183 | 0.184 | 0.185 | 0.185 | 0.185 |
| 0.9 | 0.168 | 0.178 | 0.186 | 0.192 | 0.194 | 0.195 | 0.196 | 0.196 | 0.196 |
| 1.0 | 0.175 | 0.185 | 0.193 | 0.200 | 0.202 | 0.203 | 0.204 | 0.205 | 0.205 |
| 1.2 | 0.185 | 0.196 | 0.205 | 0.212 | 0.215 | 0.216 | 0.217 | 0.218 | 0.218 |
| 1.5 | 0.193 | 0.205 | 0.215 | 0.223 | 0.226 | 0.228 | 0.229 | 0.230 | 0.230 |
| 2.0 | 0.200 | 0.212 | 0.223 | 0.232 | 0.236 | 0.238 | 0.239 | 0.240 | 0.240 |
| 2.5 | 0.202 | 0.215 | 0.226 | 0.236 | 0.240 | 0.242 | 0.244 | 0.244 | 0.244 |
| 3.0 | 0.203 | 0.216 | 0.228 | 0.238 | 0.242 | 0.244 | 0.246 | 0.247 | 0.247 |
| 5.0 | 0.204 | 0.217 | 0.229 | 0.239 | 0.244 | 0.246 | 0.249 | 0.249 | 0.249 |
| 10.0 | 0.205 | 0.218 | 0.230 | 0.240 | 0.244 | 0.247 | 0.249 | 0.250 | 0.250 |
| ∞ | 0.205 | 0.218 | 0.230 | 0.240 | 0.244 | 0.247 | 0.249 | 0.250 | 0.250 |

*Source: Newmark, N.M.,* Simplified Computation of Vertical Pressures in Elastic Foundations. *Circ. 24. Engrg. Exp. Stn., Univ. of Illinois (1935).*

Table 6-1 Values* of modulus of soil reaction, E′ (psi) based on depth of cover, type of soil, and relative compaction

| | Depth of Cover | | Standard AASHTO relative compaction‡ 85% | | 90% | | 95% | | 100% | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type of Soil† | *ft* | *(m)* | *psi* | *(kPa)* | *psi* | *(kPa)* | *psi* | *(kPa)* | *psi* | *(kPa)* |
| Fine-grained soils with less than 25% sand content (CL, ML, CL-ML) | 2–5 | (0.06–1.5) | 500 | (3,450) | 700 | (4,830) | 1,000 | (6,895) | 1,500 | (10,340) |
| | 5–10 | (1.5–3.1) | 600 | (4,140) | 1,000 | (6,895) | 1,400 | (9,655) | 2,000 | (13,790) |
| | 10–15 | (3.1–4.6) | 700 | (4,830) | 1,200 | (8,275) | 1,600 | (11,030) | 2,300 | (15,860) |
| | 15–20 | (4.6–6.1) | 800 | (5,520) | 1,300 | (8,965) | 1,800 | (12,410) | 2,600 | (17,930) |
| Coarse-grained soils with fines (SM, SC) | 2–5 | (0.06–1.5) | 600 | (4,140) | 1,000 | (6,895) | 1,200 | (8,275) | 1,900 | (13,100) |
| | 5–10 | (1.5–3.1) | 900 | (6,205) | 1,400 | (9,655) | 1,800 | (12,410) | 2,700 | (18,615) |
| | 10–15 | (3.1–4.6) | 1,000 | (6,895) | 1,500 | (10,340) | 2,100 | (14,480) | 3,200 | (22,065) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,600 | (11,030) | 2,400 | (16,545) | 3,700 | (25,510) |
| Coarse-grained soils with little or no fines (SP, SM, GP, GW) | 2–5 | (0.06–1.5) | 700 | (4,830) | 1,000 | (6,895) | 1,600 | (11,030) | 2,500 | (17,235) |
| | 5–10 | (1.5–3.1) | 1,000 | (6,895) | 1,500 | (10,340) | 2,200 | (15,170) | 3,300 | (22,750) |
| | 10–15 | (3.1–4.6) | 1,050 | (7,240) | 1,600 | (11,030) | 2,400 | (16,545) | 3,600 | (24,820) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,700 | (11,720) | 2,500 | (17,235) | 3,800 | (26,200) |

* Hartley, James D. and Duncan, James M., "*E′* and its Variation with Depth." *Journal of Transportation,* Division of ASCE, Sept. 1987.

† Soil type symbols are from the Unified Classification System.

‡ *Soil compaction.* When specifying the amount of compaction required, it is very important to consider the degree of soil compaction that is economically obtainable in the field for a particular installation. The density and supporting strength of the native soil should be taken into account. The densification of the backfill envelope must include the haunches under the pipe to control both the horizontal and vertical pipe deflections. Specifying an unobtainable soil compaction value can result in inadequate support and injurious deflection. Therefore, a conservative assumption of the supporting capability of a soil is recommended, and good field inspection should be provided to verify that design assumptions are met.

Table 6-2 Unified soil classification

| Symbol | Description |
|---|---|
| GW | Well-graded gravels, gravel-sand mixtures, little or no fines |
| GP | Poorly graded gravels, gravel-sand mixtures, little or no fines |
| GM | Silty gravels, poorly graded gravel-sand-silt mixtures |
| GC | Clayey gravels, poorly graded gravel-sand-clay mixtures |
| SW | Well-graded sands, gravelly sands, little or no fines |
| SP | Poorly graded sands, gravelly sands, little or no fines |
| SM | Silty sands, poorly graded sand-silt mixtures |
| SC | Clayey sands, poorly graded sand-clay mixtures |
| ML | Inorganic silts and very fine sand, silty or clayey fine sands |
| CL | Inorganic clays of low to medium plasticity |
| MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts |
| CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silt-clays of low plasticity |
| OH | Organic clays of medium to high plasticity |
| Pt | Peat and other highly organic soils |

*Source:* Classification of Soils for Engineering Purposes. ASTM Standard D2487-69, *ASTM, Philadelphia, Pa. (1969).*

## Steel Pipe Wall Design - Trench Condition

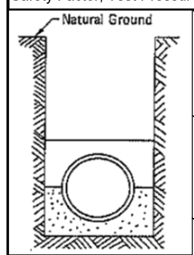
Steel Pipe Wall Design - Trench Condition

**Steel Cylinder Structural Calculations per AWWA M11 - Fourth Edition (2004)**

| Legend | |
|---|---|
| *Red Numbers =* | Input required |

### Minimum Thickness for Internal Pressure (Eqn 4-1, AWWA M11)

| Input Section | | Output Section | |
|---|---|---|---|
| Nominal Diameter of Pipe (DN, in.) = | 48.000 | | |
| Select type of Lining = | Epoxy | Allowable Stress, Working ($s_w$, psi), $Y_s/SF_w$ = | 16,500 |
| Internal Working Pressure ($p_w$, psi) = | 24.00 | Allowable Stress, Transient ($s_s$, psi), $Y_s/SF_s$ = | 22,000 |
| Test Pressure- ($p_t$, psi) = | 150.00 | Allowable Stress, Test/Shutoff ($s_t$, psi), $Y_s/SF_t$ = | 22,000 |
| Transient Pressure ($p_s$, psi) [Limit to $1.33p_w$] (See note 1) = | 31.92 | | |
| Pump Shutoff Pressure ($p_o$, psi) = | 300.00 | | |
| Specified Minimum Yield Point of Steel ($Y_s$, psi) (See note 2) = | 33,000 | Mortar Lining Thickness ($t_L$, in.) = | 0.000 |
| Safety Factor, Working ($SF_w$) = | 2.0 | Internal Diameter (ID, in.) = | 48.00 |
| Safety Factor, Transient Pressure (SFs )= | 1.5 | ID requirement based on (see note 2A) = | MWH |
| Safety Factor, Test Pressure/Pump Shutoff ($SF_t$) = | 1.5 | | |




| | |
|---|---|
| **Pipe Wall Thickness due to Pressure:** | |
| Min Steel Thickness from Working Pressure Calc ($t_w$, in), $p_wOD/(2s_w)$ = | 0.0356 |
| Min Steel Thickness from Test Pressure Calc ($t_t$, in), $p_tOD/(2s_t)$ = | 0.1670 |
| Min Steel Thickness from Transient Pressure Calc ($t_s$,in), $p_sOD/(2s_s)$ = | 0.0355 |
| Min Steel Thickness from Shutoff Pressure Calc ($t_o$,in), $p_oOD/(2s_t)$ = | 0.3341 |
| **Pipe Wall Thickness due to Handling/Constructability:** User Defined OD/t = | 200 |
| Min Steel Thickness for Handling (OD/t ≤ 240, mortar lining) (see note 3) = | 0.2042 |
| Min Steel Thickness for Handling (OD/t ≤ 288, flexible lining) (see note 4) = | 0.1701 |
| Min Steel Thickness for Constructibility (from 'Min. Pipe Can' table) = | 0.2000 |
| Min Steel Thickness for User Specified Handling (OD/t ≤ 200) = | 0.2450 |
| **Pipe Wall Thickness Results:** Min Pipe Wall Thickness Required ($t_{min}$, in) (see note 5) = | 0.3341 |
| Standard Pipe Wall Thickness per AWWA M11 Table A-1 ($t_{std}$, in) = | 0.3750 |
| **Design OD/t =** | **98** |

### Deflection Calculation, (Eqn. 6-5, AWWA M11)

| Input Section | | Output Section | |
|---|---|---|---|
| Wall thickness to use in design ($t_s$, in) = | 0.5000 | Mean Dia (D, in), OD - $t_s$ - $t_L$ = | 48.50 |
| Mortar Coating Thickness ($t_c$, in) (See note 7) = | 1.00 | Cylinder Outside Dia (OD, in), ID + $2t_L$ + $2t_s$ = | 49.00 |
| Soil backfill type | Sand & gravel | Pipe Outside Dia ($B_c$, ft), OD + $2t_c$ = | 4.250 |
| Depth of soil cover (H, ft) = | 5.50 | Wall stiffness (EI, $in^4$/in), $30E10^6.I_s+4E10^6(I_L+I_c)$ = | 645,833 |
| Distance beyond pipe OD to trench wall (m, ft) = | 1.00 | Steel moment of inertia ($I_s$, $in^4$/linear in), $t_s^3/12$ = | 0.0104 |
| Trench width at top of the pipe ($B_d$, ft) = $B_c$ + 2m | 6.25 | Lining moment of inertia ($I_L$, $in^4$/linear in), $t_L^3/12$ = | 0.0000 |
| Transition width ($B_{dt}$, ft) (**Go to "transition" tab to calculate $B_{dt}$**) | 7.05 | Coating moment of inertia ($I_c$, $in^4$/linear in), $t_c^3/12$ = | 0.0833 |
| | | Mean radius (r, in), D/2 = | 24.25 |
| Included additional load to apply to pipe | distributed load | $B_d/B_c$ = | 1.47 |
| Load, (Y, lbs) | 67,500.0 | ------------------------> Distributed load impact factor, I = | 1.00 |
| Length of loaded surface area, a (ft) | 3.40 | | |
| Width of loaded surface area, b (ft) | 2.01 | Surcharge load (Wy, psf), Y.I/[(a+H)(b+H)] = | 1,010 |
| Unit weight of soil (w, pcf) = | 120.00 | Lane loading (LL, psf) = | 0 |
| Height of water surface above top of pipe ($h_w$, ft) = | 0.00 | Wheel load spread width (A, ft), 5.67+fH = | 0.00 |
| Include saturated soil weight in deflection calc (Y/N) (see note 10) = | No | Wheel load spread length (B, ft), 0.83+fH = | 0.00 |
| Live load (HS-20 Single/HS-20 ALT./E80/NA)= | NA | Alternate live load backfill factor (f) = | 0.00 |
| Modulus of soil reaction, E' | Per AWWA M11 | Govn dimension parallel to long axis of pipe (L, ft) = | 0.00 |
| Modulus of the soil reaction (E', psi) (See table 6-1 and note 8) = | 500.00 | $E'_n/E'_b$ = | NA |
| Native soil modulus ($E'_n$, psi) (See table 5-6) = | 0.00 | Modulus of soil reaction (E', psi) = | 500.00 |
| Modulus of the backfill soil ($E'_b$, psi) (See table 6-1 and note 8) = | 0.00 | Bedding constant (K) = | 0.110 |
| Soil support combining factor (Sc) (See table 5-5) = | 0.00 | | |
| Deflection lag factor ($D_L$, 1.0-1.5) (See note 9) = | 1.50 | | |
| Select bedding angle (Θ, degree) = | 0 | | |

#### Determination of External Load and Deflection for Trench Condition

| | |
|---|---|
| **Earth load** | |
| Earth load for trench condition ($W_c$, lb/linear in.), Non-saturated soil: $HwB_c/12$ -or- Saturated soil: $0.0361h_wB_c + R_wHwB_c/12$ = | 233.75 |
| **Determination of Live Load for HS-20 wheel Or Cooper E-80 Railroad Loading** | |
| **Highway loading per AWWA M11** | |
| Single HS-20 truck live load on pipe from table 6-3 ($P_L$, psf) = | 0.00 |
| Single HS-20 truck live load on pipe ($W_L$,lb/linear in.), $P_LBc/12$ = | 0.00 |
| **Alternate Highway loading per AASHTO** | |
| Impact factor for highway ($I_f$, %), 33*(1-0.125H))/100 = | 0% |
| Total wheel load applied at the surface (P,lbs) = | 0 |
| Total live load assuming truck travel transverse to pipe centerline ($W_T$, lbs), $[P(1+I_f)/(AB)+LL].A.Min(B,B_c)$ = | 0 |
| Total live load assuming truck travel parallel to pipe centerline ($W_P$, lbs), $[P(1+I_f)/(AB)+LL].B.Min(A,B_c)$ = | 0 |
| HS-20 ALT,Maximum AASHTO HS-20 Passing truck live load on pipe ($W_L$, lb/linear in.), $\{Max(W_T,W_P) / [L+1.75(0.75B_c)]\} / 12$ = | 0.00 |
| **Railroad loading per AWWA M11** | |
| Railroad loading on pipe from table 6-3 ($W_L$, lb/linear in.) = | 0.00 |
| **Surcharge loading** | |
| Surcharge loading on pipe (Wy, lb/linear in.) = | 357.67 |
| **Total External Load** | |
| Total external load on pipe (W, lb/linear in.) = | 591.42 |
| **Deflection Results (Eqn 6-5, AWWA M11)** | |
| Vertical/Horizontal deflection of the pipe (Δx, in), $D_L\ [KWr^3/(EI+0.061E'r^3)]$ = | 1.29 |
| Percent deflection, Δx/D = | 2.65% |
| This is not a standard type of pipe | |

### Buckling Results (Eqns. 6-7, 6-8, 6-9, AWWA M11)

| Input Section | | Output Section | |
|---|---|---|---|
| Include internal vacuum pressure | Yes | Water bouyancy factor ($R_w$), $1-(0.33(h_w/H))$ = | 1.00 |
| Internal vacuum pressure ($P_v$, psi) = | 14.70 | Elastic support coefficient, (B'), $1 / (1+4e^{-0.065H})$ = | 0.26 |
| Buckling factor of safety based on AWWA M-11 (3rd Ed/4th Ed) | 4th Ed (2004) | $H/B_c$ = | 1.29 |
| | | Buckling factor of safety, FS (See note 13) = | 2.0 |

| | |
|---|---|
| Allowable buckling pressure ($q_a$, psi), $(1/FS)\ [32\ R_wB'E'(EI/B_c^3)]^{0.5}$ = | 71.61 |
| Total Negative Pressure, live load condition (psi), $0.0361h_w + R_wW_{c(dry)}/B_c + W_L/B_c$ (See note 14) = | 4.58 |
| Total Negative Pressure, vacuum condition (psi), $0.0361h_w + R_wW_{c(dry)}/B_c + P_v$ (See note 14) = | 19.28 |

### Sheet Notes:

1. MWH surge allowance is limited to 1.33 $p_w$ - Use actual surge value if higher. (See Hydraulic Lead/Surge report for surge values)
2. Yield Stress -$Y_s$ limited to:
   33,000 psi - Mortar Lined and Coated pipe
   42,000 psi - Mortar Lined - Flexible Coated pipe
   50,000 psi - Flexible Lined and Coated pipe

2A. MWH ID requirement is based on ID for 14" dia and larger.

3. Use OD/t = 240 for handling, unless justified otherwise, for mortar lined pipe.
4. Use OD/t ≤ 288 for OD up to 54" (M11 Eq 4-5).
   For OD ≥ 54", use t≥ (OD+20)/400 (M11 Eq 4-6).
5. Use the maximum of the wall thicknesses calculated by pressure, handling or the minimum thickness shown for the pipe or fitting.
6. Minimum allowable pressure to avoid vapor pressure of fluid and associated cavitation is -5.00 psi

### Notes for Designer:

7. Limit Mortar Coating to 1" max in Δx Calculations
8. Selection of E' value from Table 6-1 shall be limited to 85% relative compaction effort, unless otherwise approved by Geotechnical Engineer. Coordinate with Geotechnical Report for suitable E' value for pipeline design.
9. The deflection Lag factor is 1.0 for a pressurized pipe, however, if the pipe will sit empty for periods of time the value would be greater than 1.0.
10. Saturated soil weight is accounted for using bouyancy reduction factor ($R_w$).

Non-saturated soil

11. Allowable deflections used herein are set at 75% of allowable deflections shown in AWWA M11, consistent with MWH standards.

**Deflection Result : Deflection is Within Allowable Limits**

12. Where internal vacuum occurs with cover depth less than 4 ft but not less than 2 ft care should be exercised in defining allowable buckling pressure. (AWWA M11 buckling footnote)
13. Design factor FS=2.0 is recommended by AWWA M11 4th Ed for all depths in buckling calculation. AWWA M11 3rd Ed recommended FS=3.0 for $H/B_c$<2.0 and FS=2.5 for $H/B_c$≥2.
14. Total negative pressure does not include surcharge load.

**Buckling Result : Pipe stiffness acceptable**

### Pipe Reference Data

| Bedding Constant K | |
|---|---|
| Bedding Angle (degree) | Bedding Constant |
| 0 | 0.11 |
| 30 | 0.108 |
| 45 | 0.105 |
| 60 | 0.102 |
| 90 | 0.096 |
| 120 | 0.090 |
| 180 | 0.083 |

| MWH Min. Wall Thickness Requirements Fittings and Specials - Thickness | |
|---|---|
| 24" Dia. & under - 3/16" = | 0.1875 |
| 25" to 48" Dia. - 1/4" = | 0.2500 |
| Over 48" Dia. - 5/16" = | 0.3125 |

| Min. Pipe Can - Thickness | |
|---|---|
| ND, (in) | Min. t, (in) |
| 6 | 0.1345 |
| 12 | 0.1345 |
| 18 | 0.1345 |
| 24 | 0.1345 |
| 30 | 0.1345 |
| 36 | 0.1500 |
| 42 | 0.1750 |
| 48 | 0.2000 |
| 54 | 0.2250 |
| 60 | 0.2500 |
| 66 | 0.2750 |
| 72 | 0.3000 |
| 78 | 0.3250 |
| 84 | 0.3500 |
| 90 | 0.3750 |
| 96 | 0.4000 |
| 102 | 0.4250 |
| 108 | 0.4500 |
| 114 | 0.4750 |
| 120 | 0.5000 |

| Mortar Lining Thickness MWH | | | |
|---|---|---|---|
| Diameter (in) | Lining Thickness (in) | Diameter (in) | Lining Thickness (in) |
| 4 | 0.25 | 60 | 0.5 |
| 6 | 0.25 | 66 | 0.5 |
| 8 | 0.25 | 72 | 0.5 |
| 10 | 0.25 | 78 | 0.5 |
| 12 | 0.313 | 84 | 0.5 |
| 14 | 0.313 | 90 | 0.5 |
| 16 | 0.313 | 96 | 0.5 |
| 18 | 0.313 | 102 | 0.5 |
| 20 | 0.313 | 108 | 0.5 |
| 24 | 0.375 | 114 | 0.5 |
| 26 | 0.375 | 120 | 0.5 |
| 28 | 0.375 | 126 | 0.5 |
| 30 | 0.375 | 132 | 0.5 |
| 32 | 0.375 | 138 | 0.5 |
| 34 | 0.375 | 144 | 0.5 |
| 36 | 0.375 | | |
| 38 | 0.5 | | |
| 40 | 0.5 | | |
| 42 | 0.5 | | |
| 44 | 0.5 | | |
| 46 | 0.5 | | |
| 48 | 0.5 | | |
| 50 | 0.5 | | |
| 52 | 0.5 | | |
| 54 | 0.5 | | |
| 56 | 0.5 | | |
| 58 | 0.5 | | |

**Backfill Materials**:

Table 6-1 Values* of modulus of soil reaction, $E$ (psi) based on depth of cover, type of soil, and relative compaction

| | | | Standard AASHTO relative compaction‡ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of Cover | | 85% | | 90% | | 95% | | 100% | |
| Type of Soil† | ft | (m) | psi | (kPa) | psi | (kPa) | psi | (kPa) | psi | (kPa) |
| Fine-grained soils with less than 25% sand content (CL, ML, CL-ML) | 2–5 | (0.6–1.5) | 500 | (3,450) | 700 | (4,830) | 1,000 | (6,895) | 1,500 | (10,340) |
| | 5–10 | (1.5–3.1) | 600 | (4,140) | 1,000 | (6,895) | 1,400 | (9,655) | 2,000 | (13,790) |
| | 10–15 | (3.1–4.6) | 700 | (4,830) | 1,200 | (8,275) | 1,600 | (11,030) | 2,300 | (15,860) |
| | 15–20 | (4.6–6.1) | 800 | (5,520) | 1,300 | (8,965) | 1,800 | (12,410) | 2,600 | (17,930) |
| Coarse-grained soils with fines (SM, SC) | 2–5 | (0.6–1.5) | 600 | (4,140) | 1,000 | (6,895) | 1,200 | (8,275) | 1,900 | (13,100) |
| | 5–10 | (1.5–3.1) | 900 | (6,205) | 1,400 | (9,655) | 1,800 | (12,410) | 2,700 | (18,615) |
| | 10–15 | (3.1–4.6) | 1,000 | (6,895) | 1,500 | (10,340) | 2,100 | (14,480) | 3,200 | (22,065) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,600 | (11,030) | 2,400 | (16,545) | 3,700 | (25,510) |
| Coarse-grained soils with little or no fines (SP, SM, GP, GW) | 2–5 | (0.6–1.5) | 700 | (4,830) | 1,000 | (6,895) | 1,600 | (11,030) | 2,500 | (17,235) |
| | 5–10 | (1.5–3.1) | 1,000 | (6,895) | 1,500 | (10,340) | 2,200 | (15,170) | 3,300 | (22,750) |
| | 10–15 | (3.1–4.6) | 1,050 | (7,240) | 1,600 | (11,030) | 2,400 | (16,545) | 3,600 | (24,820) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,700 | (11,720) | 2,500 | (17,235) | 3,800 | (26,200) |

**Native Soils**:

Table 5-6 Values for the modulus of soil reaction $E'_n$ for the native soil at pipe zone elevation

| Native in Situ Soils* | | | | |
|---|---|---|---|---|
| Granular | | Cohesive | | $E'_n$ (psi) |
| Blows/ft† | Description | $q_u$(Tons/sf) | Description | |
| >0–1 | very, very loose | >0–0.125 | very, very soft | 50 |
| 1–2 | very loose | 0.125–0.25 | very soft | 200 |
| 2–4 | | 0.25–0.50 | soft | 700 |
| 4–8 | loose | 0.50–1.0 | medium | 1,500 |
| 8–15 | slightly compact | 1.0–2.0 | stiff | 3,000 |
| 15–30 | compact | 2.0–4.0 | very stiff | 5,000 |
| 30–50 | dense | 4.0–6.0 | hard | 10,000 |
| >50 | very dense | >6.0 | very hard | 20,000 |

**Composite E' Coefficients**:

Table 5-5 Values for the soil support combining factor $S_c$

| $M_{sn}/M_{sb}$ | $B_d/D = 1.25$ | $B_d/D = 1.5$ | $B_d/D = 1.75$ | $B_d/D = 2$ | $B_d/D = 2.5$ | $B_d/D = 3$ | $B_d/D = 4$ | $B_d/D = 5$ |
|---|---|---|---|---|---|---|---|---|
| 0.005 | 0.02 | 0.05 | 0.08 | 0.12 | 0.23 | 0.43 | 0.72 | 1.00 |
| 0.01 | 0.03 | 0.07 | 0.11 | 0.15 | 0.27 | 0.47 | 0.74 | 1.00 |
| 0.02 | 0.05 | 0.10 | 0.15 | 0.20 | 0.32 | 0.52 | 0.77 | 1.00 |
| 0.05 | 0.10 | 0.15 | 0.20 | 0.27 | 0.38 | 0.58 | 0.80 | 1.00 |
| 0.1 | 0.15 | 0.20 | 0.27 | 0.35 | 0.46 | 0.65 | 0.84 | 1.00 |
| 0.2 | 0.25 | 0.30 | 0.38 | 0.47 | 0.58 | 0.75 | 0.88 | 1.00 |
| 0.4 | 0.45 | 0.50 | 0.56 | 0.64 | 0.75 | 0.85 | 0.93 | 1.00 |
| 0.6 | 0.65 | 0.70 | 0.75 | 0.81 | 0.87 | 0.94 | 0.98 | 1.00 |
| 0.8 | 0.84 | 0.87 | 0.90 | 0.93 | 0.96 | 0.98 | 1.00 | 1.00 |
| 1 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1.5 | 1.40 | 1.30 | 1.20 | 1.12 | 1.06 | 1.03 | 1.00 | 1.00 |
| 2 | 1.70 | 1.50 | 1.40 | 1.30 | 1.20 | 1.10 | 1.05 | 1.00 |
| 3 | 2.20 | 1.80 | 1.65 | 1.50 | 1.35 | 1.20 | 1.10 | 1.00 |
| ≥5 | 3.00 | 2.20 | 1.90 | 1.70 | 1.50 | 1.30 | 1.15 | 1.00 |

NOTE: In-between values of $S_c$ may be determined by straight-line interpolation from adjacent values.

| Table 6-3; AWWA M11 | | | |
|---|---|---|---|
| Highway HS-20 Load | | Railroad E-80 Load | |
| Soil Cover | Load | Soil Cover | Load |
| ft | psf | ft | psf |
| 1 | 1800 | 2 | 3800 |
| 2 | 800 | 5 | 2400 |
| 3 | 600 | 8 | 1600 |
| 4 | 400 | 10 | 1100 |
| 5 | 250 | 12 | 800 |
| 6 | 200 | 15 | 600 |
| 7 | 176 | 20 | 300 |
| 8 | 100 | 30 | 100 |

Note: Neglect live load when less than 100 psf; use dead load only.

**Typical Trench Section**

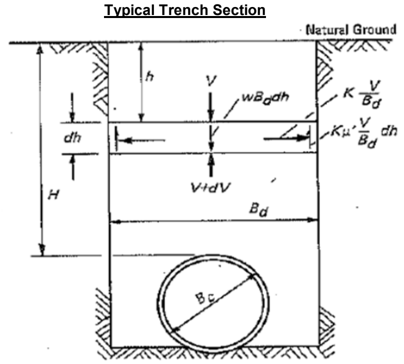



**Figure 4.3.** Trench Condition.

**Client:** (Client Name here)
**Project:** (Project Name Here)
**Description:** (Description of what is being calculated, specific building, system, discipline, etc…)

**Sheet:** ________ **of** ________
**Date:** mm/dd/yy
**Job No:** xxxxxx
**By:** (Author) **Chkd By:** xxx

## Steel Pipe Wall Design - Trench Condition

Steel Pipe Wall Design - Trench Condition

**Equations used**

**Barlow Formula - Hoop Stress**

$$t = \frac{pd}{2s}$$

Where:
- $t$ = minimum pipe wall thickness for the specified internal design pressure, in. (mm)
- $p$ = internal design pressure, psi (kPa)
- $d$ = outside diameter of pipe steel cylinder (not including coatings), in. (mm)
- $s$ = allowable design stress, psi (kPa)

**Buckling Equations**

Allowable Buckling Pressure

$$q_a = \left(\frac{1}{FS}\right)\left(32R_w B' E' \frac{EI}{D^3}\right)^{1/2}$$

Vacuum Press Live Load Pressure

$$\gamma_w h_w + R_w \frac{W_c}{D} + \frac{W_L}{D} \leq \quad \gamma_w h_w + R_w \frac{W_c}{D} + P_v \leq q_a$$

Where:
- $h_w$ = height of water above conduit in in. (mm)
- $\gamma_w$ = specific weight of water = 0.0361 lb/cu in. (0.0098 kPa/mm$^3$)
- $P_v$ = internal vacuum pressure in psi (kPa) = atmospheric pressure less absolute pressure inside pipe, in psi (kPa)
- $W_c$ = vertical soil load on pipe per unit length, in lb/in. (kPa/mm)

**EARTH LOADING**
**Embankment Condition**

$$W_c = C_c w B_c^2$$

Where:
$C_c$ = coefficient for embankment conditions, a function of soil properties.

For flexible pipe, the settlement ratio (Spangler 1947) is assumed to be zero, in which case

Where:
$H_c$ = height of fill above top of pipe in ft (m)

Then:

$$W_c = \frac{H_c}{B_c} w B_c^2 = w H_c B_c$$

**PIPE DEFLECTION**

$$\text{Deflx} = \frac{D_L\, K\, W\, r^3}{EI + 0.0614E'r3}$$

**Where:**

**Deflx = Vertical deflection of pipe in inches, (not to exceed 0.015 times the nominal diameter for mortar-lined and coated pipe, 0.025 times the nominal diameter for mortar-lined and dielectric coated pipe and 0.05 times the nominal diameter for dielectric lined and coated pipe.)**

**DL = Deflection lag factor.**
**K = Bedding constant**
**W = Vertical load on pipe, lb/in.**
**r = Mean radius of pipe shell, inches**
**EI = Pipe stiffness, lb in.**
**E' = Modulus of soil reaction, lb/in2 A specific, rational method must be used to develop this number for soils at the site. The method must be reviewed.**

Stantec

Burris Basin - 48" Line

$ID = 48"$
$OD = 49"$
$D_c = 51"$
$D = ID + t_L + t_s = 48.5"$
$t_s = .5"$
$t_c = 1"$
$t_L = 0"$
$r = .5D = 24.25"$
$r_o = .5OD = 24.5"$
$H_c = 5.5'$
$H_w = 0'$
$w = 120\ lb/ft^2$
$D_l = 1.5$
$K = .1$
$I_x = t_x^3/12$
$E_s = 30 \times 10^6\ lb/in^2$
$E_c = 4 \times 10^6\ lb/in^2$
$EI = E_s I_s + E_c (I_L + I_c) \longrightarrow 30 \times 10^6 \left(\frac{.5^3}{12}\right) + 4 \times 10^6 \left(\frac{1^3}{12} + 0\right) \longrightarrow 645833$
* $E' = 500$
$C_n = .55$
$\varphi_s = .9$
$K_v = .74$
$FS_B = 2$
$\gamma_w = 62.4\ lb/ft^3$
$P_v = 14.7\ lb/in^2$

* Note: E' taken from table 5-3. Assumes most conservative SC @ 90% Compaction. Apply a F.S. of 2 (½).

Designed by: Checked by:

## Earth Load & Live Load

$$W_c = w H_c \left(\frac{D_c}{12}\right) \qquad \text{(Eq. 5.3)}$$

$$= (120)(5.5)\left(\frac{51}{12}\right) \rightarrow 2805.0 \text{ lb/ft or } 233.75 \text{ lb/in}$$

### Live Load — Cat 657

$P = 135{,}000$ lb (axle load)

$\frac{P}{2} = 67{,}500$ lb (single tire)

tire dimension: 40.8" × 24.12"

Surface Area: $(40.8 \times 24.12)/144 \rightarrow 6.834 \text{ ft}^2$

Surface Pressure: $(67{,}500 / 6.834) \rightarrow 9{,}877.09 \text{ lb/ft}^2$

$A_T = .5\left(\frac{40.8}{12}\right) \rightarrow 1.7$

$B_T = .5\,(24.12/12) \rightarrow 1.0$

$m = A_T / H_c \rightarrow 1.7/5.5 \rightarrow .31$

$n = B_T / H_c \rightarrow 1.0/5.5 \rightarrow .18$

Use table 5-2 for Newmark Vertical influence Coefficients = .026

$W_L = (4)(.026)(9877.09) \rightarrow 1027.21 \text{ lb/ft}^2$

$W_y = W_L\left(\frac{D_c}{12}\right) \rightarrow 1027.21\left(\frac{51}{12}\right) \rightarrow 4365.64 \text{ lb/ft or } 363.80 \text{ lb/in}$

$W = W_c + W_L \rightarrow 233.75 \text{ lb/in} + 363.80 \text{ lb/in} \rightarrow \boxed{597.55 \text{ lb/in}}$

Designed by: Checked by:

Stantec

Deflection

$$\Delta x = \left(\frac{D_l K W r^3}{EI + .61 E' r^3}\right) \quad \text{(Eq 5.4)}$$

$$= \left[\frac{(1.5)(.1)(597.55)(24.25)^3}{(645833) + (.061(500)(24.25^3))}\right] \text{———} \ldots$$

$$\ldots \rightarrow \left(\frac{1278205.667}{1080778.727}\right) \rightarrow 1.18 \text{ in}$$

$$\% \text{ Deflection} = \frac{\Delta x}{OD} \rightarrow \frac{1.18}{49} \rightarrow 2.41\%$$

Designed by:

Checked by:

Stantec

Buckling

$$q_a = \frac{(1.2C_n)(EI)^{.33}(\varphi_s E' K_v)^{.67} R_H}{(FS_B) r_o}$$

$$= \frac{(1.2(.55))(645833)^{.33}((.9)(500)(.74))^{.67} R_H}{(2)(24.5)} \text{ ...}$$

$$\text{...} \rightarrow \frac{2672.52 R_H}{49} \rightarrow 54.54 R_H \rightarrow \boxed{52.96 \text{ lb/in}^2}$$

$$R_H = \frac{11.4}{11 + \left(\frac{2r}{H_c}\right)} \rightarrow \frac{11.4}{11 + \left(\frac{2(24.25)}{(5.5 \times 12)}\right)} \rightarrow \frac{11.4}{11.73} \rightarrow .971$$

$$q_a \geq \frac{\gamma_w}{1728} H_w + R_w \frac{W_c}{12 D_o} + P_v$$

$$\geq \frac{(62.4)}{1728}(0) + R_w \frac{(233.75 \times 12)}{(12 \times (49))} + (14.7) \text{ ...}$$

$$\text{...} \rightarrow 4.770 R_w + 14.7 \rightarrow \boxed{19.47 \text{ lb/in}^2}$$

$$R_w = 1 - .33\left(\frac{H_w}{H_c}\right) \rightarrow 1 - .33\left(\frac{0}{5.5}\right) \rightarrow 1$$

$$52.96 \geq 19.47 \quad ✓$$

Designed by: Checked by:

Table 6-4 Influence coefficients for rectangular areas

| $m = A/H$ or $n = B/H$ | $n = B/H$ or $m = A/H$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| 0.1 | 0.005 | 0.009 | 0.013 | 0.017 | 0.020 | 0.022 | 0.024 | 0.026 | 0.027 |
| 0.2 | 0.009 | 0.018 | 0.026 | 0.033 | 0.039 | 0.043 | 0.047 | 0.050 | 0.053 |
| 0.3 | 0.013 | 0.026 | 0.037 | 0.047 | 0.056 | 0.063 | 0.069 | 0.073 | 0.077 |
| 0.4 | 0.017 | 0.033 | 0.047 | 0.060 | 0.071 | 0.080 | 0.087 | 0.093 | 0.098 |
| 0.5 | 0.020 | 0.039 | 0.056 | 0.071 | 0.084 | 0.095 | 0.103 | 0.110 | 0.116 |
| 0.6 | 0.022 | 0.043 | 0.063 | 0.080 | 0.095 | 0.107 | 0.117 | 0.125 | 0.131 |
| 0.7 | 0.024 | 0.047 | 0.069 | 0.087 | 0.103 | 0.117 | 0.128 | 0.137 | 0.144 |
| 0.8 | 0.026 | 0.050 | 0.073 | 0.093 | 0.110 | 0.125 | 0.137 | 0.146 | 0.154 |
| 0.9 | 0.027 | 0.053 | 0.077 | 0.098 | 0.116 | 0.131 | 0.144 | 0.154 | 0.162 |
| 1.0 | 0.028 | 0.055 | 0.079 | 0.101 | 0.120 | 0.136 | 0.149 | 0.160 | 0.168 |
| 1.2 | 0.029 | 0.057 | 0.083 | 0.106 | 0.126 | 0.143 | 0.157 | 0.168 | 0.178 |
| 1.5 | 0.030 | 0.059 | 0.086 | 0.110 | 0.131 | 0.149 | 0.164 | 0.176 | 0.186 |
| 2.0 | 0.031 | 0.061 | 0.089 | 0.113 | 0.135 | 0.153 | 0.169 | 0.181 | 0.192 |
| 2.5 | 0.031 | 0.062 | 0.090 | 0.115 | 0.137 | 0.155 | 0.170 | 0.183 | 0.194 |
| 3.0 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.171 | 0.184 | 0.195 |
| 5.0 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 |
| 10.0 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 |
| ∞ | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 |

| | 1.0 | 1.2 | 1.5 | 2.0 | 2.5 | 3.0 | 5.0 | 10.0 | ∞ |
|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 0.028 | 0.029 | 0.030 | 0.031 | 0.031 | 0.032 | 0.032 | 0.032 | 0.032 |
| 0.2 | 0.055 | 0.057 | 0.059 | 0.061 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 |
| 0.3 | 0.079 | 0.083 | 0.086 | 0.089 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 |
| 0.4 | 0.101 | 0.106 | 0.110 | 0.113 | 0.115 | 0.115 | 0.115 | 0.115 | 0.115 |
| 0.5 | 0.120 | 0.126 | 0.131 | 0.135 | 0.137 | 0.137 | 0.137 | 0.137 | 0.137 |
| 0.6 | 0.136 | 0.143 | 0.149 | 0.153 | 0.155 | 0.156 | 0.156 | 0.156 | 0.156 |
| 0.7 | 0.149 | 0.157 | 0.164 | 0.169 | 0.170 | 0.171 | 0.172 | 0.172 | 0.172 |
| 0.8 | 0.160 | 0.168 | 0.176 | 0.181 | 0.183 | 0.184 | 0.185 | 0.185 | 0.185 |
| 0.9 | 0.168 | 0.178 | 0.186 | 0.192 | 0.194 | 0.195 | 0.196 | 0.196 | 0.196 |
| 1.0 | 0.175 | 0.185 | 0.193 | 0.200 | 0.202 | 0.203 | 0.204 | 0.205 | 0.205 |
| 1.2 | 0.185 | 0.196 | 0.205 | 0.212 | 0.215 | 0.216 | 0.217 | 0.218 | 0.218 |
| 1.5 | 0.193 | 0.205 | 0.215 | 0.223 | 0.226 | 0.228 | 0.229 | 0.230 | 0.230 |
| 2.0 | 0.200 | 0.212 | 0.223 | 0.232 | 0.236 | 0.238 | 0.239 | 0.240 | 0.240 |
| 2.5 | 0.202 | 0.215 | 0.226 | 0.236 | 0.240 | 0.242 | 0.244 | 0.244 | 0.244 |
| 3.0 | 0.203 | 0.216 | 0.228 | 0.238 | 0.242 | 0.244 | 0.246 | 0.247 | 0.247 |
| 5.0 | 0.204 | 0.217 | 0.229 | 0.239 | 0.244 | 0.246 | 0.249 | 0.249 | 0.249 |
| 10.0 | 0.205 | 0.218 | 0.230 | 0.240 | 0.244 | 0.247 | 0.249 | 0.250 | 0.250 |
| ∞ | 0.205 | 0.218 | 0.230 | 0.240 | 0.244 | 0.247 | 0.249 | 0.250 | 0.250 |

*Source: Newmark, N.M.,* Simplified Computation of Vertical Pressures in Elastic Foundations. *Circ. 24. Engrg. Exp. Stn., Univ. of Illinois (1935).*

Table 6-1 Values* of modulus of soil reaction, *E′* (psi) based on depth of cover, type of soil, and relative compaction

| | | | Standard AASHTO relative compaction‡ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of Cover | | 85% | | 90% | | 95% | | 100% | |
| Type of Soil† | *ft* | *(m)* | *psi* | *(kPa)* | *psi* | *(kPa)* | *psi* | *(kPa)* | *psi* | *(kPa)* |
| Fine-grained soils with less than 25% sand content (CL, ML, CL-ML) | 2–5 | (0.06–1.5) | 500 | (3,450) | 700 | (4,830) | 1,000 | (6,895) | 1,500 | (10,340) |
| | 5–10 | (1.5–3.1) | 600 | (4,140) | 1,000 | (6,895) | 1,400 | (9,655) | 2,000 | (13,790) |
| | 10–15 | (3.1–4.6) | 700 | (4,830) | 1,200 | (8,275) | 1,600 | (11,030) | 2,300 | (15,860) |
| | 15–20 | (4.6–6.1) | 800 | (5,520) | 1,300 | (8,965) | 1,800 | (12,410) | 2,600 | (17,930) |
| Coarse-grained soils with fines (SM, SC) | 2–5 | (0.06–1.5) | 600 | (4,140) | 1,000 | (6,895) | 1,200 | (8,275) | 1,900 | (13,100) |
| | 5–10 | (1.5–3.1) | 900 | (6,205) | 1,400 | (9,655) | 1,800 | (12,410) | 2,700 | (18,615) |
| | 10–15 | (3.1–4.6) | 1,000 | (6,895) | 1,500 | (10,340) | 2,100 | (14,480) | 3,200 | (22,065) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,600 | (11,030) | 2,400 | (16,545) | 3,700 | (25,510) |
| Coarse-grained soils with little or no fines (SP, SM, GP, GW) | 2–5 | (0.06–1.5) | 700 | (4,830) | 1,000 | (6,895) | 1,600 | (11,030) | 2,500 | (17,235) |
| | 5–10 | (1.5–3.1) | 1,000 | (6,895) | 1,500 | (10,340) | 2,200 | (15,170) | 3,300 | (22,750) |
| | 10–15 | (3.1–4.6) | 1,050 | (7,240) | 1,600 | (11,030) | 2,400 | (16,545) | 3,600 | (24,820) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,700 | (11,720) | 2,500 | (17,235) | 3,800 | (26,200) |

* Hartley, James D. and Duncan, James M., "*E′* and its Variation with Depth." *Journal of Transportation,* Division of ASCE, Sept. 1987.

† Soil type symbols are from the Unified Classification System.

‡ *Soil compaction.* When specifying the amount of compaction required, it is very important to consider the degree of soil compaction that is economically obtainable in the field for a particular installation. The density and supporting strength of the native soil should be taken into account. The densification of the backfill envelope must include the haunches under the pipe to control both the horizontal and vertical pipe deflections. Specifying an unobtainable soil compaction value can result in inadequate support and injurious deflection. Therefore, a conservative assumption of the supporting capability of a soil is recommended, and good field inspection should be provided to verify that design assumptions are met.

Table 6-2 Unified soil classification

| Symbol | Description |
|---|---|
| GW | Well-graded gravels, gravel-sand mixtures, little or no fines |
| GP | Poorly graded gravels, gravel-sand mixtures, little or no fines |
| GM | Silty gravels, poorly graded gravel-sand-silt mixtures |
| GC | Clayey gravels, poorly graded gravel-sand-clay mixtures |
| SW | Well-graded sands, gravelly sands, little or no fines |
| SP | Poorly graded sands, gravelly sands, little or no fines |
| SM | Silty sands, poorly graded sand-silt mixtures |
| SC | Clayey sands, poorly graded sand-clay mixtures |
| ML | Inorganic silts and very fine sand, silty or clayey fine sands |
| CL | Inorganic clays of low to medium plasticity |
| MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts |
| CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silt-clays of low plasticity |
| OH | Organic clays of medium to high plasticity |
| Pt | Peat and other highly organic soils |

*Source:* Classification of Soils for Engineering Purposes. ASTM Standard D2487-69, *ASTM, Philadelphia, Pa. (1969).*

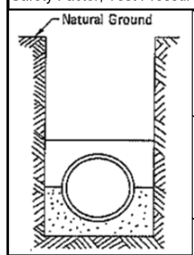
## Steel Pipe Wall Design - Trench Condition

**Steel Cylinder Structural Calculations per AWWA M11 - Fourth Edition (2004)**

| Legend | |
|---|---|
| *Red Numbers =* | Input required |

### Minimum Thickness for Internal Pressure (Eqn 4-1, AWWA M11)

| Input Section | | Output Section | |
|---|---|---|---|
| Nominal Diameter of Pipe (DN, in.) = | 60.000 | | |
| Select type of Lining = | Epoxy | Allowable Stress, Working ($s_w$,psi), $Y_s/SF_w$ = | 16,500 |
| Internal Working Pressure ($p_w$, psi) = | 24.00 | Allowable Stress, Transient ($s_s$, psi), $Y_s/SF_s$ = | 22,000 |
| Test Pressure- ($p_t$, psi) = | 150.00 | Allowable Stress, Test/Shutoff ($s_t$, psi), $Y_s/SF_t$ = | 22,000 |
| Transient Pressure ($p_s$, psi) [Limit to 1.33$p_w$] (See note 1) = | 31.92 | | |
| Pump Shutoff Pressure ($p_o$, psi) = | 300.00 | | |
| Specified Minimum Yield Point of Steel ($Y_s$, psi) (See note 2) = | 33,000 | Mortar Lining Thickness ($t_L$, in.) = | 0.000 |
| Safety Factor, Working ($SF_w$) = | 2.0 | Internal Diameter (ID, in.) = | 60.00 |
| Safety Factor, Transient Pressure (SFs )= | 1.5 | ID requirement based on (see note 2A) = | MWH |
| Safety Factor, Test Pressure/Pump Shutoff ($SF_t$) = | 1.5 | | |




**Pipe Wall Thickness due to Pressure:**

| | |
|---|---|
| Min Steel Thickness from Working Pressure Calc ($t_w$, in), $p_wOD/(2s_w)$ = | 0.0445 |
| Min Steel Thickness from Test Pressure Calc ($t_t$, in), $p_tOD/(2s_t)$ = | 0.2088 |
| Min Steel Thickness from Transient Pressure Calc ($t_s$,in), $p_sOD/(2s_s)$ = | 0.0444 |
| Min Steel Thickness from Shutoff Pressure Calc ($t_o$,in), $p_oOD/(2s_t)$ = | 0.4176 |

**Pipe Wall Thickness due to Handling/Constructability:** User Defined OD/t = 98

| | |
|---|---|
| Min Steel Thickness for Handling (OD/t ≤ 240, mortar lining) (see note 3) = | 0.2552 |
| Min Steel Thickness for Handling (OD/t ≤ 288, flexible lining) (see note 4) = | 0.2031 |
| Min Steel Thickness for Constructibility (from 'Min. Pipe Can' table) = | 0.2500 |
| Min Steel Thickness for User Specified Handling (OD/t ≤ 98) = | 0.6250 |

**Pipe Wall Thickness Results:**

| | |
|---|---|
| Min Pipe Wall Thickness Required ($t_{min}$, in) (see note 5) = | 0.6250 |
| Standard Pipe Wall Thickness per AWWA M11 Table A-1 ($t_{std}$, in) = | 0.6250 |
| Design OD/t = | 98 |

### Deflection Calculation, (Eqn. 6-5, AWWA M11)

| Input Section | | Output Section | |
|---|---|---|---|
| Wall thickness to use in design ($t_s$, in) = | 0.6250 | Mean Dia (D, in), OD - $t_s$ - $t_c$ = | 60.63 |
| Mortar Coating Thickness ($t_c$, in) (See note 7) = | 1.00 | Cylinder Outside Dia (OD, in), ID + 2$t_L$ + 2$t_s$ = | 61.25 |
| Soil backfill type | Sand & gravel | Pipe Outside Dia ($B_c$, ft), OD + 2$t_c$ = | 5.271 |
| Depth of soil cover (H, ft) = | 5.50 | Wall stiffness (EI, in$^4$/in), 30E10$^6$.$I_s$+4E10$^6$($I_l$+$I_c$) = | 943,685 |
| Distance beyond pipe OD to trench wall (m, ft) = | 1.00 | Steel moment of inertia ($I_s$, in$^4$/linear in), $t_s^3$/12 = | 0.0203 |
| Trench width at top of the pipe ($B_d$, ft) = $B_c$ + 2m | 7.27 | Lining moment of inertia ($I_l$, in$^4$/linear in), $t_L^3$/12 = | 0.0000 |
| Transition width ($B_{dt}$, ft) (**Go to "transition" tab to calculate $B_{dt}$**) | 8.57 | Coating moment of inertia ($I_c$, in$^4$/linear in), $t_c^3$/12 = | 0.0833 |
| | | Mean radius (r, in), D/2 = | 30.31 |
| Included additional load to apply to pipe | distributed load | $B_d/B_c$ = | 1.38 |
| Load, (Y, lbs) | 67,500.0 | -------------------------> Distributed load impact factor, I = | 1.00 |
| Length of loaded surface area, a (ft) | 3.40 | | |
| Width of loaded surface area, b (ft) | 2.01 | Surcharge load (Wy, psf), Y.I/[(a+H)(b+H)] = | 1,010 |
| Unit weight of soil (w, pcf) = | 120.00 | Lane loading (LL, psf) = | 0 |
| Height of water surface above top of pipe ($h_w$, ft) = | 0.00 | Wheel load spread width (A, ft), 5.67+fH = | 0.00 |
| Include saturated soil weight in deflection calc (Y/N) (see note 10) = | No | Wheel load spread length (B, ft), 0.83+fH = | 0.00 |
| Live load (HS-20 Single/HS-20 ALT./E80/NA)= | NA | Alternate live load backfill factor (f) = | 0.00 |
| Modulus of soil reaction, E' | Per AWWA M11 | Govn dimension parallel to long axis of pipe (L, ft) = | 0.00 |
| Modulus of the soil reaction (E', psi) (See table 6-1 and note 8) = | 500.00 | $E'_n/E'_b$ = | NA |
| Native soil modulus ($E'_n$, psi) (See table 5-6) = | 0.00 | Modulus of soil reaction (E', psi) = | 500.00 |
| Modulus of the backfill soil ($E'_b$, psi) (See table 6-1 and note 8) = | 0.00 | Bedding constant (K) = | 0.110 |
| Soil support combining factor (Sc) (See table 5-5) = | 0.00 | | |
| Deflection lag factor ($D_L$, 1.0-1.5) (See note 9) = | 1.50 | | |
| Select bedding angle (Θ, degree) = | 0 | | |

**Determination of External Load and Deflection for Trench Condition**

<u>Earth load</u>

| | | |
|---|---|---|
| Earth load for trench condition ($W_c$, lb/linear in.), Non-saturated soil: $HwB_c$/12 -or- Saturated soil: 0.0361$h_wB_c$ + $R_wHwB_c$/12 = | 289.90 | Non-saturated soil |

**Determination of Live Load for HS-20 wheel Or Cooper E-80 Railroad Loading**

<u>Highway loading per AWWA M11</u>

| | |
|---|---|
| Single HS-20 truck live load on pipe from table 6-3 ($P_L$, psf) = | 0.00 |
| Single HS-20 truck live load on pipe ($W_L$,lb/linear in.), $P_LBc$/12 = | 0.00 |

<u>Alternate Highway loading per AASHTO</u>

| | |
|---|---|
| Impact factor for highway ($I_f$, %), 33*(1-0.125H))/100 = | 0% |
| Total wheel load applied at the surface (P,lbs) = | 0 |
| Total live load assuming truck travel transverse to pipe centerline ($W_T$, lbs), [P(1+$I_f$)/(AB)+LL].A.Min(B,$B_c$) = | 0 |
| Total live load assuming truck travel parallel to pipe centerline ($W_P$, lbs), [P(1+$I_f$)/(AB)+LL].B.Min(A,$B_c$) = | 0 |
| HS-20 ALT,Maximum AASHTO HS-20 Passing truck live load on pipe ($W_L$, lb/linear in.), {Max($W_T$,$W_P$) / [L+1.75(0.75$B_c$)]} / 12 = | 0.00 |

<u>Railroad loading per AWWA M11</u>

| | |
|---|---|
| Railroad loading on pipe from table 6-3 ($W_L$, lb/linear in.) = | 0.00 |

<u>Surcharge loading</u>

| | |
|---|---|
| Surcharge loading on pipe (Wy, lb/linear in.) = | 443.58 |

**Total External Load**

| | |
|---|---|
| Total external load on pipe (W, lb/linear in.) = | 733.48 |

**Deflection Results (Eqn 6-5, AWWA M11)**

| | |
|---|---|
| Vertical/Horizontal deflection of the pipe (Δx, in), $D_L$ [KWr$^3$/ (EI+0.061E'r$^3$)] = | 1.88 |
| Percent deflection, Δx/D = | 3.10% |
| This is not a standard type of pipe | |

**Deflection Result : Deflection is Within Allowable Limits**

### Buckling Results (Eqns. 6-7, 6-8, 6-9, AWWA M11)

| Input Section | | Output Section | |
|---|---|---|---|
| Include internal vacuum pressure | Yes | Water bouyancy factor ($R_w$), 1-(0.33($h_w$/H)) = | 1.00 |
| Internal vacuum pressure ($P_v$, psi) = | 14.70 | Elastic support coefficient, (B'), 1 / (1+4e$^{-0.065H}$ ) = | 0.26 |
| Buckling factor of safety based on AWWA M-11 (3rd Ed/4th Ed) | 4th Ed (2004) | H/$B_c$ = | 1.04 |
| | | Buckling factor of safety, FS (See note 13) = | 2.0 |

| | |
|---|---|
| Allowable buckling pressure ($q_a$, psi), (1/FS) [32 $R_w$B'E'(EI/$B_c^3$)]$^{0.5}$ = | 62.67 |
| Total Negative Pressure, live load condition (psi), 0.0361$h_w$ + $R_wW_{c(dry)}/B_c$ + $W_L/B_c$ (See note 14) = | 4.58 |
| Total Negative Pressure, vacuum condition (psi), 0.0361$h_w$ + $R_wW_{c(dry)}/B_c$ + $P_v$ (See note 14) = | 19.28 |

**Buckling Result : Pipe stiffness acceptable**

### Sheet Notes:

1. MWH surge allowance is limited to 1.33 $p_w$ - Use actual surge value if higher. (See Hydraulic Lead/Surge report for surge values)
2. Yield Stress -$Y_s$ limited to:
   33,000 psi - Mortar Lined and Coated pipe
   42,000 psi - Mortar Lined - Flexible Coated pipe
   50,000 psi - Flexible Lined and Coated pipe

2A. MWH ID requirement is based on ID for 14" dia and larger.

3. Use OD/t = 240 for handling, unless justified otherwise, for mortar lined pipe.
4. Use OD/t ≤ 288 for OD up to 54" (M11 Eq 4-5).
   For OD ≥ 54", use t≥ (OD+20)/400 (M11 Eq 4-6).
5. Use the maximum of the wall thicknesses calculated by pressure, handling or the minimum thickness shown for the pipe or fitting.
6. Minimum allowable pressure to avoid vapor pressure of fluid and associated cavitation is -5.00 psi

### Notes for Designer:

7. Limit Mortar Coating to 1" max in Δx Calculations
8. Selection of E' value from Table 6-1 shall be limited to 85% relative compaction effort, unless otherwise approved by Geotechnical Engineer. Coordinate with Geotechnical Report for suitable E' value for pipeline design.
9. The deflection Lag factor is 1.0 for a pressurized pipe, however, if the pipe will sit empty for periods of time the value would be greater than 1.0.
10. Saturated soil weight is accounted for using bouyancy reduction factor ($R_w$).
11. Allowable deflections used herein are set at 75% of allowable deflections shown in AWWA M11, consistent with MWH standards.
12. Where internal vacuum occurs with cover depth less than 4 ft but not less than 2 ft care should be exercised in defining allowable buckling pressure. (AWWA M11 buckling footnote)
13. Design factor FS=2.0 is recommended by AWWA M11 4th Ed for all depths in buckling calculation. AWWA M11 3rd Ed recommended FS=3.0 for H/$B_c$<2.0 and FS=2.5 for H/$B_c$≥2.
14. Total negative pressure does not include surcharge load.

### Pipe Reference Data

| Bedding Constant K | |
|---|---|
| Bedding Angle (degree) | Bedding Constant |
| 0 | 0.11 |
| 30 | 0.108 |
| 45 | 0.105 |
| 60 | 0.102 |
| 90 | 0.096 |
| 120 | 0.090 |
| 180 | 0.083 |

| MWH Min. Wall Thickness Requirements | |
|---|---|
| **Fittings and Specials - Thickness** | |
| 24" Dia. & under - 3/16" = | 0.1875 |
| 25" to 48" Dia. - 1/4" = | 0.2500 |
| Over 48" Dia. - 5/16" = | 0.3125 |
| **Min. Pipe Can - Thickness** | |
| ND, (in) | Min. t, (in) |
| 6 | 0.1345 |
| 12 | 0.1345 |
| 18 | 0.1345 |
| 24 | 0.1345 |
| 30 | 0.1345 |
| 36 | 0.1500 |
| 42 | 0.1750 |
| 48 | 0.2000 |
| 54 | 0.2250 |
| 60 | 0.2500 |
| 66 | 0.2750 |
| 72 | 0.3000 |
| 78 | 0.3250 |
| 84 | 0.3500 |
| 90 | 0.3750 |
| 96 | 0.4000 |
| 102 | 0.4250 |
| 108 | 0.4500 |
| 114 | 0.4750 |
| 120 | 0.5000 |

**Mortar Lining Thickness MWH**

| Diameter (in) | Lining Thickness (in) | Diameter (in) | Lining Thickness (in) |
|---|---|---|---|
| 4 | 0.25 | 60 | 0.5 |
| 6 | 0.25 | 66 | 0.5 |
| 8 | 0.25 | 72 | 0.5 |
| 10 | 0.25 | 78 | 0.5 |
| 12 | 0.313 | 84 | 0.5 |
| 14 | 0.313 | 90 | 0.5 |
| 16 | 0.313 | 96 | 0.5 |
| 18 | 0.313 | 102 | 0.5 |
| 20 | 0.313 | 108 | 0.5 |
| 24 | 0.375 | 114 | 0.5 |
| 26 | 0.375 | 120 | 0.5 |
| 28 | 0.375 | 126 | 0.5 |
| 30 | 0.375 | 132 | 0.5 |
| 32 | 0.375 | 138 | 0.5 |
| 34 | 0.375 | 144 | 0.5 |
| 36 | 0.375 | | |
| 38 | 0.5 | | |
| 40 | 0.5 | | |
| 42 | 0.5 | | |
| 44 | 0.5 | | |
| 46 | 0.5 | | |
| 48 | 0.5 | | |
| 50 | 0.5 | | |
| 52 | 0.5 | | |
| 54 | 0.5 | | |
| 56 | 0.5 | | |
| 58 | 0.5 | | |

**Backfill Materials**:

Table 6-1 Values* of modulus of soil reaction, E (psi) based on depth of cover, type of soil, and relative compaction

| Type of Soil† | Depth of Cover ft | (m) | 85% psi | (kPa) | 90% psi | (kPa) | 95% psi | (kPa) | 100% psi | (kPa) |
|---|---|---|---|---|---|---|---|---|---|---|
| Fine-grained soils with less than 25% sand content (CL, ML, CL-ML) | 2–5 | (0.6–1.5) | 500 | (3,450) | 700 | (4,830) | 1,000 | (6,895) | 1,500 | (10,340) |
| | 5–10 | (1.5–3.1) | 600 | (4,140) | 1,000 | (6,895) | 1,400 | (9,655) | 2,000 | (13,790) |
| | 10–15 | (3.1–4.6) | 700 | (4,830) | 1,200 | (8,275) | 1,600 | (11,030) | 2,300 | (15,860) |
| | 15–20 | (4.6–6.1) | 800 | (5,520) | 1,300 | (8,965) | 1,800 | (12,410) | 2,600 | (17,930) |
| Coarse-grained soils with fines (SM, SC) | 2–5 | (0.6–1.5) | 600 | (4,140) | 1,000 | (6,895) | 1,200 | (8,275) | 1,900 | (13,100) |
| | 5–10 | (1.5–3.1) | 900 | (6,205) | 1,400 | (9,655) | 1,800 | (12,410) | 2,700 | (18,615) |
| | 10–15 | (3.1–4.6) | 1,000 | (6,895) | 1,500 | (10,340) | 2,100 | (14,480) | 3,200 | (22,065) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,600 | (11,030) | 2,400 | (16,545) | 3,700 | (25,510) |
| Coarse-grained soils with little or no fines (SP, SM, GP, GW) | 2–5 | (0.6–1.5) | 700 | (4,830) | 1,000 | (6,895) | 1,600 | (11,030) | 2,500 | (17,235) |
| | 5–10 | (1.5–3.1) | 1,000 | (6,895) | 1,500 | (10,340) | 2,200 | (15,170) | 3,300 | (22,750) |
| | 10–15 | (3.1–4.6) | 1,050 | (7,240) | 1,600 | (11,030) | 2,400 | (16,545) | 3,600 | (24,820) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,700 | (11,720) | 2,500 | (17,235) | 3,800 | (26,200) |

(Standard AASHTO relative compaction‡)

**Native Soils**:

Table 5-6 Values for the modulus of soil reaction $E'_n$ for the native soil at pipe zone elevation

| Granular Blows/ft† | Granular Description | Cohesive $q_u$(Tons/sf) | Cohesive Description | $E'_n$ (psi) |
|---|---|---|---|---|
| >0–1 | very, very loose | >0–0.125 | very, very soft | 50 |
| 1–2 | very loose | 0.125–0.25 | very soft | 200 |
| 2–4 | | 0.25–0.50 | soft | 700 |
| 4–8 | loose | 0.50–1.0 | medium | 1,500 |
| 8–15 | slightly compact | 1.0–2.0 | stiff | 3,000 |
| 15–30 | compact | 2.0–4.0 | very stiff | 5,000 |
| 30–50 | dense | 4.0–6.0 | hard | 10,000 |
| >50 | very dense | >6.0 | very hard | 20,000 |

(Native in Situ Soils*)

**Composite E' Coefficients**:

Table 5-5 Values for the soil support combining factor $S_c$

| $M_{sn}/M_{sb}$ | $B_d/D$ = 1.25 | $B_d/D$ = 1.5 | $B_d/D$ = 1.75 | $B_d/D$ = 2 | $B_d/D$ = 2.5 | $B_d/D$ = 3 | $B_d/D$ = 4 | $B_d/D$ = 5 |
|---|---|---|---|---|---|---|---|---|
| 0.005 | 0.02 | 0.05 | 0.08 | 0.12 | 0.23 | 0.43 | 0.72 | 1.00 |
| 0.01 | 0.03 | 0.07 | 0.11 | 0.15 | 0.27 | 0.47 | 0.74 | 1.00 |
| 0.02 | 0.05 | 0.10 | 0.15 | 0.20 | 0.32 | 0.52 | 0.77 | 1.00 |
| 0.05 | 0.10 | 0.15 | 0.20 | 0.27 | 0.38 | 0.58 | 0.80 | 1.00 |
| 0.1 | 0.15 | 0.20 | 0.27 | 0.35 | 0.46 | 0.65 | 0.84 | 1.00 |
| 0.2 | 0.25 | 0.30 | 0.38 | 0.47 | 0.58 | 0.75 | 0.88 | 1.00 |
| 0.4 | 0.45 | 0.50 | 0.56 | 0.64 | 0.75 | 0.85 | 0.93 | 1.00 |
| 0.6 | 0.65 | 0.70 | 0.75 | 0.81 | 0.87 | 0.94 | 0.98 | 1.00 |
| 0.8 | 0.84 | 0.87 | 0.90 | 0.93 | 0.96 | 0.98 | 1.00 | 1.00 |
| 1 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1.5 | 1.40 | 1.30 | 1.20 | 1.12 | 1.06 | 1.03 | 1.00 | 1.00 |
| 2 | 1.70 | 1.50 | 1.40 | 1.30 | 1.20 | 1.10 | 1.05 | 1.00 |
| 3 | 2.20 | 1.80 | 1.65 | 1.50 | 1.35 | 1.20 | 1.10 | 1.00 |
| ≥5 | 3.00 | 2.20 | 1.90 | 1.70 | 1.50 | 1.30 | 1.15 | 1.00 |

NOTE: In-between values of $S_c$ may be determined by straight-line interpolation from adjacent values.

| Table 6-3; AWWA M11 | | | |
|---|---|---|---|
| **Highway HS-20 Load** | | **Railroad E-80 Load** | |
| Soil Cover | Load | Soil Cover | Load |
| ft | psf | ft | psf |
| 1 | 1800 | 2 | 3800 |
| 2 | 800 | 5 | 2400 |
| 3 | 600 | 8 | 1600 |
| 4 | 400 | 10 | 1100 |
| 5 | 250 | 12 | 800 |
| 6 | 200 | 15 | 600 |
| 7 | 176 | 20 | 300 |
| 8 | 100 | 30 | 100 |

Note: Neglect live load when less than 100 psf; use dead load only.

**Typical Trench Section**

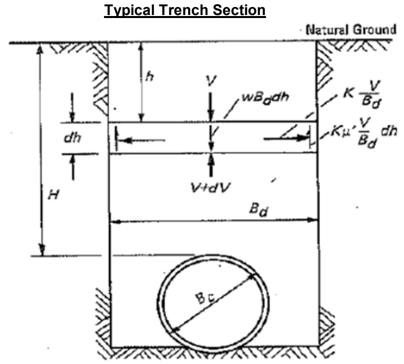



**Figure 4.3.** Trench Condition.

**Client:** *(Client Name here)*
**Project:** *(Project Name Here)*
**Description:** *(Description of what is being calculated, specific building, system, discipline, etc…)*

**Sheet:** ________ **of** ________
**Date:** *mm/dd/yy*
**Job No:** *xxxxxx*
**By:** *(Author)* **Chkd By:** *xxx*

## Steel Pipe Wall Design - Trench Condition

Steel Pipe Wall Design - Trench Condition

### Equations used

**Barlow Formula - Hoop Stress**

$$t = \frac{pd}{2s}$$

Where:

$t$ = minimum pipe wall thickness for the specified internal design pressure, in. (mm)
$p$ = internal design pressure, psi (kPa)
$d$ = outside diameter of pipe steel cylinder (not including coatings), in. (mm)
$s$ = allowable design stress, psi (kPa)

**Buckling Equations**

Allowable Buckling Pressure

$$q_a = \left(\frac{1}{FS}\right)\left(32R_w B'E'\frac{EI}{D^3}\right)^{1/2}$$

Vacuum Press Live Load Pressure

$$\gamma_w h_w + R_w \frac{W_c}{D} + \frac{W_L}{D} \leq \quad \gamma_w h_w + R_w \frac{W_c}{D} + P_v \leq q_a$$

Where:

$h_w$ = height of water above conduit in in. (mm)
$\gamma_w$ = specific weight of water = 0.0361 lb/cu in. (0.0098 kPa/mm$^3$)
$P_v$ = internal vacuum pressure in psi (kPa) = atmospheric pressure less absolute pressure inside pipe, in psi (kPa)
$W_c$ = vertical soil load on pipe per unit length, in lb/in. (kPa/mm)

**EARTH LOADING**

**Embankment Condition**

$$W_c = C_c w B_c^2$$

Where:

$C_c$ = coefficient for embankment conditions, a function of soil properties.

For flexible pipe, the settlement ratio (Spangler 1947) is assumed to be zero, in which case

Where:

$H_c$ = height of fill above top of pipe in ft (m)

Then:

$$W_c = \frac{H_c}{B_c} w B_c^2 = w H_c B_c$$

**PIPE DEFLECTION**

$$\text{Deflx} = \frac{D_L\,K\,W\,r^3}{EI + 0.0614E'r3}$$

**Where:**

**Deflx = Vertical deflection of pipe in inches, (not to exceed 0.015 times the nominal diameter for mortar-lined and coated pipe, 0.025 times the nominal diameter for mortar-lined and dielectric coated pipe and 0.05 times the nominal diameter for dielectric lined and coated pipe.)**

**DL = Deflection lag factor.**
**K = Bedding constant**
**W = Vertical load on pipe, lb/in.**
**r = Mean radius of pipe shell, inches**
**EI = Pipe stiffness, lb in.**
**E' = Modulus of soil reaction, lb/in2 A specific, rational method must be used to develop this number for soils at the site. The method must be reviewed.**

Stantec

Burris Basin - 60" line

$ID = 60"$
$OD = 61.25"$
$t_s = .6250"$
$t_c = 1"$
$w = 120\ lb/ft^2$
$H_c = 5.5'$
$D_c = 63.25"$
$D_l = 1.5$
$K = .1$
$r = .5D \rightarrow 30.3125"$
$D = ID + t_s + t_L \rightarrow 60.625"$
$t_L = 0"$
$E_s = 30\times10^6\ lb/in^2$
$E_c = 4\times10^6\ lb/in^2$
$EI = E_sI_s + E_c(I_L + I_c) \rightarrow 30\times10^6\left(\frac{.6250^3}{12}\right) + 4\times10^6\left(\frac{1^3}{12} + 0\right) \rightarrow 943684\ i$
$I = t^3/12$
*$E' = 500$
$C_n = .55$
$\varphi_s = .9$
$K_v = .74$
$FS_B = 2$
$r_o = .5OD \rightarrow 30.625$
$\gamma_w = 62.4\ lb/ft^3$
$H_w = 0$
$P_v = 14.7\ lb/in^2$

* Note E' taken from table 5-3. Assume most conservative SC @ 90% Compaction. Apply 1/2 F.S.

Designed by: Checked by:

Stantec

~~Deflection~~ Earth Load & Live Load

$$W_c = w H_c \left(\frac{D_c}{12}\right) \quad (\text{Eq. } 5.3)$$

$$= (120)(5.5)\left(\frac{63.25}{12}\right) \rightarrow 3478.75 \text{ lb/ft} \text{ or } 289.90 \text{ lb/in}$$

Live Load — Cat 657

$P = 135{,}000$ lb (axle load)

$\frac{P}{2} = 67{,}500$ lb (single tire)

tire dimension = 40.8" × 24.12"

Surface Area = $(40.8" \times 24.12")\left(\frac{1}{144}\right) \rightarrow 6.834 \text{ ft}^2$

Surface Pressure = $(67{,}500)/6.834 \rightarrow 9877.09 \text{ lb/ft}^2$

$$A_T = .5\left(\frac{40.8}{12}\right) \rightarrow 1.7$$

$$B_T = .5\left(\frac{24.12}{12}\right) \rightarrow 1.0$$

$$m = \left(\frac{A_T}{H_c}\right) \rightarrow .31$$

$$n = \left(\frac{B_T}{H_c}\right) \rightarrow .18$$

Use table 5-2 for Newmark Vertical influence Coefficients = .026

$$W_L = (4)(.026)(9877.09) \rightarrow 1027.21 \text{ lb/ft}^2$$ ~~or 85.60 lb/in~~

$$W_y = W_L\left(\frac{D_c}{12}\right) \rightarrow 1027.21\left(\frac{63.25}{12}\right) \rightarrow 5414.25 \text{ lb/ft} \text{ or } 451.19 \text{ lb/in}$$

$$W = W_c + W_y \rightarrow 289.9 + 451.19 \rightarrow \boxed{741.09 \text{ lb/in}}$$

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Deflection

$$\Delta x = \left(\frac{D_1 K W r^3}{EI + .061E'r^3}\right) \quad \text{(Eq 5.4)}$$

$$= \left[\frac{(1.5)(.1)(741.09)(30.3125^3)}{(943684 + .061(500)(30.3125^3))}\right] \longrightarrow \ldots$$

$$\ldots \longrightarrow \frac{3096189.119}{1793187.372} \longrightarrow 1.72 \text{ in}$$

$$\% \text{ Deflection} = \frac{\Delta x}{OD} \rightarrow \frac{1.72}{61.25} \longrightarrow 2.81\%$$

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Buckling

$$q_a = \frac{(1.2C_n)(EI)^{.33}(\phi_s E' K_v)^{.67} R_H}{(FS_B) r_o} \quad \text{(Eq 5.7)}$$

$$= \frac{(1.2(.55))(943684)^{.33}((.9)(500)(.74))^{.67} R_H}{2(30.625)} \text{———...}$$

$$\ldots \longrightarrow \frac{3028.83 R_H}{61.25} \longrightarrow 49.45 R_H \longrightarrow 47.27 \text{ lb/in}^2$$

$$R_H = \frac{11.4}{11 + (2r/H_c)} \longrightarrow \frac{11.4}{11 + \frac{2(30.3125)}{(5.5 \times 12)}} \longrightarrow \frac{11.4}{11.92} \longrightarrow .956$$

$$q_a \geq \frac{\gamma_w}{1{,}728} H_w + R_w \frac{W_c}{12 D_o} + P_v$$

$$\geq \frac{62.4}{1{,}728} 0 + R_w \frac{(289.9 \times 12)}{12(61.25)} + (14.7) \text{———...}$$

$$\ldots \longrightarrow 4.733 R_w + 14.7 \longrightarrow 4.733(1) + 14.7 \longrightarrow 19.433 \text{ lb/in}^2$$

$$R_w = 1 - .33\left(\frac{H_w}{H_c}\right) \longrightarrow 1 - .33\left(\frac{0}{5.5}\right) \longrightarrow 1$$

$47.27 \geq 19.433$ ✓

Designed by: Checked by:

Table 6-4 Influence coefficients for rectangular areas

| $m = A/H$ or $n = B/H$ | $n = B/H$ or $m = A/H$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| 0.1 | 0.005 | 0.009 | 0.013 | 0.017 | 0.020 | 0.022 | 0.024 | 0.026 | 0.027 |
| 0.2 | 0.009 | 0.018 | 0.026 | 0.033 | 0.039 | 0.043 | 0.047 | 0.050 | 0.053 |
| 0.3 | 0.013 | 0.026 | 0.037 | 0.047 | 0.056 | 0.063 | 0.069 | 0.073 | 0.077 |
| 0.4 | 0.017 | 0.033 | 0.047 | 0.060 | 0.071 | 0.080 | 0.087 | 0.093 | 0.098 |
| 0.5 | 0.020 | 0.039 | 0.056 | 0.071 | 0.084 | 0.095 | 0.103 | 0.110 | 0.116 |
| 0.6 | 0.022 | 0.043 | 0.063 | 0.080 | 0.095 | 0.107 | 0.117 | 0.125 | 0.131 |
| 0.7 | 0.024 | 0.047 | 0.069 | 0.087 | 0.103 | 0.117 | 0.128 | 0.137 | 0.144 |
| 0.8 | 0.026 | 0.050 | 0.073 | 0.093 | 0.110 | 0.125 | 0.137 | 0.146 | 0.154 |
| 0.9 | 0.027 | 0.053 | 0.077 | 0.098 | 0.116 | 0.131 | 0.144 | 0.154 | 0.162 |
| 1.0 | 0.028 | 0.055 | 0.079 | 0.101 | 0.120 | 0.136 | 0.149 | 0.160 | 0.168 |
| 1.2 | 0.029 | 0.057 | 0.083 | 0.106 | 0.126 | 0.143 | 0.157 | 0.168 | 0.178 |
| 1.5 | 0.030 | 0.059 | 0.086 | 0.110 | 0.131 | 0.149 | 0.164 | 0.176 | 0.186 |
| 2.0 | 0.031 | 0.061 | 0.089 | 0.113 | 0.135 | 0.153 | 0.169 | 0.181 | 0.192 |
| 2.5 | 0.031 | 0.062 | 0.090 | 0.115 | 0.137 | 0.155 | 0.170 | 0.183 | 0.194 |
| 3.0 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.171 | 0.184 | 0.195 |
| 5.0 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 |
| 10.0 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 |
| ∞ | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 |

| | 1.0 | 1.2 | 1.5 | 2.0 | 2.5 | 3.0 | 5.0 | 10.0 | ∞ |
|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 0.028 | 0.029 | 0.030 | 0.031 | 0.031 | 0.032 | 0.032 | 0.032 | 0.032 |
| 0.2 | 0.055 | 0.057 | 0.059 | 0.061 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 |
| 0.3 | 0.079 | 0.083 | 0.086 | 0.089 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 |
| 0.4 | 0.101 | 0.106 | 0.110 | 0.113 | 0.115 | 0.115 | 0.115 | 0.115 | 0.115 |
| 0.5 | 0.120 | 0.126 | 0.131 | 0.135 | 0.137 | 0.137 | 0.137 | 0.137 | 0.137 |
| 0.6 | 0.136 | 0.143 | 0.149 | 0.153 | 0.155 | 0.156 | 0.156 | 0.156 | 0.156 |
| 0.7 | 0.149 | 0.157 | 0.164 | 0.169 | 0.170 | 0.171 | 0.172 | 0.172 | 0.172 |
| 0.8 | 0.160 | 0.168 | 0.176 | 0.181 | 0.183 | 0.184 | 0.185 | 0.185 | 0.185 |
| 0.9 | 0.168 | 0.178 | 0.186 | 0.192 | 0.194 | 0.195 | 0.196 | 0.196 | 0.196 |
| 1.0 | 0.175 | 0.185 | 0.193 | 0.200 | 0.202 | 0.203 | 0.204 | 0.205 | 0.205 |
| 1.2 | 0.185 | 0.196 | 0.205 | 0.212 | 0.215 | 0.216 | 0.217 | 0.218 | 0.218 |
| 1.5 | 0.193 | 0.205 | 0.215 | 0.223 | 0.226 | 0.228 | 0.229 | 0.230 | 0.230 |
| 2.0 | 0.200 | 0.212 | 0.223 | 0.232 | 0.236 | 0.238 | 0.239 | 0.240 | 0.240 |
| 2.5 | 0.202 | 0.215 | 0.226 | 0.236 | 0.240 | 0.242 | 0.244 | 0.244 | 0.244 |
| 3.0 | 0.203 | 0.216 | 0.228 | 0.238 | 0.242 | 0.244 | 0.246 | 0.247 | 0.247 |
| 5.0 | 0.204 | 0.217 | 0.229 | 0.239 | 0.244 | 0.246 | 0.249 | 0.249 | 0.249 |
| 10.0 | 0.205 | 0.218 | 0.230 | 0.240 | 0.244 | 0.247 | 0.249 | 0.250 | 0.250 |
| ∞ | 0.205 | 0.218 | 0.230 | 0.240 | 0.244 | 0.247 | 0.249 | 0.250 | 0.250 |

*Source: Newmark, N.M.,* Simplified Computation of Vertical Pressures in Elastic Foundations. *Circ. 24. Engrg. Exp. Stn., Univ. of Illinois (1935).*

Table 6-1 Values* of modulus of soil reaction, E′ (psi) based on depth of cover, type of soil, and relative compaction

| | | | Standard AASHTO relative compaction‡ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Depth of Cover | | 85% | | 90% | | 95% | | 100% | |
| Type of Soil† | *ft* | *(m)* | *psi* | *(kPa)* | *psi* | *(kPa)* | *psi* | *(kPa)* | *psi* | *(kPa)* |
| Fine-grained soils | 2–5 | (0.06–1.5) | 500 | (3,450) | 700 | (4,830) | 1,000 | (6,895) | 1,500 | (10,340) |
| with less than 25% | 5–10 | (1.5–3.1) | 600 | (4,140) | 1,000 | (6,895) | 1,400 | (9,655) | 2,000 | (13,790) |
| sand content (CL, | 10–15 | (3.1–4.6) | 700 | (4,830) | 1,200 | (8,275) | 1,600 | (11,030) | 2,300 | (15,860) |
| ML, CL-ML) | 15–20 | (4.6–6.1) | 800 | (5,520) | 1,300 | (8,965) | 1,800 | (12,410) | 2,600 | (17,930) |
| Coarse-grained soils | 2–5 | (0.06–1.5) | 600 | (4,140) | 1,000 | (6,895) | 1,200 | (8,275) | 1,900 | (13,100) |
| with fines (SM, SC) | 5–10 | (1.5–3.1) | 900 | (6,205) | 1,400 | (9,655) | 1,800 | (12,410) | 2,700 | (18,615) |
| | 10–15 | (3.1–4.6) | 1,000 | (6,895) | 1,500 | (10,340) | 2,100 | (14,480) | 3,200 | (22,065) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,600 | (11,030) | 2,400 | (16,545) | 3,700 | (25,510) |
| Coarse-grained soils | 2–5 | (0.06–1.5) | 700 | (4,830) | 1,000 | (6,895) | 1,600 | (11,030) | 2,500 | (17,235) |
| with little or no fines | 5–10 | (1.5–3.1) | 1,000 | (6,895) | 1,500 | (10,340) | 2,200 | (15,170) | 3,300 | (22,750) |
| (SP, SM, GP, GW) | 10–15 | (3.1–4.6) | 1,050 | (7,240) | 1,600 | (11,030) | 2,400 | (16,545) | 3,600 | (24,820) |
| | 15–20 | (4.6–6.1) | 1,100 | (7,585) | 1,700 | (11,720) | 2,500 | (17,235) | 3,800 | (26,200) |

* Hartley, James D. and Duncan, James M., "*E′* and its Variation with Depth." *Journal of Transportation,* Division of ASCE, Sept. 1987.

† Soil type symbols are from the Unified Classification System.

‡ *Soil compaction.* When specifying the amount of compaction required, it is very important to consider the degree of soil compaction that is economically obtainable in the field for a particular installation. The density and supporting strength of the native soil should be taken into account. The densification of the backfill envelope must include the haunches under the pipe to control both the horizontal and vertical pipe deflections. Specifying an unobtainable soil compaction value can result in inadequate support and injurious deflection. Therefore, a conservative assumption of the supporting capability of a soil is recommended, and good field inspection should be provided to verify that design assumptions are met.

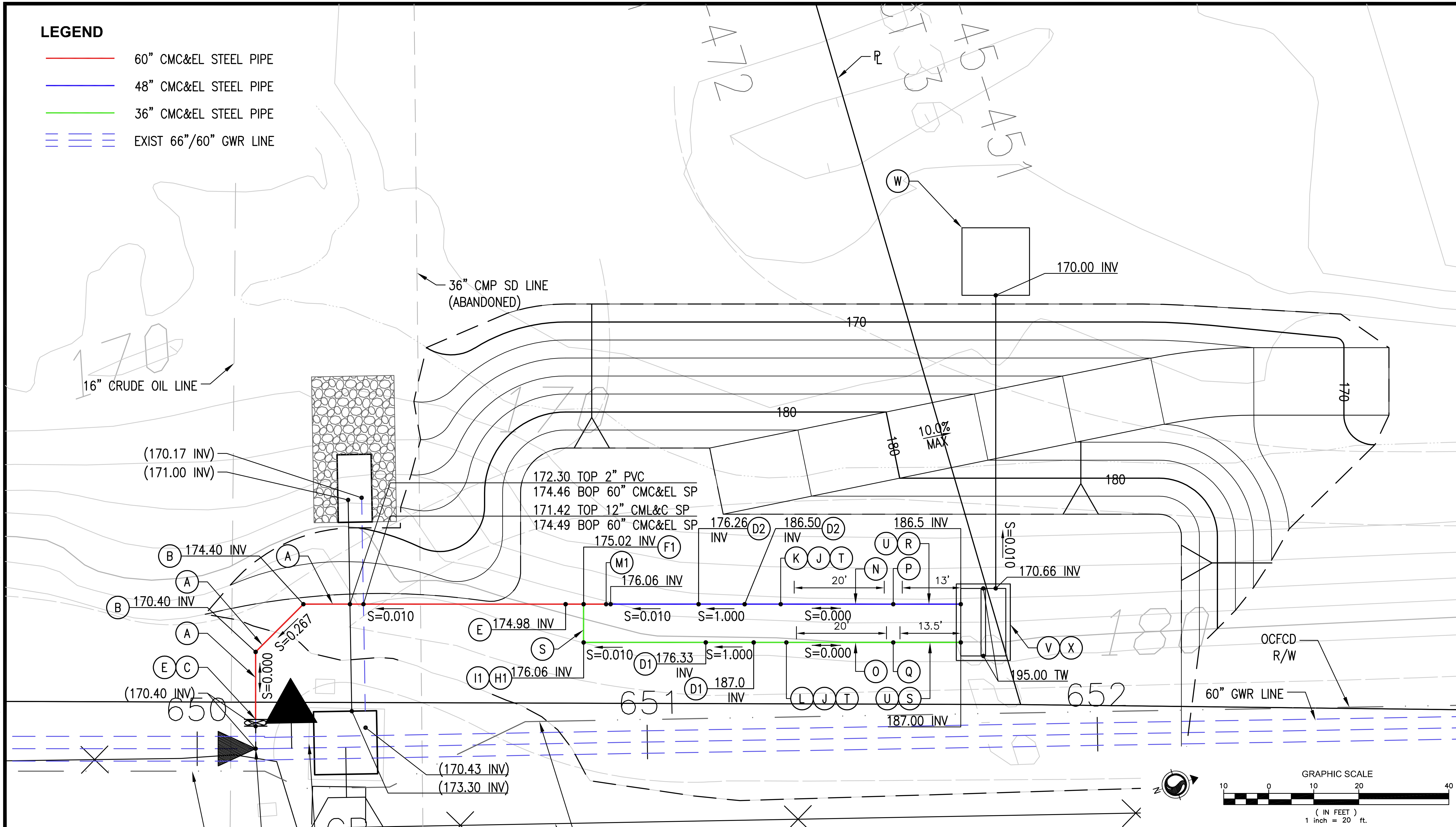
Table 6-2 Unified soil classification

| Symbol | Description |
|---|---|
| GW | Well-graded gravels, gravel-sand mixtures, little or no fines |
| GP | Poorly graded gravels, gravel-sand mixtures, little or no fines |
| GM | Silty gravels, poorly graded gravel-sand-silt mixtures |
| GC | Clayey gravels, poorly graded gravel-sand-clay mixtures |
| SW | Well-graded sands, gravelly sands, little or no fines |
| SP | Poorly graded sands, gravelly sands, little or no fines |
| SM | Silty sands, poorly graded sand-silt mixtures |
| SC | Clayey sands, poorly graded sand-clay mixtures |
| ML | Inorganic silts and very fine sand, silty or clayey fine sands |
| CL | Inorganic clays of low to medium plasticity |
| MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts |
| CH | Inorganic clays of high plasticity, fat clays |
| OL | Organic silts and organic silt-clays of low plasticity |
| OH | Organic clays of medium to high plasticity |
| Pt | Peat and other highly organic soils |

*Source:* Classification of Soils for Engineering Purposes. ASTM Standard D2487-69, *ASTM, Philadelphia, Pa. (1969).*

# Appendix D

## D.1 SCHEMATIC DESIGNS

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**BURRIS BASIN**
**GROUNDWATER REPLENISHMENT SYSTEM**
**PIPELINE OUTLET PROJECT**
**ALTERNATIVE 1**

DATE: 7/1/2019

SHEET 1 OF 2

JOB NO. 2042499004

DRAWING: v:\2042\active\2042499004\drawing\model_files\499004c-pb003.dwg PLOTTED: 7/1/2019 4:20 PM BY: Wagstaff, Matt

- (A) FURNISH AND INSTALL 60" CMC&EL STEEL PIPE (WELDxWELD)
- (B) FURNISH AND INSTALL 60" CMC&EL 4-PIECE 47.42° BEND, ROTATED VERTICALLY 18.35° (CLASS 150) (WELDxWELD)
- (C) FURNISH AND INSTALL 60" BUTTERFLY VALVE (FExFE)
- (D1) FURNISH AND INSTALL 36" CMC&EL 4-PIECE 45° VERT. BEND (CLASS 150) (WELDxWELD)
- (D2) FURNISH AND INSTALL 48" CMC&EL 4-PIECE 45° VERT. BEND (CLASS 150) (WELDxWELD)
- (E) FURNISH AND INSTALL 60" SLIP ON FLANGE (WELD)
- (F1) FURNISH AND INSTALL 60"x36" CMC&EL STEEL TEE
- (H1) FURNISH AND INSTALL 36" CMC&EL 4-PIECE 45° VERT. BEND (CLASS 150) (WELDxWELD)
- (I1) FURNISH AND INSTALL 36" SLIP ON FLANGE (WELD)
- (J) FURNISH AND INSTALL PRESSURE GAUGE AND PRESSURE TRANSMITTER PER DETAIL X, SHEET X-X
- (K) FURNISH AND INSTALL 48" FLANGED BALL VALVE (CLASS 150) WITH MOTOR OPERATED ACTUATOR AND HANDWHEEL
- (L) FURNISH AND INSTALL 36" FLANGED BALL VALVE (CLASS 150) WITH MOTOR OPERATED ACTUATOR AND HANDWHEEL
- (M1) FURNISH AND INSTALL 60"x48" ECCENTRIC REDUCER (FOT)
- (N) FURNISH AND INSTALL 48" CMC&EL SPOOL. LENGTH AS REQUIRED (CLASS 150) (FExFE)
- (O) FURNISH AND INSTALL 36" CMC&EL SPOOL. LENGTH AS REQUIRED (CLASS 150) (FExFE)
- (P) FURNISH AND INSTALL 48" MAGNETIC FLOW METER (CLASS 150), MAX FLOW RATE = 70,000 GPM, WITH STAINLESS STEEL GROUNDING RINGS PER SPECIFICATION
- (Q) FURNISH AND INSTALL 36" MAGNETIC FLOW METER (CLASS 150), MAX FLOW RATE = 70,000 GPM, WITH STAINLESS STEEL GROUNDING RINGS PER SPECIFICATION
- (R) FURNISH AND INSTALL 48" CMC&EL SPOOL. LENGTH AS REQUIRED (CLASS 150) (FExPE)
- (S) FURNISH AND INSTALL 36" CMC&EL SPOOL. LENGTH AS REQUIRED (CLASS 150) (FExPE)
- (T) FURNISH AND INSTALL 8" COMBINATION AIR AND VACUUM RELEASE VALVE ASSEMBLY PER DETAIL X ON SHEET X (FExFE)
- (U) FURNISH AND INSTALL PRESSURE GAUGE SIMILAR TO DETAIL X ON SHEET X WITHOUT PRESSURE TRANSMITTER. CAP AT TEE
- (V) CONSTRUCT AIR-GAP STRUCTURE PER STRUCTURAL SHEETS
- (W) CONSTRUCT DISSIPATER STRUCTURE PER DETAIL X ON SHEET X
- (X) FURNISH AND INSTALL ULTRASONIC LEVEL SENSOR PER DETAIL X ON SHEET X

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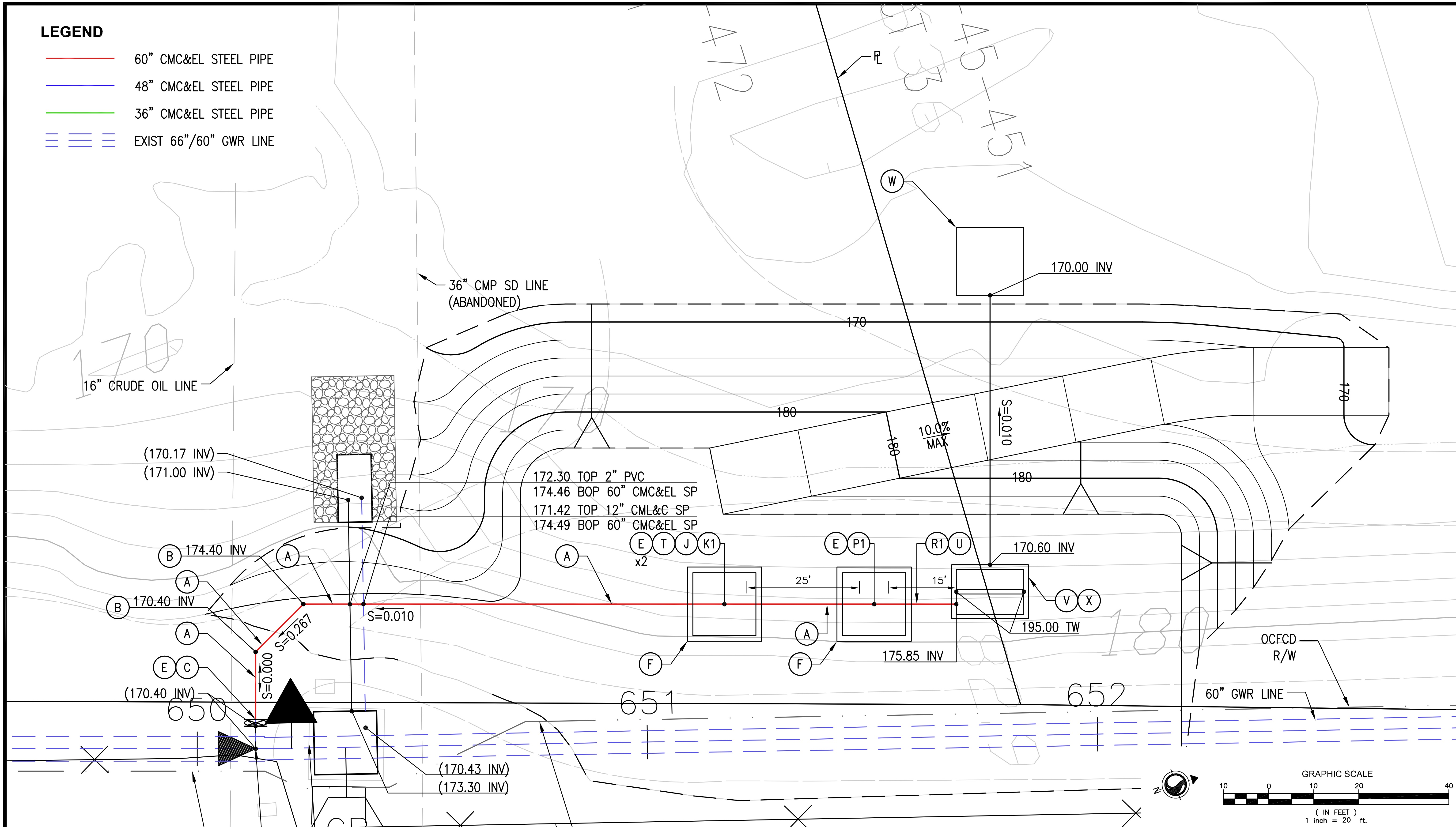


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**BURRIS BASIN**
**GROUNDWATER REPLENISHMENT SYSTEM**
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**ALTERNATIVE 2**

DATE: 7/1/2019

SHEET 1 OF 2

JOB NO. 2042499004

- (A) — FURNISH AND INSTALL 60" CMC&EL STEEL PIPE (WELDxWELD)
- (B) — FURNISH AND INSTALL 60" CMC&EL 4–PIECE 47.42° BEND, ROTATED VERTICALLY 18.35° (CLASS 150) (WELDxWELD)
- (C) — FURNISH AND INSTALL 60" BUTTERFLY VALVE (FExFE)
- (E) — FURNISH AND INSTALL 60" SLIP ON FLANGE (WELD)
- (F) — CONSTRUCT 14'x14' UNDERGROUND VAULT FOR 60" GWRS APPURTENANCE
- (J) — FURNISH AND INSTALL PRESSURE GAUGE AND PRESSURE TRANSMITTER PER DETAIL X, SHEET X–X
- (K1) — FURNISH AND INSTALL 60" FLANGED BALL VALVE (CLASS 150) WITH MOTOR OPERATED ACTUATOR AND HANDWHEEL
- (P1) — FURNISH AND INSTALL 60" MAGNETIC FLOW METER (CLASS 150), MAX FLOW RATE = 70,000 GPM, WITH STAINLESS STEEL GROUNDING RINGS PER SPECIFICATION
- (R1) — FURNISH AND INSTALL 60" CMC&EL SPOOL. LENGTH AS REQUIRED (CLASS 150) (FExPE)
- (T) — FURNISH AND INSTALL 8" COMBINATION AIR AND VACUUM RELEASE VALVE ASSEMBLY PER DETAIL X ON SHEET X (FExFE)
- (U) — FURNISH AND INSTALL PRESSURE GAUGE SIMILAR TO DETAIL X ON SHEET X WITHOUT PRESSURE TRANSMITTER. CAP AT TEE
- (V) — CONSTRUCT AIR–GAP STRUCTURE PER STRUCTURAL SHEETS
- (W) — CONSTRUCT DISSIPATER STRUCTURE PER DETAIL X ON SHEET X
- (X) — FURNISH AND INSTALL ULTRASONIC LEVEL SENSOR PER DETAIL X ON SHEET X

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# Appendix E

## E.1 CATALOGUE CUT SHEETS