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April 13, 2018

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

Initial Structural Stability Assessment
Sluice Trench and Area East of Sluice Trench
EPA Final CCR Rule
TVA Kingston Fossil Plant
Kingston, Tennessee

1.0 PURPOSE

This letter documents AECOM's certification of the initial structural stability assessment for the TVA Kingston Fossil Plant's Sluice Trench and Area East of the Sluice Trench. Based on this assessment, the Sluice Trench and Area East of the Sluice Trench is in compliance with the structural stability requirements in the Final CCR Rule at 40 CFR 257.73(d).

2.0 INITIAL STRUCTURAL STABILITY ASSESSMENT

As described in 40 CFR 257.73(d), documentation is required on how the Sluice Trench and Area East of the Sluice Trench has been designed, constructed, operated, and maintained according to the structural stability requirements listed in the section. The majority of the Sluice Trench and Area East of the Sluice Trench was closed in 2016 as part of an adjacent area closure and KIF Flow Management project construction. Currently, a Non-CCR Process Water Basin designed to treat non-CCR related plant wastewater has been constructed over the majority of the historic Sluice Trench location. In addition, hydraulic structure Junction Chamber 01 was constructed within the center of the southeastern portion of the historical Sluice Trench alignment for the purpose of directing outflow from the Non-CCR Process Water Basin to the new outlet structure along Dike C. This assessment considered the current conditions and construction within the limits of the historical Sluice Trench and Area East of the Sluice Trench.

3.0 SUMMARY OF FINDINGS

The attached report presents the initial structural stability assessment of the Sluice Trench and Area East of the Sluice Trench. The results show that the Sluice Trench and Area East of the Sluice Trench meets the structural stability requirements set forth in 40 CFR 257.73(d)(1)-(2).

4.0 LIMITATIONS

The signature of AECOM's authorized representative on this document represents that to the best of AECOM's knowledge, information and belief in the exercise of its professional judgment, it is AECOM's professional opinion that the aforementioned information is accurate as of the date of such signature. Any recommendation, opinion, or decisions by AECOM are made on the basis of AECOM's experience, qualifications and professional judgment and are not to be construed as warranties or guaranties. In addition, opinions relating to environmental, geologic, and geotechnical conditions or other estimates are based on available data and actual conditions may vary from those encountered at the times and locations where data are obtained, despite the use of due care.

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5.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Thomas A. Kovacic PE, being a Professional Engineer in good standing in the State of Tennessee, do hereby certify, to the best of my knowledge, information, and belief:

1. that the information contained in this certification is prepared in accordance with the accepted practice of engineering;

2. that the information contained herein is accurate as of the date of my signature below; and

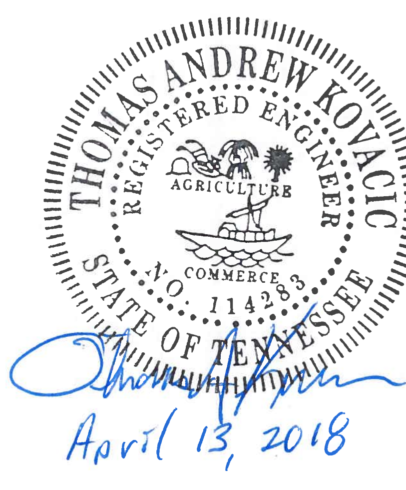
3. that the initial structural stability assessment for the TVA Kingston Fossil Plant's Sluice Trench meets the requirements specified in 40 CFR 257.73(d)(1)-(2).

SIGNATURE ______________________ DATE 4/13/18

ADDRESS: AECOM
1300 E. 9th Street, Suite 500
Cleveland, OH 44114

TELEPHONE: (216) 622-2300

ATTACHMENTS: Initial Structural Stability Assessment 40 CFR 257.73(d)(1); Existing CCR Surface Impoundments; TVA Kingston Fossil Plant; Sluice Trench and Area East of the Sluice Trench



COAL COMBUSTION PRODUCT DISPOSAL PROGRAM

Tennessee Valley Authority – Sluice Trench and Area East of the Sluice Trench
Roane County, Tennessee

Initial Structural Stability Assessment
40 CFR 257.73(d)(1)
Existing CCR Surface Impoundments
TVA Kingston Fossil Plant

Prepared for

Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402-2801

April 13, 2018

Prepared by

AECOM

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Appendices

1.0 Project Background

On April 17, 2015 the "Disposal of Coal Combustion Residuals (CCR) from Electric Utilities" (CCR Rule) was published in the Federal Register. AECOM has been contracted by TVA to analyze the Structural Stability of the Kingston Fossil (KIF) Plant's CCR surface impoundments and evaluate compliance with §257.73 of the CCR Rule.

As required by §257.73 of the EPA Final CCR Rule, an initial structural integrity evaluation is required and must include an initial structural stability assessment for each existing CCR surface impoundment that meets the conditions of paragraph (b) as follows:

1. Has a height of five feet or more and a storage volume of 20 acre-feet or more or
2. Has a height of 20 feet or more.

The historical Sluice Trench that flowed to the Stilling Pond and the Area East of the Sluice Trench, although no longer active, were identified initially as units that would require consideration under the CCR Rule based on the first condition above. The majority of the sluice ditch was closed in 2016 as part of an adjacent area closure and KIF Flow Management project construction. Currently, a Non-CCR Process Water Basin designed to treat non-CCR related plant wastewater has been constructed over the majority of the historic Sluice Trench location. In addition, hydraulic structure Junction Chamber 01 was constructed within the center of the southeastern portion of the historical Sluice Trench alignment for the purpose of directing otuflow from the Non-CCR Process Water Basin to the new outlet structure along Dike C. The Area East of the Sluice Trench will be closed in place. Therefore, this assessment will consider the current conditions and construction within the limits of the historical Sluice Trench and the Area East of the Sluice Trench at the project site. A plan view showing the historical location of the Sluice Trench is shown below in **Figure 1**. A view of the current site conditions is provided in **Figure 2.**

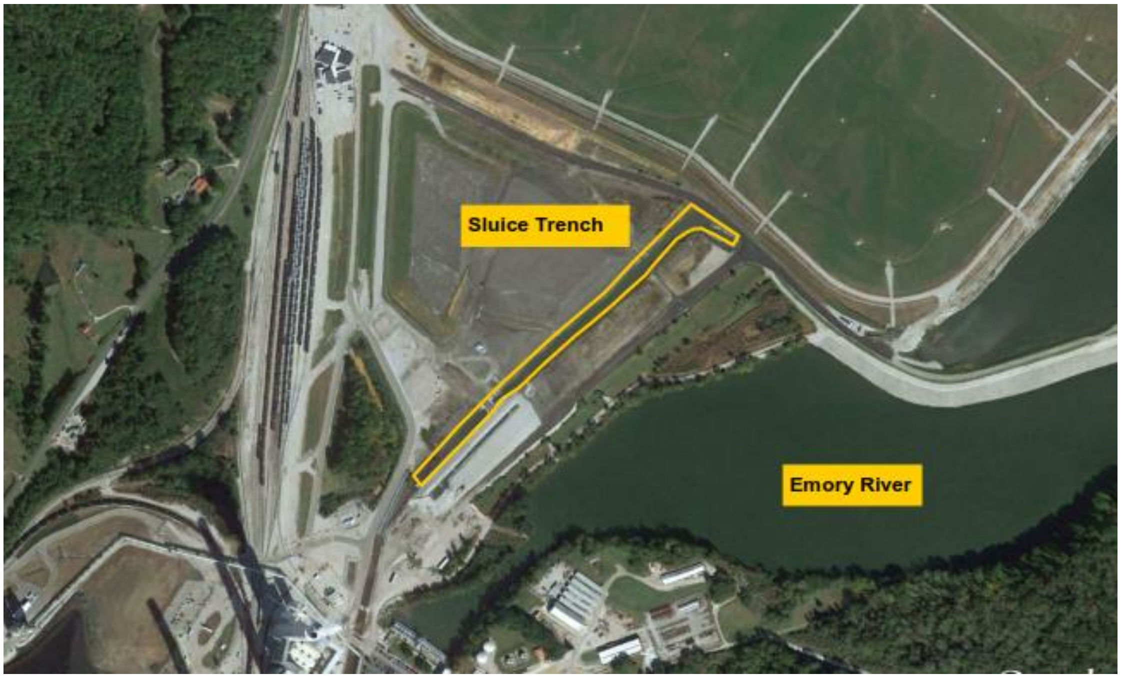

Figure 1: Sluice Trench

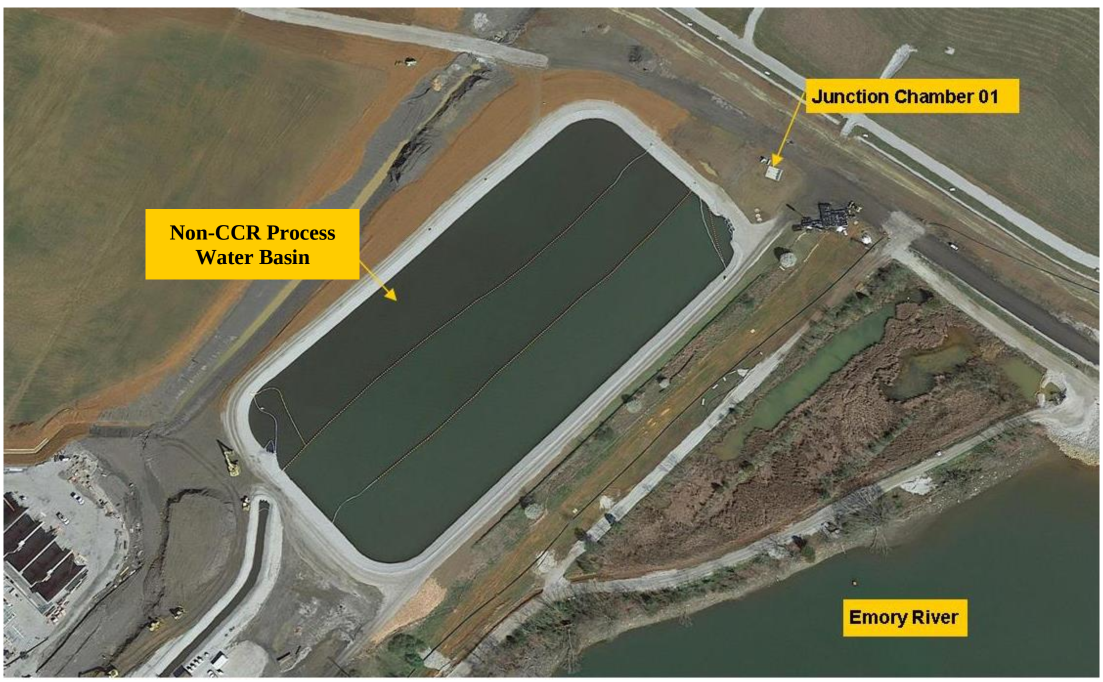

Figure 2: Current Site Conditions

2.0 Structural Stability Assessment - §257.73(d)(1)

40 CFR 257.73(d)(1). *Periodic structural stability assessments. (1) The owner or operator of the CCR unit must conduct initial and periodic structural stability assessments and document whether the design, construction, operation, and maintenance of the CCR unit is consistent with recognized and generally accepted good engineering practices for the maximum volume of CCR and CCR wastewater which can be impounded therein. The assessment must, at a minimum, document whether the CCR unit has been designed, constructed, operated, and maintained with:*

(i) Stable foundations and abutments;

(ii) Adequate slope protection to protect against surface erosion, wave action, and adverse effects of sudden drawdown;

(iii) Dikes mechanically compacted to a density sufficient to withstand the range of loading conditions in the CCR unit;

(iv) Vegetated slopes of dikes and surrounding areas, except for slopes which have an alternate form or forms of slope protection;

(v) A single spillway or a combination of spillways configured as specified in paragraph (d)(1)(v)(A) of this section. The combined capacity of all spillways must be designed, constructed, operated, and maintained to adequately manage flow during and following the peak discharge from the event specified in paragraph (d)(1)(v)(B) of this section.

(vi) Hydraulic structures underlying the base of the CCR unit or passing through the dike of the CCR unit that maintain structural integrity and are free of significant deterioration, deformation, distortion, bedding deficiencies, sedimentation, and debris which may negatively affect the operation of the hydraulic structure; and

(vii) For CCR units with downstream slopes which can be inundated by the pool of an adjacent water body, such as a river, stream or lake, downstream slopes that maintain structural stability during low pool of the adjacent water body or sudden drawdown of the adjacent water body.

2.1 Foundations and Abutments - §257.73(d)(1)(i)

The KIF Plant is located along the banks of Emory and Clinch River junction in Roane County, TN. The geologic map for the area indicates that the plant is underlain by Lower Ordovician and Cambrian age limestone and shale bedrock formations. Previous drilling programs at the plant have encountered alluvial deposits consisting of fine sands, silty sands, and sandy silts. These alluvial deposits are commonly found adjacent to rivers. The majority of the plant is underlain by the Conassauga Shale Formation which consists of an argillaceous to silty shale with zones of shaley limestone scattered throughout.

The Sluice Trench is now closed, but the Non-CCR Process Water Basin, and Junction Chamber 01 were constructed within the limits of the historical Sluice Trench alignment. Therefore, the foundations of these structures are assessed for stability.

The foundation of the Non-CCR Process Water Basin within the limits of the former Sluice Trench consists of the following:

- 6-inch protective layer of TDOT No. 2 gravel;
- 12-inch TDOT No. 57 aggregate;
- Non-woven geotextile cushion;
- Geomembrane liner;
- Two layers of geosynthetic clay liner;
- Minimum 24-inch thick layer of compacted clay liner; and
- Re-worked ash subgrade.

Specifically, construction documentation shows that the Non-CCR Process Water Basin subgrade within the limits of the Sluice Trench was stabilized and repaired utilizing rock fill. The foundation of the Non-CCR Process Water Basin within the limits of the historical Sluice Trench is provided in the KIF Drainage and Flow Management (Downstream) Constructions Plans issued June 1, 2016, see reference [2].

Junction Chamber 01, located within the southeastern limits of the former Sluice Trench, is constructed of concrete and founded on nine driven steel H-piles. The piles (HP10x42) were driven to bedrock, and the top of the piles are embedded 12 inches into the structures' base. The design calculations for the Junction Chamber 01 foundation piles can be reviewed in the engineering report for the drainage and flow management project, see reference [1]. The report shows that the deep pile foundations are adequate to resist the combined weight of the junction chamber and the process flows.

Based on existing analytical data and results, the existing foundations are performing acceptably in comparison to current criteria. Further, no physical or visual evidence of heave or uplift has been observed.

2.2 Slope Protection - §257.73(d)(ii)

The Non-CCR Process Water Basin within the limits of the historical Sluice Trench is incised, with rock fill constructed on in-board slopes. The East Dike, located approximately 350 feet southeast along the Clinch River, retains the overall Non-CCR Process Water Basin area. Along the southwestern portions of the Non-CCR Process Water Basin the East Dike exterior slope features a rock buttress with reverse graded filter. Further to the northeast along the East Dike, an engineered wetland is present downstream of the Non-CCR Process Water Basin and historical Sluice Trench and Area East of the Sluice Trench Limits.

2.3 Embankment Dike Compaction - §257.73(d)(1)(iii)

Compaction data associated with the construction of the East Dike is not currently available. Geotechnical engineering reports performed by Geosyntec and AECOM were reviewed to assess the embankment soils (see reference 5 and 6). Based on the results of borings advanced through the East Dike, the embankment consists of sandy silt (ML) with shale fragments varying from 10 to 30 feet in thickness. An average Standard Penetration Test (Nvalue) of 12 was obtained over all the boring data obtained within the embankment, which is generally consistent with well compacted fill.

2.4 Vegetated Slopes - §257.73(d)(1)(iv)

The East Dike slopes along the perimeter of the Non-CCR Process Water Basin and Junction Chamber 01 have been maintained with either dense grass or riprap; no trees or large, bushy vegetation are currently present on the slopes.

2.5 Spillway Capacity - §257.73(d)(1)(v)

The Non-CCR Process Water Basin and Junction Chamber 01 are not CCR units so the CCR Rule requirements for spillway capacity are not applicable.

2.6 Hydraulic Structures - §257.73(d)(1)(vi)

Currently, process streams flow into a water quality channel. The water is then conveyed through a geomembrane-lined inflow channel and three 36" HDPE pipes into the Non-CCR Process Water Basin. The process flows then discharge through a box spillway to three 36" HDPE pipes into Junction Chamber 01. The flow from the Junction Chamber 01 discharges to three 48" HDPE outlet pipes and is conveyed to Outfall 001.

2.6.1 Pipes

The existing pipes through the perimeter road around the Non-CCR Process Water Basin and from the Non-CCR Process Water Basin to Junction Chamber 01 are 36-inch IPS SDR-26 HDPE pipes. The outlet pipes from Junction Chamber 01 are 48-inch HDPE pipes.

Visual inspections of the perimeter road where pipes pass through do not show any signs of deformation. The pipes have been evaluated for buckling stability for two different limit states: usual loading conditions associated with regularly occurring pool levels and unusual loading conditions associated with the design flood event. All associated calculations, including the structure's geometry and material properties are included in **Appendix A**. The pipes satisfy the stability checks for the limit states considered.

2.6.2 Junction Chamber 01

All associated calculations, including structure geometry and material properties are included in reference [1]. Junction Chamber 01 satisfies all strength and stability checks for the limit states considered.

2.7 Sudden Drawdown - §257.73(d)(1)(vii)

The Non-CCR Process Water Basin will not experience the sudden drawdown condition because the 100-yr. floodplain of the Emory River does not inundate the perimeter road.

3.0 Conclusion

Based on the results of the initial structural stability assessment, the current conditions of construction within the limits of the historical Sluice Trench and Area East of the Sluice Trench units meet the requirements of the CCR Rule as discussed in **Section 2.0**.

4.0 References

[1] AECOM, "Polishing Pond Engineering Report, Drainage and Flow Management Project," April 2016.

[2] AECOM, "Kingston Fossil Plant Drainage and Flow Management Construction Drawings," June 2016.

[3] Stantec and AECOM, "Annual Instrumentation and Monitoring Program Final Report (Rev. 2); Fiscal Year 2015; Tennessee Valley Authority Instrumentation Monitoring Program; Coal Combustion Product (CCP) Storage Facilities; Various Plants Alabama, Kentucky, and Tennessee.," February 2016.

[4] Tennessee Valley Authority, "2017 Annual (Intermediate) Inspection of CCR facilites at Kingston Fossil (KIF) Plant," May 2017.

[5] Geosyntec, "East Dike Stability Analysis," June 2010.

[6] AECOM, "Geotechnical Exploration and Analysis Report, Interim Ash Staging Area Closure and Drainage and Flow Management Project," March 2016.

APPENDIX A

HYDRAULIC STRUCTURES ASSESSMENT CALCULATION PACKAGE

Initial Structural Stability Assessment for Structures in Sluice Trench at TVA Kingston Fossil Plant

Prepared for

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402-2801

Prepared by

AECOM

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Discussion

The following calculations detail the structural stability assessment for the existing pipe structures in the conveyance network at Tennessee Valley Authority (TVA) Kingston Fossil (KIF) Plant. The Sluice Trench is no longer active, but the Polishing Pond and Junction Chamber 01 were constructed within it's footprint. The process streams will flow from the water quality channel through a geomembrane-lined inflow channel to the Polishing Pond and is conveyed through a network of pipes to the existing outfall. The flow goes through the inflow channel into a set of three 36" HDPE pipes before it is discharged into the Polishing Pond. Then it is conveyed through three 36" HDPE pipes to Junction Chamber 01. The outlet pipes from Junction Chamber 01 consists of three 48" HDPE pipes. The flow is then conveyed through a network of pipes and junction chambers to the existing Outfall 001.

The calculations were completed in accordance with United States Environmental Protection Agency's (EPA) requirements under the Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals (CCR) from Electric Utilities [RIN-250-AE81; FRL-9149-4] (EPA Final CCR Rule) section 257.73(d).

References

1.) TVA-CCR Rule Template 257.73 (d).
2.) AECOM Kingston Fossil Plant Drainage and Flow Management Construction Drawings dated June 2016.
3.) AWWA M55 - PE Pipe Design and Installation, January 1, 2006.

Material Properties and Geometry

The material properties and geometry defined below are determined using TVA CCR rule template 257.73(d), existing project drawings, geotechnical data report, historical data, and engineering judgement.

<u>Soil properties</u>

Unit weight of water	$\gamma_w := 62.4\text{pcf}$
Unit weight of foundation soil	$\gamma_s := 117\text{pcf}$
Friction angle of foundation soil	$\phi_s := 32°$
Cohesion of foundation soil	$c_s := 0\text{psf}$

36-inch HDPE

Pipe buckling was analyzed as part of the CCR Rule demonstration. Buckling is caused by excessive vertical loading applied to the pipe through cover and surcharge loads. The buckling analysis was performed for the existing 36-inch outer diameter HDPE pipe. The pipes have a cover height of 2 ft minimum near inlet of Polishing Pond. Normal pool is considered to be with pipes running full and flood pools is considered with water at top of ground. Reference: AWWA M55 - PE Pipe - Design and Installation for the HDPE pipes.

Apparent modulus of elasticity	$E_{pipe} := 28250psi$ (AWWA M55, Table 5-6, long term)
HDPE outside diameter	$OD := 36in$
HDPE wall thickness	$t_{pipe} := 1.39in$
HDPE inside diameter	$ID := OD - 2 \cdot t_{pipe} = 33.22 \cdot in$
Dimension ratio	$DR := \frac{OD}{t_{pipe}} = 26$
Ground elevation	$EL_{ground} := 772ft$
Pipe invert elevation	$EL_{in} := 767ft$
Normal pool elevation	$EL_{np} := EL_{in} + ID = 769.768\,ft$ (Assumes normal pool at full pipe)
Flood pool elevation	$EL_{fp} := EL_{ground} = 772\,ft$ (Assumes flood pool at ground elevation)
Height of maximum soil cover	$H_{cover} := EL_{ground} - (EL_{in} + OD - t_{pipe}) = 2.12\,ft$
Height of soil above normal pool	$H_{soil\_np} := \min(H_{cover}, EL_{ground} - EL_{np}) = 2.12\,ft$
Height of soil submerged, normal pool	$H_{submerged\_np} := H_{cover} - H_{soil\_np} = 0\,ft$
Height of soil above flood pool	$H_{soil\_fp} := \min(H_{cover}, EL_{ground} - EL_{fp}) = 0\,ft$
Height of soil submerged, flood pool	$H_{submerged\_fp} := H_{cover} - H_{soil\_fp} = 2.12\,ft$
Modulus of soil reaction	$E' := 1000psi$ (Coarse-grained soils w/ little or no fines, 0-5 ft cover, relative compaction 90%, AWWA Table 5-8)
Safety factor for design	$FS_{PE} := 2$

Allowable Buckling - normal pool

Buoyancy factor $R_{b\_np} := 1 - 0.33 \cdot \frac{H_{submerged\_np}}{H_{cover}} = 1$

Soil elastic support factor $B' := \frac{1}{1 + 4 \cdot e^{\frac{-0.065}{ft} \cdot H_{cover}}} = 0.223$

Allowable external pressure for constrained pipe - buckling

$$P_{CA\_np} := \frac{5.65}{FS_{PE}} \cdot \sqrt{R_{b\_np} \cdot B' \cdot E' \cdot \frac{E_{pipe}}{12 \cdot (DR - 1)^3}} = 16.471\,psi$$

Allowable Buckling - flood pool

Buoyancy factor $R_{b\_fp} := 1 - 0.33 \cdot \frac{H_{submerged\_fp}}{H_{cover}} = 0.67$

Allowable external pressure for constrained pipe - buckling

$$P_{CA\_fp} := \frac{5.65}{FS_{PE}} \cdot \sqrt{R_{b\_fp} \cdot B' \cdot E' \cdot \frac{E_{pipe}}{12 \cdot (DR - 1)^3}} = 13.482\,psi$$

Calculate Applied Loads

Dead load - usual condition

$$DL_u := \left[\gamma_s \cdot H_{soil\_np} + (\gamma_s - \gamma_w) \cdot H_{submerged\_np}\right] \cdot R_{b\_np} + \gamma_w \cdot H_{submerged\_np} = 1.719\,psi$$

Dead load - unusual condition

$$DL_{un} := \left[\gamma_s \cdot H_{soil\_fp} + (\gamma_s - \gamma_w) \cdot H_{submerged\_fp}\right] \cdot R_{b\_fp} + \gamma_w \cdot H_{submerged\_fp} = 1.454\,psi$$

Live load for AASHTO H20 loading under unpaved roads (AWWA M55, Table 5-3)

$$cover := \begin{pmatrix} 1.5 \\ 2.0 \\ 2.5 \\ 3.0 \\ 3.5 \\ 4.0 \\ 6.0 \\ 8.0 \\ 10.0 \end{pmatrix} \cdot ft \qquad live_{load} := \begin{pmatrix} 13.9 \\ 9.5 \\ 7.0 \\ 5.4 \\ 4.3 \\ 3.6 \\ 2.0 \\ 1.3 \\ 0.8 \end{pmatrix} \cdot psi$$

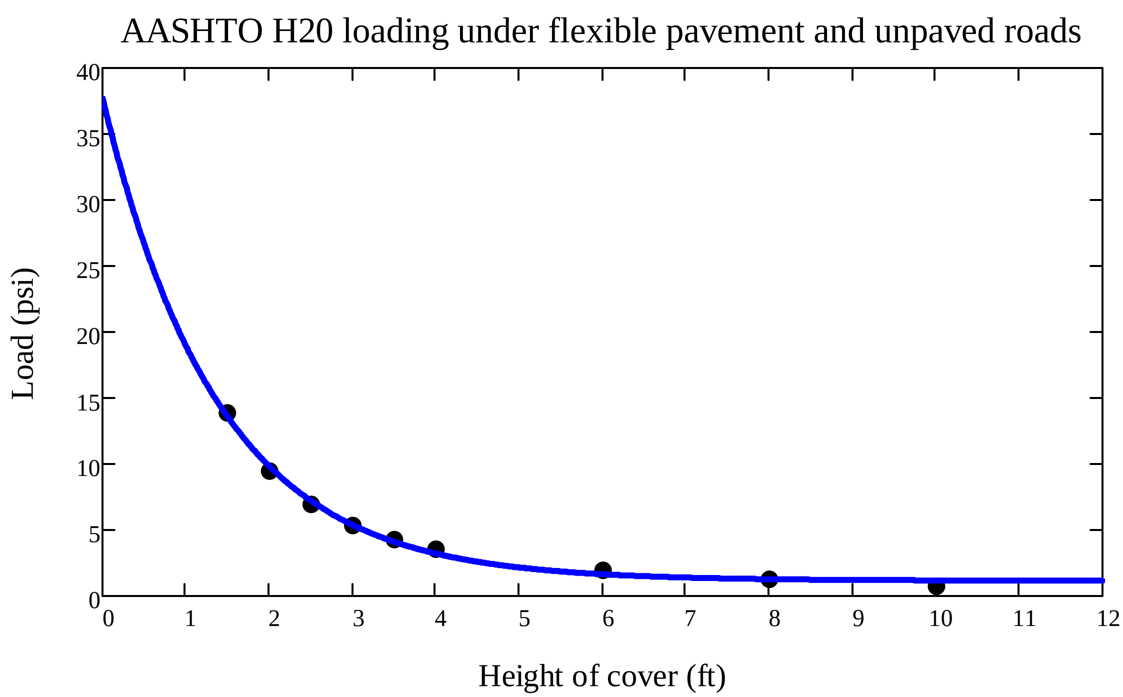
Exponential curve fit

$$efit := expfit\left(\frac{cover}{ft}, \frac{live_{load}}{psi}\right) = \begin{pmatrix} 36.548 \\ -0.72 \\ 1.203 \end{pmatrix}$$

$$aa := efit_0 = 36.548 \qquad bb := efit_1 = -0.720 \qquad cc := efit_2 = 1.203$$

$$f(x) := aa \cdot e^{bb \cdot x} + cc \rightarrow 36.548373145638216 \cdot e^{-0.71974758459671384 \cdot x} + 1.2033362039448283$$

Plot height of cover versus load for unpaved roads



Live load on pipe $LL := f\left(\frac{H_{cover}}{ft}\right) \cdot psi = 9.174\,psi$

Total load - usual condition $TL_u := DL_u + LL = 10.893\,psi$

Total load - unusual condition $TL_{un} := DL_{un} + LL = 10.628\,psi$

Check critical buckling pressure - usual loading condition

$$check_{Pcr\_u} := \begin{array}{|l} \text{"Satisfactory"} \ \text{ if } P_{CA\_np} \geq TL_u \\ \text{"No good"} \ \text{ otherwise} \end{array} = \text{"Satisfactory"}$$

Check critical buckling pressure - unusual loading condition

$$check_{Pcr\_un} := \begin{array}{|l} \text{"Satisfactory"} \ \text{ if } P_{CA\_fp} \geq TL_{un} \\ \text{"No good"} \ \text{ otherwise} \end{array} = \text{"Satisfactory"}$$

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48-inch HDPE

Pipe buckling was analyzed as part of the CCR Rule demonstration. Buckling is caused by excessive vertical loading applied to the pipe through cover and surcharge loads. The buckling analysis was performed for the existing 48-inch outer diameter HDPE pipe. The pipes have a cover height of 4 ft near Junction Chamber 01. Normal pool is considered to be with pipes running full and flood pools is considered with water at top of ground. Reference: AWWA M55 - PE Pipe - Design and Installation for the HDPE pipes.

Apparent modulus of elasticity $E_{pipe} := 28250psi$ (AWWA M55, Table 5-6, long term)

HDPE outside diameter $OD := 48in$

HDPE wall thickness $t_{pipe} := 3.556in$

HDPE inside diameter $ID := OD - 2 \cdot t_{pipe} = 40.888 \cdot in$

Dimension ratio $DR := \frac{OD}{t_{pipe}} = 13.498$

Ground elevation $EL_{ground} := 766ft$

Pipe invert elevation $EL_{in} := 758ft$

Normal pool elevation $EL_{np} := EL_{in} + ID = 761.407\,ft$

(Assumes normal pool at full pipe)

Flood pool elevation $EL_{fp} := EL_{ground} = 766\,ft$

(Assumes flood pool at ground elevation)

Height of maximum soil cover $H_{cover} := EL_{ground} - (EL_{in} + OD - t_{pipe}) = 4.3\,ft$

Height of soil above normal pool $H_{soil\_np} := \min(H_{cover}, EL_{ground} - EL_{np}) = 4.3\,ft$

Height of soil submerged, normal pool $H_{submerged\_np} := H_{cover} - H_{soil\_np} = 0\,ft$

Height of soil above flood pool $H_{soil\_fp} := \min(H_{cover}, EL_{ground} - EL_{fp}) = 0\,ft$

Height of soil submerged, flood pool $H_{submerged\_fp} := H_{cover} - H_{soil\_fp} = 4.3\,ft$

Modulus of soil reaction $E' := 1000psi$

(Coarse-grained soils w/ little or no fines, 0-5 ft cover, relative compaction 90%, AWWA Table 5-8)

Safety factor for design $FS_{PE} := 2$

Allowable Buckling - normal pool

Buoyancy factor

$$R_{b\_np} := 1 - 0.33 \cdot \frac{H_{submerged\_np}}{H_{cover}} = 1$$

Soil elastic support factor

$$B' := \frac{1}{1 + 4 \cdot e^{\frac{-0.065}{ft} \cdot H_{cover}}} = 0.248$$

Allowable external pressure for constrained pipe - buckling

$$P_{CA\_np} := \frac{5.65}{FS_{PE}} \cdot \sqrt{R_{b\_np} \cdot B' \cdot E' \cdot \frac{E_{pipe}}{12 \cdot (DR - 1)^3}} = 48.894\,psi$$

Allowable Buckling - flood pool

Buoyancy factor

$$R_{b\_fp} := 1 - 0.33 \cdot \frac{H_{submerged\_fp}}{H_{cover}} = 0.67$$

Allowable external pressure for constrained pipe - buckling

$$P_{CA\_fp} := \frac{5.65}{FS_{PE}} \cdot \sqrt{R_{b\_fp} \cdot B' \cdot E' \cdot \frac{E_{pipe}}{12 \cdot (DR - 1)^3}} = 40.022\,psi$$

Calculate Applied Loads

Dead load - usual condition

$$DL_u := \left[\gamma_s \cdot H_{soil\_np} + (\gamma_s - \gamma_w) \cdot H_{submerged\_np}\right] \cdot R_{b\_np} + \gamma_w \cdot H_{submerged\_np} = 3.491\,psi$$

Dead load - unusual condition

$$DL_{un} := \left[\gamma_s \cdot H_{soil\_fp} + (\gamma_s - \gamma_w) \cdot H_{submerged\_fp}\right] \cdot R_{b\_fp} + \gamma_w \cdot H_{submerged\_fp} = 2.953\,psi$$

Live load for AASHTO H20 loading under unpaved roads (AWWA M55, Table 5-3)

$$cover := \begin{pmatrix} 1.5 \\ 2.0 \\ 2.5 \\ 3.0 \\ 3.5 \\ 4.0 \\ 6.0 \\ 8.0 \\ 10.0 \end{pmatrix} ft \qquad live_{load} := \begin{pmatrix} 13.9 \\ 9.5 \\ 7.0 \\ 5.4 \\ 4.3 \\ 3.6 \\ 2.0 \\ 1.3 \\ 0.8 \end{pmatrix} psi$$

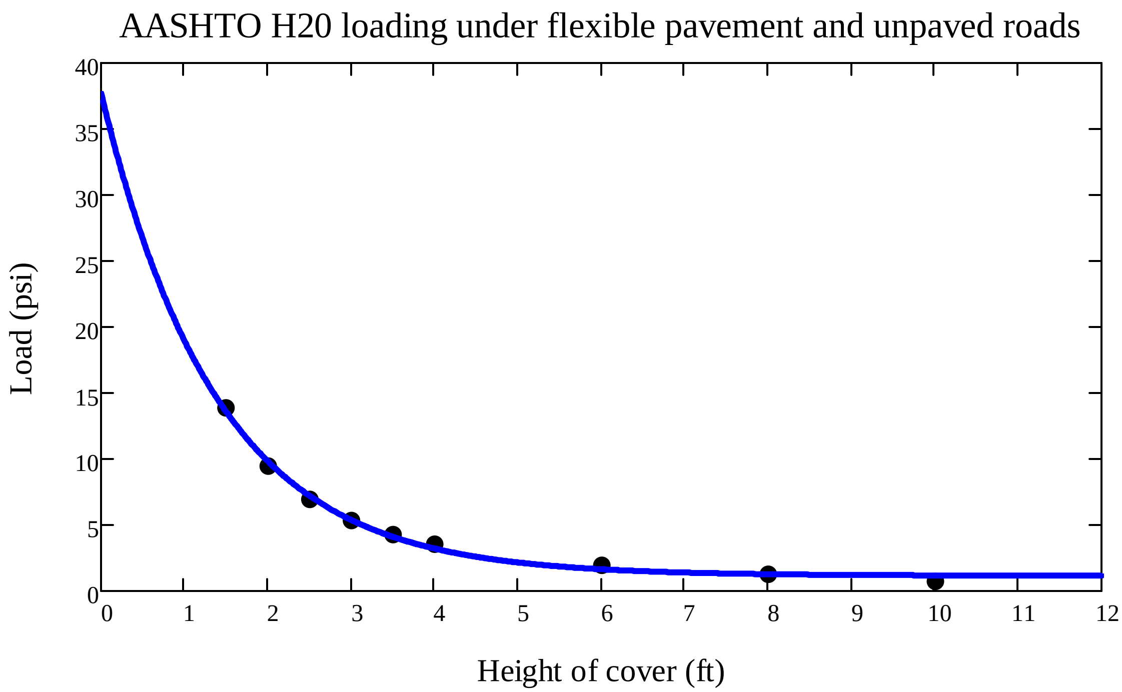
Exponential curve fit

$$efit := expfit\left(\frac{cover}{ft}, \frac{live_{load}}{psi}\right) = \begin{pmatrix} 36.548 \\ -0.72 \\ 1.203 \end{pmatrix}$$

$aa := efit_0 = 36.548$ $bb := efit_1 = -0.720$ $cc := efit_2 = 1.203$

$$f(x) := aa \cdot e^{bb \cdot x} + cc \rightarrow 36.548373145638216 \cdot e^{-0.71974758459671384 \cdot x} + 1.2033362039448283$$

Plot height of cover versus load for unpaved roads



Live load on pipe $LL := f\left(\frac{H_{cover}}{ft}\right)\cdot psi = 2.863\,psi$

Total load - usual condition $TL_u := DL_u + LL = 6.353\,psi$

Total load - unusual condition $TL_{un} := DL_{un} + LL = 5.816\,psi$

Check critical buckling pressure - usual loading condition

$$check_{Pcr\_u} := \begin{cases} \text{"Satisfactory"} & \text{if } P_{CA\_np} \geq TL_u \\ \text{"No good"} & \text{otherwise} \end{cases} = \text{"Satisfactory"}$$

Check critical buckling pressure - unusual loading condition

$$check_{Pcr\_un} := \begin{cases} \text{"Satisfactory"} & \text{if } P_{CA\_fp} \geq TL_{un} \\ \text{"No good"} & \text{otherwise} \end{cases} = \text{"Satisfactory"}$$

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