**Pipeline Structural Capacity Analysis for TX-113 at US-04538**

Ground displacements from slope failures can cause significant strains on buried pipelines and compromise pipeline integrity. A “soil springs” calculation was performed on the segment of pipeline within the <1.5 FOS failure surfaces determined from the stability analyses. The method employed in the soil spring forces calculation is based on several simplifications and conservative assumptions. However, it does not consider pipe bends, pipeline welds and other defects that may exist. Complex pipeline integrity problems may require use of finite element method and further guidance from geotechnical and pipeline integrity engineers.

The soil around the pipe is idealized as a series of uncoupled “springs”. Those forces are thought to be acting in different directions (lateral, vertical, and axial) and are considered to be independent. This implies that forces in each direction will be calculated differently. The material behavior of these elements can vary from linearly elastic to non-linear, hysteretic and rate dependent. For simplicity, we assume that these springs are linearly elastic and perfectly plastic. That means that as the displacement increases so does the force, until it reaches a maximum value and then it remains constant.

The length of pipe within the failure plane is important because force and displacement relationships are usually expressed in terms of force on a unit length of pipe. The length of pipe parallel to the slope that lies within the FOS failure surfaces less than 1.5 was estimated from the stability analysis plates presented in the Geosyntec Report dated January 31, 2025. Left and right banks have similar failure surfaces; thus only one representative analysis was run. Estimated length of pipe within the failure surface and pipeline depth of cover for the banks are provided in Table 1. Similar to the bending stress calculations for maximum allowable unsupported length of pipe, pipe properties such as wall thickness, specified minimum yield strength (SMYS) and internal pressure affect the outcome of the soil springs calculations in terms of remaining allowable stress.

**Table 1. Left and Right Bank Parameters**

|  |  |
| --- | --- |
| **Parameter** | **Left and Right Banks** |
| Pipe DOC (ft): | 15 |
| Length of Pipe in Permanent Ground Deformation (ft): | 50 |

The pipe–soil interaction forces are influenced by many factors, such as the physical properties of the soil and pipe, depth of cover, and pipeline orientation with respect to soil movement. Pipe properties are provided in Table 2. These factors affect the calculation of soil forces and conservative assumptions were made. The largest depth of cover within the slope failure and the undrained soil were used in the calculations to be conservative.

**Table 2. Pipe Properties**

|  |  |
| --- | --- |
| **Pipe Properties** | |
| Pipe OD (in): | 8.63 |
| Pipe Wall Thickness (in): | 0.322 |
| Pipe SMYS (psi): | Grade B |
| Pipe Coating | None/Rough Steel |
| Internal Pressure (psi): | 1440 |

The calculations for the banks are attached. Results indicate that the bending stress of the slope failure induced permanently displaced ground (PDG) on the pipeline is within allowable limits for the existing 8.6-inch diameter, grade B pipe. The results are summarized in Table 3.

**Table 3. Soil Springs Analysis Results**

|  |  |
| --- | --- |
| **Analysis Output Representative of Both Banks** | |
| Longitudinal Force (lb/ft) | 1,249 |
| Axial Stress (psi) | 3,578 |
| Remaining Allowable Stress (psi) | 9,257 |
| Allowable Pipe Length in PGD (ft): | 129 |
| Exceeds Allowable: | **Does Not Exceed** |