# Pipeline Freezing Analysis

## 1 Introduction

Coutts and Konrad (1994) presented the solution from a freezing analysis of a buried pipeline using the "node state" finite element method. This example compares TEMP/W to the published solution.

## 2 Feature Highlights

GeoStudio feature highlights include:

- Transient heat flow
- Circular regions
- Activation temperatures

## 3 Numerical Model

Figure 1 presents the geometry, mesh and boundary conditions for the buried pipeline model. The analysis takes advantage of symmetry and models only half of the problem. The pipeline was created by drawing a circular opening at the left edge of the domain. No material has been applied to this region. A constant temperature boundary condition of - 2 °C and + 3 °C has been applied to the pipeline and ground surface, respectively. The initial soil temperature is assumed to be + 3 °C and is established using the Activation Temperature of the material.

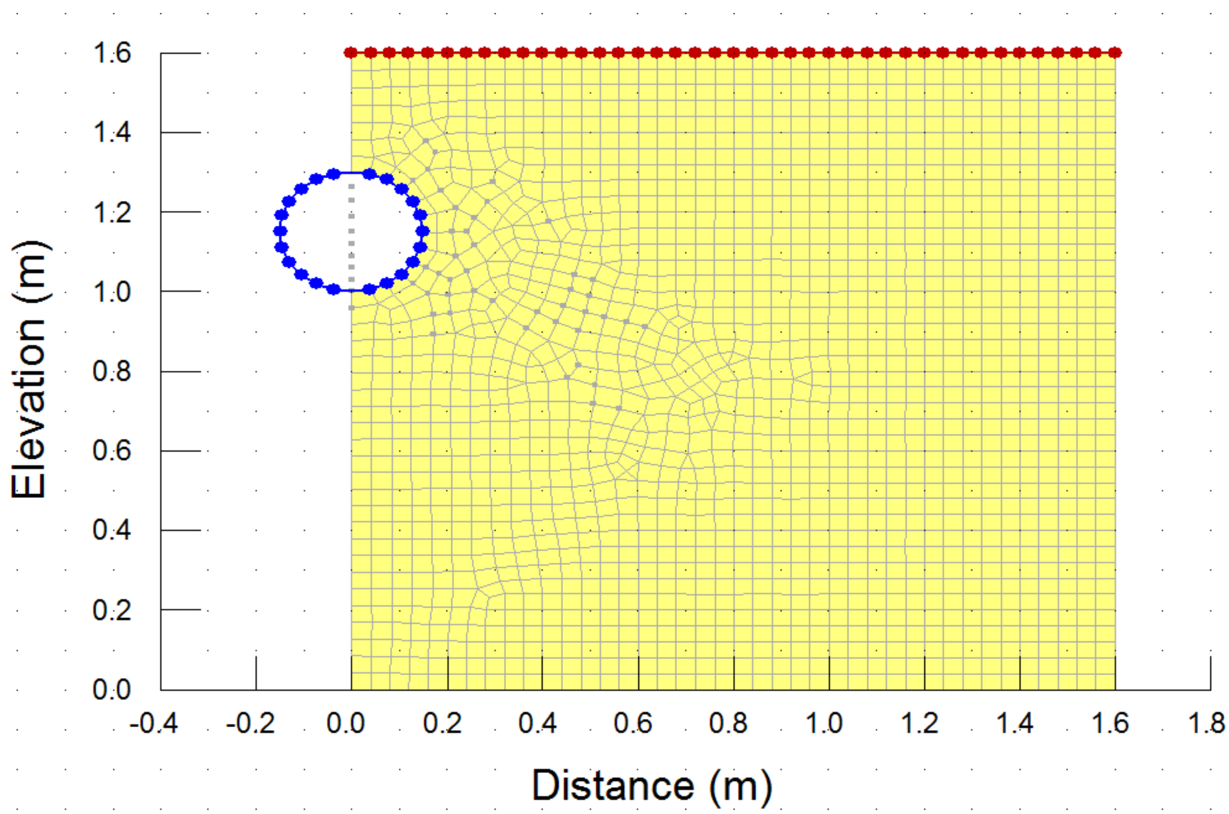

**Figure 1 - Model geometry, mesh, and boundary conditions**

The material properties used in the publication are shown in the table below. These properties are represented in TEMP/W using the simplified thermal model (Figure 2). The energy units of MJ are not supported in TEMP/W, so the generic unit "H" is designated.

**Table 3-1 Material properties used in pipeline freezing analysis**

| Material Property | Frozen | Unfrozen | Units |
|---|---|---|---|
| Thermal Conductivity | 0.15552 | 0.12960 | MJ/(day.m·°C) |
| Volumetric Heat Capacity | 1.95 | 1.95 | MJ/(m$^3$·°C) |
| Phase Change Temperature Range | 0.2 | – | °C |
| Phase Change Temperature | 0 | – | °C |
| Latent Heat | 334 | – | MJ/m$^3$ |
| Volumetric Water Content | 0.3772 | 0.3772 | – |

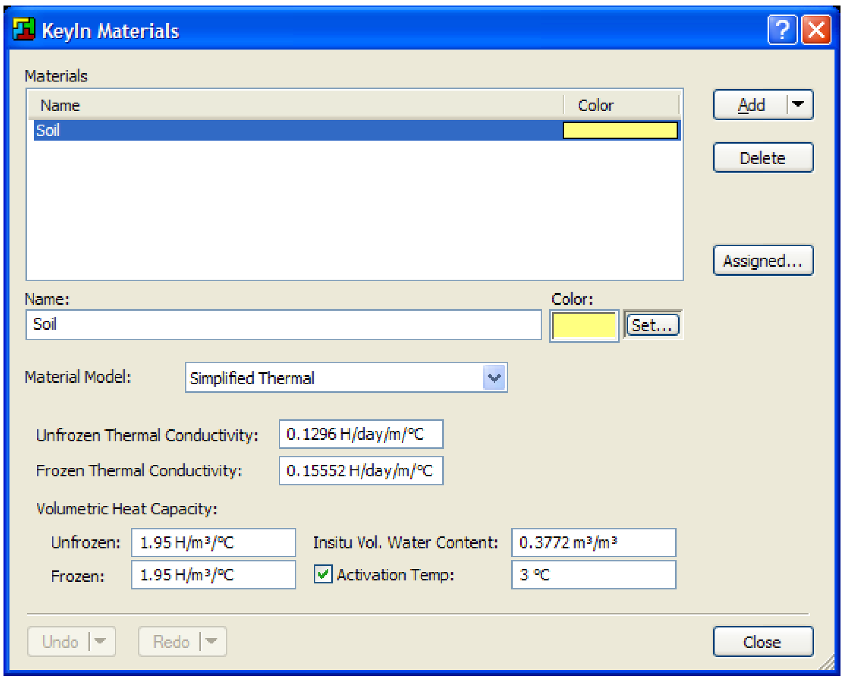


**Figure 2 - Material inputs for a simplified thermal material model**

The problem is simulated in TEMP/W for a duration of 730 days (2 years) using ten time steps and an exponential time series.

## 4 Results and Discussion

Table 4-1 compares the computed positions of the freezing front after 730 days for TEMP/W and the original publication. Figure 3 and Figure 4 are used to compare the temperature contours from the original publication to TEMP/W. TEMP/W compares very well to the publication for both freezing front propagation and the spatial distribution of temperatures.

**Table 4-1 Comparison of freezing front after 730 days**

| Position | Freezing Front from Pipe (m) | |
|---|---|---|
| | Coutts and Konrad | TEMP/W |
| Below pipe | 0.60 | 0.58 |
| Right side of pipe | 0.23 | 0.22 |

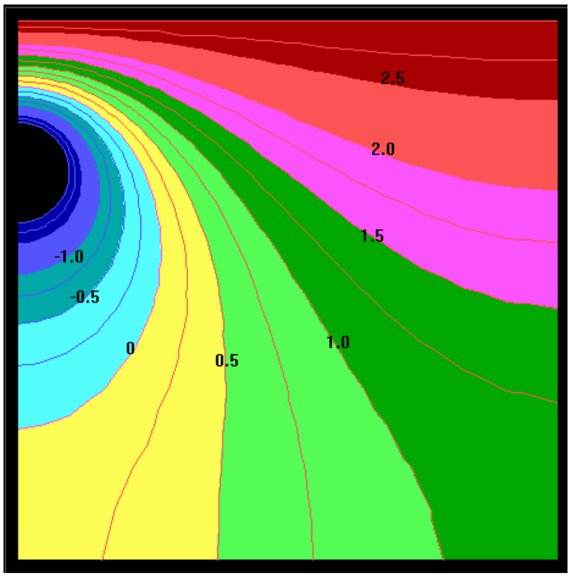


**Figure 3 - Temperature contours from Coutts and Konrad (1994)**

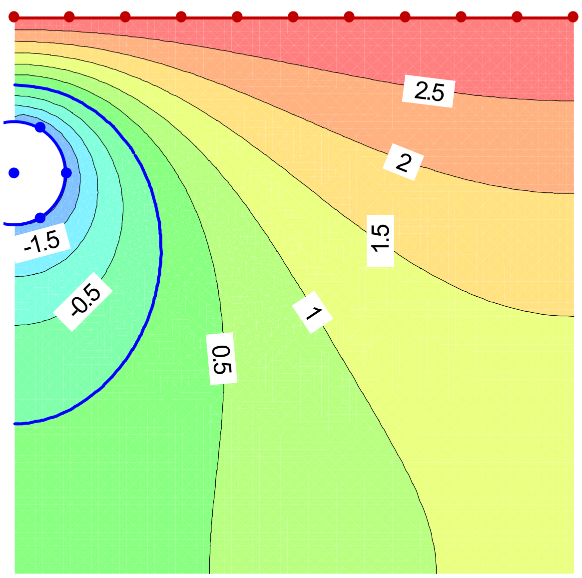


**Figure 4 - TEMP/W contours**

## 5 Summary and Conclusions

TEMP/W is used to model the freezing front propagation around a pipeline. The examples demonstrates the use of circular regions and the application of the appropriate boundary conditions and material properties.