Analysis of Risk Due to Trees Near Pipelines

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PG&E’s Pipeline Pathways

Commitment to enhance public safety, PG&E conducted a “Pipeline Pathways Program”

This program included:

- A comprehensive survey of transmission pipeline system
- Increased marking of the pipeline in the right-of-way (ROW)
- Identified structures and vegetation (e.g., trees) along the ROW
- Working cooperatively with property owners to remove or replace structures or vegetation that interfere with ability to maintain, inspect, or safely operate its natural gas transmission pipelines.

As part of the Program, conducted tree root studies to better understand the potential interaction between tree roots and transmission pipeline.
• **Vegetation Zone Design:** Allows landscape to have a balanced “feather cut” from the pipe zone out to the border zone.

• **Pipe Zone:** Does not allow trees or woody shrubs. Does allow lawns, flowers, low-profile grasses and low-growing herbaceous plants

• **Border Zone:** Does not allow trees or woody shrubs with
  - DBH > 8in or
  - Trunk/main branch within 5 to 10ft from outer edge of pipeline
Tree Root Studies

• Previous ROW standard was an effective reclamation approach for trees on ROW

• Additional considerations
  – Landscape esthetics, environmental concerns, site specific circumstances and/or protected species, among others

• Address these additional considerations while effectively managing operational risks including:
  – Integrity threats, such as external corrosion, weather related outside forces, excavation damage
  – Impacts to operations and maintenance of pipelines including:
    ▪ Ability to perform pipeline patrols
    ▪ Public awareness and damage prevention
    ▪ Effective emergency response (including accessibility)
### Relative Risk Assessment

#### Presence of Trees on ROW

<table>
<thead>
<tr>
<th>Threats</th>
<th>RISK PROFILE: ROW with Trees compared to Historically Cleared ROW</th>
<th>RISK PROFILE: ROW with Trees Removed compared to Trees Remaining on ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Corrosion</td>
<td>Higher</td>
<td>No Change/Lower</td>
</tr>
<tr>
<td>Environmentally Assisted Cracking</td>
<td>Higher</td>
<td>No Change/Lower</td>
</tr>
<tr>
<td>Weather – Lightning</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Weather – Wind/Flooding</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Outside Force – Seismic</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Manufacturing and Construction Related</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td><strong>Monitoring/Mitigation Methods</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage Prevention – Monitor ROW</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Damage Prevention - Publicly Recognized ROW</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Cathodic Protection (CP) Surveys</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td><strong>Ability for timely response</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency Response</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Integrity Assessment Response</td>
<td>Higher</td>
<td>Lower</td>
</tr>
</tbody>
</table>
Excavation was accomplished by destructive methods using a trackhoe excavator. The integrity of the root system could not be maintained as the excavation proceeded, therefore, this graphic is strictly the root inspector and graphic artist's best estimate of the actual root architecture that existed underground.
Field Case Study

- Lateral root turns downward
- Flow
- Roots flattened between pipe and hardpan
- Root penetrating coating
- Oblique root mass
Bio-mechanical Study on the Interaction of Roots with Gas Pipelines

- Mechanical fatigue damage (wind loading) to pipelines can be caused by the trees roots when in close proximity which is called the minimum root plate radius.

- The graph represents ranges within pipelines that can be damaged by roots based on a variety of different tree species and size.

- Figure from “Biomechanical Study on the Interactions of Roots with Gas and Water Pipelines for the Evaluation of Tree Sites”, Arboricultural Journal 2000, Vol. 23, pp. 343-377
Initial Risk Screening

- Tested against 53 tree root excavations (Dynamic Risk report)
- Leverages “Biomechanical Study…” in the Arboricultural Journal 2000 as the basis
- Results show a risk category differentiation at 17 in. DBH

Legend:
- L = Monitor
- M = Mitigate
- H = Eliminate
ROW Standard Changes

• Recognizes that Pipe-zone, Border-zone methods produce the lowest risk.

• Changes made to ROW standard to allow for additional considerations including landscape esthetics, environmental concerns, site specific circumstances and/or protected species, among others

• Revised standard addresses additional considerations while effectively managing operational risks including:
  – Integrity threats, such as external corrosion, weather related outside forces, excavation damage
  – Impacts to operations and maintenance of pipelines including:
    ▪ Ability to perform pipeline patrols
    ▪ Public awareness and damage prevention
    ▪ Effective emergency response (including accessibility)
Risk Analysis Approach When Needed

Step 1  
Initial Risk Screening

- "Eliminate" Threat
  - Leave trees identified as "Monitor" Threat
  - "Additional Analysis"

Step 2  
Site Specific Risk Assessment

- "Eliminate" Threat
- Leave trees identified as "Monitor" Threat
- Leave trees and implement P&M measures that are identified as "Mitigate" Threat

- Coating type
- Lightning exposure
- Wind and flood exposure
- Seismic exposure
- Soil instability
- Pipe diameter
- Date of construction
- Presence/visibility of line markers
- Emergency response and maintenance accessibility

Collect Data  Vegetation Standard Application  Identified considerations

- DBH - Tree diameter breast height
- DOC – Depth of cover
- P&M – Preventative and maintenance measures
- Turquoise boxes - Discussion will need to occur for approaching cities
**Step 1: Initial Screening**

- **Initial Screening** is performed using:
  - Tree species and associated DBH at maturity,
  - Horizontal distance of the tree from the pipeline centerline, and
  - Pipeline DOC.

**Monitor:** Tree may remain and continue to be monitored through the appropriate processes for pipeline patrol and emergency response unless the appropriate processes cannot be established, then the site must be elevated to eliminate.

**Additional Analysis:** A more detailed **Site Specific Risk Analysis** is necessary to determine how to manage the threat.

**Eliminate:** Company must make full efforts to remove the threat.
Step 2: Site Specific Risk Analysis

• A Site Specific Risk Analysis must be performed if the initial screening provides an Additional Analysis result.

• Site Specific Risk Analysis includes assessment of the following risks:
  – Coating type
  – Lightning exposure
  – Wind and flood exposure
  – Seismic exposure
  – Soil instability
  – Pipe diameter
  – Date of construction
  – Presence and visibility of line markers
  – Ability to enter site and accessibility to assess during emergency response
The site specific risk analysis is a relative risk model which incorporates the above threats and risk factors determined by subject matter expert input and results from the 53 tree root excavations.

The different risk factors sum together using a weighting average approach to determine the appropriate threat level by the following scores:

- Monitor ≤ 451
- 606 ≥ Mitigate > 451
- Eliminate > 606
Site Specific Risk Analysis results:

- **Monitor**: Tree may remain and continue to be monitored through the appropriate processes for pipeline patrol and emergency response unless the appropriate processes cannot be established, then the site must be elevated to eliminate.

- **Mitigate**: Preventative and maintenance (P&M) measures and/or additional monitoring, patrolling and emergency response guidance shall be considered.

- **Eliminate**: Company must make full efforts to negotiate with the owner to remove the tree or take alternative action to remove the threat.
## Examples of Additional P&M Measures

<table>
<thead>
<tr>
<th>Mitigation Category</th>
<th>Additional Mitigations to Consider</th>
</tr>
</thead>
</table>
| **Patrol**                  | Tree canopy trimming and/or thinning to allow for aerial patrol  
Switch from aerial patrol to foot patrol  
Infrared camera usage for heat signature detection                                                                                                                                                                                                                       |
| **Emergency Response**      | Develop alternative emergency response plans, such as additional education of fire fighters, identification of alternative access points, etc.                                                                                                                                                                                                                     |
| **Damage Prevention**       | Add additional line markers to improve line of sight and knowledge of pipeline centerline.                                                                                                                                                                                                                                                                          |
| **Leak Survey**             | Schedule more frequent leak surveys                                                                                                                                                                                                                                                                                                                                  |
| **Corrosion Control**       | Evaluate the need for and establish higher CP criteria, such as 950 mV to account for potential bacterial corrosion and a higher IR component.                                                                                                                                                                                                                       |
| **Integrity Management**    | **Risk Analysis**  
• Incorporate elevated risk from trees into risk algorithm at these sites.  
**When using ILI for assessment,**  
• Cross reference tree locations with ILI indications  
• Establish more stringent dig criteria.  
• Establish a shorter re-assessment interval.  
**When using DA or CIS,**  
• Establish a more stringent direct examination criterion, such as 950 mV as one of the CIS criteria.                                                                                                                                                                                                                       |
Monitor Example

ROW Standard

• Tree edge of “Border Zone” removed

Tree Specific Risk Analysis

• Initial Screening (291 Trees)
  – Species: Poplar, Max DBH > 17 in.
  – Tree distance: 7.9 ft.
  – Depth of cover: 55 in.
  – Screening Result: Monitor
  – Site access or patrol limitations: No
  – Recommended Action: Leave in place, and continue with existing risk management and O&M practices

• Detailed Risk Analysis
  – Not necessary

• Results
  – Monitor: 291
  – Mitigate: 0
  – Eliminate: 0
Mitigate Example

ROW Standard
• Tree edge of “Border Zone” removed

Tree Specific Risk Analysis
• Initial Screening
  – Species: Tulip, Max DBH > 17 in.
  – Tree distance: 5 ft.
  – Depth of cover: 36 in.
  – Screening Result: Additional Analysis
  – Site access or patrol limitations: No
  – Recommended Action: Detailed Risk Analysis

• Detailed Risk Analysis
  – Coating type: HAA
  – Pipe age: pre 1962
  – Pipe diameter: > 12 in.
  – Fault crossings: No
  – Wind load potential: Yes
  – Lightning potential: No
  – Soil stability: Stable
  – Site access limitations: No
  – Patrol limitations: No

• Result:
  Leave trees / implement P&M measures that are identified as “Mitigate” Threat
Eliminate Example

ROW Standard
• Large tree in “Pipe Zone” removed

Tree Specific Risk Analysis
• Initial Screening
  – Species: Valley Oak, Max DBH > 17 in.
  – Tree distance: 0 ft.
  – Depth of cover: 48 in.
  – Screening Result: Eliminate
  – Site access or patrol limitations: No
  – Recommended Action: Negotiate to remove tree

• Detailed Risk Analysis
  • Not necessary
Species: Pistache, Chinese
DOC: 62in
Dist. to pipe: 0-1ft
Mature DBH > 17in
Remove Tree

Species: Pistache, Oak & Liquidambar
DOC: 68-75in
Dist. to pipe: 2-10ft
Mature DBH > 17in
Trees to remain

Species: Pistache, Chinese
DOC: 72in
Dist. to pipe: 0-1ft
Mature DBH > 17in
Remove Tree

Increased Risk For:

<table>
<thead>
<tr>
<th>Threats posed by Tree(s) at this Site</th>
<th>Corrosion</th>
<th>Weather Related</th>
<th>Outside Force</th>
<th>Interaction - Construction / Manufacturing</th>
<th>Third Party Damage</th>
<th>Emergency Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating type is less resistant to root penetration</td>
<td>✔</td>
<td></td>
<td></td>
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<tr>
<td>Tree exposed to wind loading/lightning</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Area susceptible to moderate/high liquefaction potential</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>On top of pipe</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstructs access for emergency response</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
</tr>
</tbody>
</table>
Field Application Example
Tree Specific Analysis Overview

Factors used in risk analysis:
– Coating resistance to roots
– Age and size of pipe
– Lightning strike potential
– Loading from wind/floods
– Seismic activity
– Soil instability
– Tree species
– Depth of Cover
– Proximity of tree roots to pipeline
– Line of sight for pipeline markers
– Patrol effectiveness
– Ability to access for emergency response

Note: Data from Field Applied Analysis
Questions?