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GUIDE FOR TRANSMISSION LINE FOUNDATIONS WITH LEAST IMPACT TO THE ENVIRONMENT

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Foundations with Least Impact to the Environment

Objectives of Guidelines

- Develop decision making processes that aid in the selection of transmission line foundation alternatives which best meet the economic, engineering, and environmental needs of the project.
- Provide methodology to organize information and to perform a rational assessment that arrives at an economical foundation alternative for a project producing the least environmental impact.
- Develop foundation selection decision-making criteria;
  - *Each foundation type has unique design & construction characteristics*.
- Provide guidance regarding foundation design methods.
- Allow engineering judgment to be incorporated into the process to recognize the unique nature of each project.

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Scope of Project

- Identify factors and processes related to transmission line foundation design and construction in environmentally sensitive areas.
- Assess the environmental impacts of various transmission line foundation designs and other factors involved in foundation construction in sensitive environments.
- Understand the application and use of various traditional and alternate transmission line foundation technologies.
- Compare the environmental effects, remediation needs, and costs of various transmission line foundation options.
- Apply information to select, specify, and contract various alternative transmission line foundation design alternatives located in environmentally sensitive areas.

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Background

- Case studies indicate that sensitive environments can be generally categorized as follows:
  - Wet environments (wetland, waterway, coast, estuary);
  - Rough terrain (mountainous, desert); and
  - Frozen ground (seasonal frozen ground, permafrost).
- Access mitigation for traditional foundations is used to construct transmission line foundations in just under 40% of published case histories.
- Alternate foundations (e.g. micropiles, vibratory caissons, and helical piles) along with minimally invasive access methods (helicopters, barges, boats, marsh buggies, light/small equipment, etc.) are used in the remaining.
- 85% of unpublished case studies indicate access mitigation as the preferred alternative for foundation construction in sensitive environments.
- Few case histories of comparative foundation assessments are available.

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Identify - Decision Selection Criteria

- Site Access in Sensitive Environments
- Foundation Design Considerations
  - Subsurface Limitations / Feasibility;
  - Geotechnical Investigation Needs;
  - Groundwater Impacts; and
  - Material Fabrication & Delivery.
- Foundation Construction Controls
  - Schedule Impacts/Sensitivity – includes contractor availability;
  - Installation/Construction Equipment;
  - Foundation Materials – quantity, variety;
  - Site Impacts on Construction – corrosion, temperature; and
  - Construction Impact on Site – Noise, Dust, Vibration.
- Risk & Cost

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Assess – Traditional Foundations

- Needs driving access or barge on water;
- Can construct in nearly any soil/gw condition;
- Good subsurface data needed;
- Concrete & reinforcing steel;
- Takes time to construct; and
- Flexible sizes & high capacity loads.

- Needs driving access or barge on water;
- Can construct in nearly any soil condition (groundwater can create challenges);
- Limited geotech data ok;
- Backfill material can vary;
- Generally rapid construction; and
- Size/capacity limited by pole.

Assess – Traditional Foundations

- Needs minimal road access;
- Best suited with soil; can use in rock (groundwater can create challenges);
- Good subsurface data needed;
- Concrete & reinforcing steel;
- Minimal construction time; and
- Requires large excav/backfill area.

- Needs minimal road access;
- Best suited with soil; can use in rock (groundwater can create challenges);
- Good subsurface data needed;
- Backfill material can vary;
- Moderate time to assemble; quick install; and
- Requires large excav/backfill area.

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Assess – Traditional Foundations

- Needs driving access or barge on water;
- Can construct in gw; refuses in dense soil/rock;
- Limited geo data ok; can be proof tested;
- Typically steel elements;
- Rapid installation;
- Flexible sizes & high capacity loads; and
- Needs transfer plate or cast concrete.

- Small; installs with minimal access;
- Can construct in nearly any soil condition;
- Limited geo data ok; can be proof tested;
- Typically steel elements; can grout;
- Generally rapid installation; and
- Tension only element; use with limited types of structures.

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Assess – Alternative Foundations

- Ideal for restricted access sites;
- Best in rock but can construct in nearly any soil/gw condition;
- Limited geo data ok; can be proof tested;
- Small volume of grout and bars;
- Rapid installation; and
- Needs transfer plate or cast concrete.

- Suitable for sites with limited access;
- Best in soft soils; ideal for high gw;
- Limited geo data ok; can be proof tested;
- Numerous vendors; self-contained;
- Capacity depends on subsurface;
- Needs transfer plate or cast concrete; and
- Generally rapid construction.

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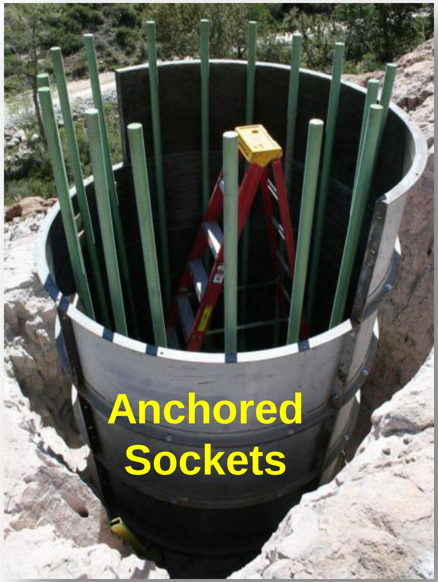
Assess – Alternative Foundations



- Ideal for restricted access sites;
- Used in rock or cemented soils;
- Requires good estimate of rock properties, but can be proof tested;
- Small volume of grout and bars;
- Generally slow installation; and
- Can achieve very high capacities.

- Suitable for sites with limited access;
- Can construct in gw; refuses in dense soil/clay/rock;
- Good subsurface data needed;
- No other materials typically needed;
- Rapid installation; and
- Design poorly understood.

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Assess – Mitigation Strategies

- Avoidance of Sensitive/Difficult Environments
  - Primary strategy used to limit impacts;
  - Increase span length; and
  - Reroute alignment.
- Activity Minimization
  - Minimize grading/road building;
  - Construct spur roads;
  - Restricted access (seasonal or temporal);
  - Limit equipment size & traffic; and
  - Alternative access (helicopter, boat, barge, marsh buggy, ATV, foot).
- Protection at Sensitive Sites
  - Mats and geotextiles;
  - Countermeasures / BMP’s; and
  - Ice roads / frozen ground.

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Compare - Rational Model

- Organization information is critical for performing a logical assessment that arrives at the optimal foundation alternative.
- Rational model → step-by-step process assigning values to all decision criteria.

Define Environment → **Identify Criteria** → **Evaluate All Alternatives** → **Rank Feasible Alternatives** → **Final Evaluation & Design** → **Foundation Assessment**

- Goal: select one or more foundation option with the highest likelihood of successfully meeting project objectives.

Flowcharts & Matrixes

- Decision-Making Process Flowchart
  - Application of the Rational Model;
- Environmental Impact Factor Flowcharts (numerical values)
  - Design Considerations;
  - Site Access; and
  - Construction Controls.
- Decision Matrix
  - Define Environment;
  - Identify Criteria (tabular information for each foundation alternative);
  - Evaluate Alternatives (rank each impact factor for all foundation types);
  - Select Importance Factor, i.e. risk (I – average; II – elevated; III – high);
  - Evaluate Alternatives (numerical comparison); and
  - Select Feasible Design Alternatives.

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Foundation Evaluation & Design

- Although feasible, the highest ranked option(s) may not necessarily be the least costly.
- Preliminary design and cost estimation should be performed for the most feasible options to determine the best course of action.
- Traditional Foundation Assessment
  - Prepare foundation design;
  - Estimate foundation cost; and
  - Develop project schedule.
- Alternative Foundation Assessment
  - Prepare preliminary foundation designs/specs;
  - Bid multiple alternatives – have contractors provide costs/schedules; and
  - Integrate “value engineering” – contractor/owner jointly perform final design.

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Conclusions

- Environmental impacts can be mitigated by a combination of good planning, design, and construction practices.
- Geotechnical investigations help determine subsurface conditions that are conducive to the application of each foundation alternative.
- Improved access practices offer the best opportunity to minimize environmental impacts.
- Organizing relevant information is critical to the performance of a logical assessment that arrives at the best foundation alternative for the project.
  - Flowcharts to guide the process;
  - Criteria to categorize and quantify options and impacts; and
  - Matrixes to assemble information and provide a quantitative comparison.
- Subjectivity (engineering judgment) in combination with rational methods provide an excellent tool for making good decisions.

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Application & Future Work

- Application
  - Methods provided can be used by project owners to assess the most favorable alternatives.
  - This is best done early in the project – starting with the planning and land acquisition phase of the project.
  - This guide provides a step-by-step approach to foundation assessment.
- Future Work
  - Trial cases are needed for the evaluation of optimized alternatives – transmission foundation assessment is ripe for value engineering.
  - Vibratory caissons design and performance requires more R&D.
  - Formal guide specifications for electric system foundations should be developed – presently, most are borrowed from the transportation sector.