NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Maintaining Transmission Line Ratings Consistent with As-built Conditions

Good Utility Practices

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RELIABILITY | ACCOUNTABILITY




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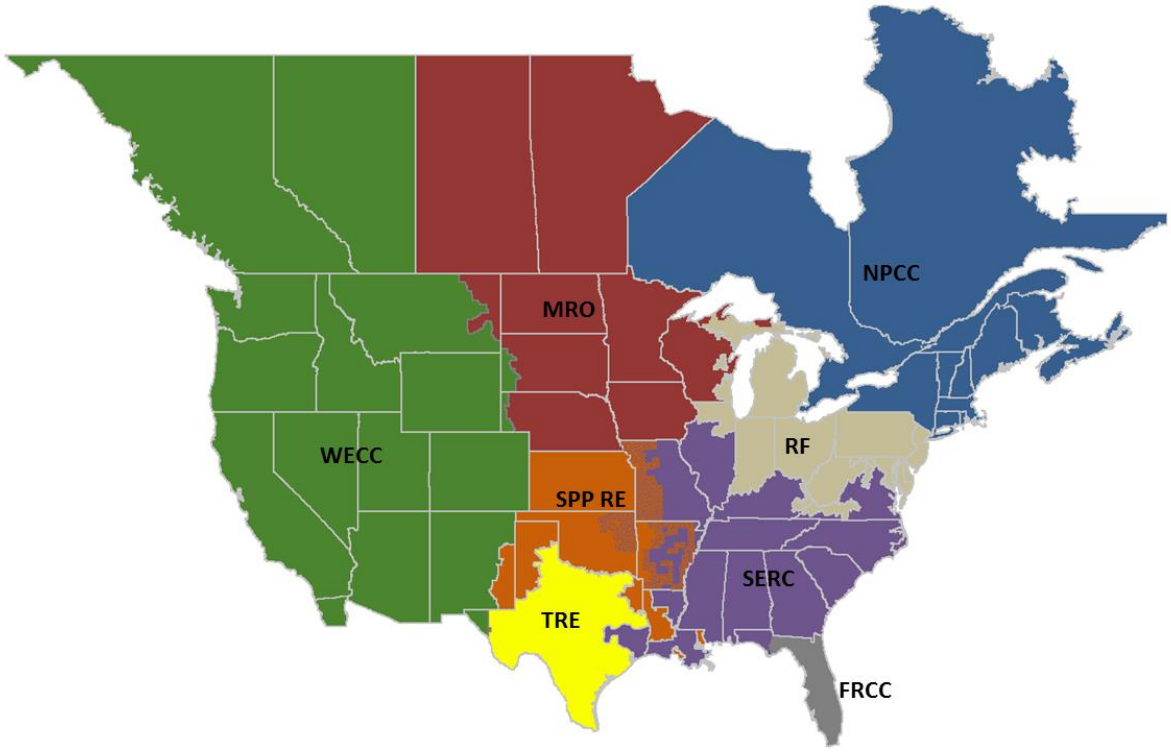
Preface

The North American Electric Reliability Corporation (NERC) is a not-for-profit international regulatory authority whose mission is to assure the reliability of the bulk power system (BPS) in North America. NERC develops and enforces Reliability Standards; annually assesses seasonal and long-term reliability; monitors the BPS through system awareness; and educates, trains, and certifies industry personnel. NERC's area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico. NERC is the electric reliability organization (ERO) for North America, subject to oversight by the Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada. NERC's jurisdiction includes users, owners, and operators of the BPS, which serves more than 334 million people.

The North American BPS is divided into several assessment areas within the eight Regional Entity (RE) boundaries, as shown in the map and corresponding table below.



The Regional boundaries in this map are approximate. The highlighted area between SPP and SERC denotes overlap as some load-serving entities participate in one Region while associated transmission owners/operators participate in another.

FRCC	Florida Reliability Coordinating Council
MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
SPP RE	Southwest Power Pool Regional Entity
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

Executive Summary

As a result of the ERO Enterprise[1] assurance activity on the status of actions taken by industry in response to the NERC Facility Ratings Alert[2], this report was developed to share good utility practices with industry stakeholders. This report contains observed programs and procedures developed in response to the Alert by registered Transmission Owners (TOs) and Generator Owners (GOs) to sustain adequate conductor clearances consistent with transmission facility ratings. For this report, sustaining adequate conductor clearances consistent with transmission facility ratings pertains to the practices needed to maintain safe clearances of the conductor above ground, from other conductors, or from stationary objects. Generally these practices focus on maintaining transmission rights-of-way (ROW) to identify and prevent future encroachments that may affect facility ratings[3], and ensuring those ratings reflect as-built conditions, particularly after transmission construction or ROW related changes are completed.

The practices described were based on the responses of 20 selected TOs to a voluntary data request made by the ERO Enterprise. The transmission systems of the selected entities in aggregate represents a significant portion of the total number high priority Bulk Electric System (BES) circuits that were assessed, evaluated, and remediated in response to the Alert. However, the good utility practices being implemented by the selected entities is not an all-inclusive list of the best practices available. ERO Enterprise staff concluded during the review of these practices that written procedures, guidelines, or both are important to ensure sustainability and continuity of ROW integrity and provide a means of capturing the institutional knowledge regarding ROW sustainability that exists within each entity. Some of the good utility practices adopted by the selected entities include:

- **As-Built Verification Practices:** Transmission line as-built verification practices include field verification measurements after all transmission line construction or maintenance projects are completed.
- **ROW Encroachment Practices**: ROW encroachment practices are procedures designed to manage the acceptable non-transmission uses and placement of various facilities or objects within ROWs to ensure the safe location of those facilities.
- **Periodic Line Patrol Practices:** Periodic line patrol practices routinely performed by entities to inspect transmission lines for vegetation growth and structural issues have been enhanced to also focus on identifying unauthorized ROW encroachments.
- **Clearance Buffer Practices:** Clearance buffer practices refers to the systematic program of incorporating conductor clearance sag heights above the minimum clearance requirements of the National Electric Safety Code (NESC) or other clearance requirements when designing new or modified transmission structures and lines. This program has been re-evaluated, increased, or both over past practices.
- **Corporate Management Practices:** Corporate management practices refers to organized management level support for remediating ROW clearance and line ratings issues.
- **Survey Frequency Practices:** Survey frequency practices refers to conducting periodic transmission system surveys using aerial based Light Detection and Ranging (LiDAR)[4], which supplements or works in combination with other good utility practices.

[1] NERC and the Regional Entities are collectively the "ERO Enterprise".

[2] On October 7, 2010, and revised on November 30, 2010, NERC distributed a Level 2 Alert, *Recommendation to Industry: Consideration of Actual Field Conditions in Determination of Facility Ratings (*http://www.nerc.com/pa/rrm/bpsa/Pages/Facility-Ratings-Alert.aspx*).*

[3] The good utility practices in this report do not necessarily pertain to transmission vegetation management and the prevention of encroachments into minimum vegetation clearances distances.

[4] LiDAR "is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light" (https://en.wikipedia.org/wiki/Lidar).

Introduction

The good utility practices described in this report were based on the responses from selected TOs to a voluntary data request issued by the ERO Enterprise. The data request was conducted both off-site and on-site and included a total of 20 selected entities. The off-site data requests included 11 participants who submitted written responses to a series of questions focused on entity input regarding best practices, lessons learned, and sustainability programs developed. The on-site data requests included nine participants who provided in-person responses to ERO Enterprise staff to the same best practices, lessons learned, and sustainability program questions. The on-site engagements occurred at nine separate entity office locations and provided for an open and interactive discussion between entity staff and ERO Enterprise staff. In addition, all participating on-site entities provided follow-up information to the ERO Enterprise staff after the on-site meetings.

The ERO Enterprise is very grateful for the voluntary participation of the entities involved, and in particular those that hosted on-site engagements. The specific responses, related procedures, and identities of the participating entities are confidential.

Background

The Alert requested that TOs and GOs develop a plan and conduct assessments of the as-built conditions of their high, medium and low priority BES transmission facilities. Discrepancies between actual and design conditions resulting in incorrect facility ratings were to be reported to the respective Regional Entity, including a timeline for remediation to correct the conditions or modify the facility ratings. NERC did not use a formal compliance monitoring activity to evaluate the actions taken by TOs and GOs in response to the Alert. Instead, it has worked with industry to gather information from industry on a voluntarily basis.

In 2015, NERC initiated the ROW project to review the actions taken by registered entities in response to the Alert, and included this project in the ERO Enterprise Strategic Plan 2015-2018[5]. A ROW project team was formed that included staff from the ERO Enterprise. The ROW project had two major objectives:

The first objective was to perform on-site validation reviews of selected entities to verify that a representative sample of high priority discrepancies were remediated. The goal of the validation review was to confirm that the identified mitigation work had occurred and that the discrepancies no longer existed. The validation review was performed on a sampled subset of high priority line discrepancies chosen using concepts and techniques recommended in the *ERO Sampling Handbook*.[6] The validation reviews were successful and confirmed mitigation work had occurred. These results are confidential and not contained in this report.

The second objective of the ROW project was to identify and document good utility practices and programs entities have developed to maintain adequate conductor clearances consistent with facility ratings in the future. The goal of the good utility practice review was to seek entity input and share with the industry the programs or procedures that have been developed in response to the Alert. This report contains a description of some good utility practices that were shared by the selected entities with the ROW team as well as associated recommendations.

[5] The *Electric Reliability Organization (ERO) Enterprise Strategic Plan, 2015-2018* and the associated ERO Enterprise Performance Metrics were developed and intended as indicators of the overall effectiveness of the ERO Enterprise in achieving its mission, along with the goals and objectives outlined. ERO Enterprise Performance Metric 3, Risk Mitigation Effectiveness and Measure 6, Right-of-Way Clearances called for NERC to initiate the ROW project in 2015.

[6] Refer to: http://www.nerc.com/pa/comp/Documents/Sampling_Handbook_Final_05292015.pdf

Chapter 1 – Method: Assessment and Remediation

Many of the work practices developed in response to the Alert by the 20 selected entities were uniquely designed to manage the large volume of assessment and remediation work within the recommended Alert timeframes. All of the entities surveyed used similar methods, to various degrees, to perform the assessment and remediation of their BES transmission facilities.

The methods for assessment and remediation generally included the following steps:

- Acquiring aerial based LiDAR survey data
- Capturing meteorological conditions (ambient temperature, wind speed and direction) and line loading to estimate conductor temperature at the time of survey[7]
- Using LiDAR survey data to build ROW models in PLS-CADD[8]
- Using PLS-CADD to perform sag-tension analysis to identify ratings discrepancies (areas where conductors do not meet NESC or other clearance requirements under the rated maximum operating temperature and/or conductor blowout conditions)
- Validating certain survey anomalies or points of interest with field visits
- Documenting and tracking ratings discrepancies using various software tools
- Implementing temporary remediation measures including some of the following, among others:
  - Lowering of facility ratings (temporarily)
  - Performing system reconfigurations
  - Removing insulator bells
  - Installing barriers to prevent public access
- Implementing permanent remediation measures including some of the following, among others:
  - Lowering of facility ratings (permanently)
  - Relocating or modifying distribution facilities, communication facilities, or both
  - Raising, modifying, or replacing transmission structures
  - Installing new mid-span transmission structures
  - Installing floating dead-ends
  - Installing dead-ends on towers or cross-arms
  - Re-sagging line sections
  - Installing new conductors

[7] Refer to the IEEE G*uidelines for Determining Conductor Temperatures During Measurement of Sag Along Overhead Transmission Lines, First Edition – February 6, 2012;* which states in Section 1. Introduction: "Proper determination of conductor temperature is critical when evaluating the thermal ratings (ampacity) of an existing overhead transmission line based on measurements of actual field conditions such as sag and ground clearance. Inaccurate assumptions, estimates and/or measurements of temperature will likely lead to erroneous conclusions. The need to establish an accurate conductor temperature during the field measurement process used to obtain other physical data, such as sag and structure heights, for example, is fundamental to all of the approaches currently being utilized" (http://www.utilityrisk.com/images/pdf/ieeeguidelinefordeterminingconductortemperature.pdf).

[8] PLS-CADD™ (Power Line Systems - Computer Aided Design and Drafting) is a "power line design program" that "integrates all aspects of line design into a single stand-alone program" (http://www.powline.com/products/pls_cadd.html).

  - Removing objects from ROW
  - Re-grading the ROW
  - Installing conductor weights to re-shape conductor sag
  - Removing insulator bells
  - Removing static wires from underbuilt lines
- Developing management teams to review and approve remediation projects
- Estimating, planning and scheduling large amounts of remediation work
- Hiring contractors, consultants, or both
- Implementing creative construction methods
- Designing remediation solutions to increase clearance buffers, to the extent possible, above the minimum clearance requirements
- Documenting the completion of remediation activities using various enterprise work management system tools
- Updating ROW models to reflect the as-built condition of remediation work
- Updating facility ratings to reflect the existing as-built field conditions

Chapter 2 – Good Utility Practices: ROW Sustainability

In response to the Alert, the ROW team observed that all of the selected entities have generally implemented the methods outlined above in Chapter 1. These efforts have significantly lowered the BES reliability risk that previously existed and have, in effect, established a new transmission system baseline whereby all BES transmission facility ratings now accurately reflect as-built conditions.[9] Sustaining this adequate conductor clearance baseline will be vitally important to ensure that the efforts undertaken in response to the Alert are maintained and to ensure facility ratings remain consistent with the as-built conditions of transmission ROWs into the future.

Sustaining adequate conductor clearances consistent with transmission facility ratings pertains to the practices needed to maintain safe clearances of the conductor above ground, from other conductors or from various stationary objects. This section details some of the good utility practices that are forward looking methods and describe the processes to identify, communicate and remediate any future encroachments into the baseline system. Generally, these future encroachments are expected to originate from distribution facilities, communication facilities, or both or various foreign objects. In addition, there is an ongoing need to verify as-built conditions after all transmission construction and maintenance activities.

The following information represents some of these good utility practices that were shared by the selected entities with the ROW team. The specifics outlined may represent a good practice of a single entity or similar practices of multiple entities and may show varying approaches to a particular practice in some cases. In general, there is a strong emphasis on highlighting programs that are documented and implemented with formal written procedures and/or guidelines. The ROW team concluded during the review of these practices that written procedures, guidelines, or both are important to help ensure sustainability and continuity of ROW integrity and further provide a means of capturing the institutional knowledge regarding ROW sustainability that exists within each entity.

2.1 As-Built Verification Practices

Transmission line as-built verification practices include field verification measurements after all transmission line construction or maintenance projects are completed. As changes are made to the transmission system, field verification measurements are important to ensure that the design specifications match the field condition and to accurately capture as-built changes that occur during construction. Changes from the design specification are then brought back into the ROW models so the models can be updated to reflect the actual field condition. In addition, transmission line ratings are re-evaluated and adjusted, as necessary, to ensure consistency with the as-built system.

Several of the selected entities have either implemented written as-built procedures or are in the process of developing a procedure to reflect the as-built processes currently in effect. As-built verification procedures are implemented after all forms of transmission construction and ROW changes, including the building of new lines, line re-conductoring upgrades, structure replacements or modifications, various maintenance activities, rebuilds due to storm damage, and new distribution or communication crossings or underbuilds.

The type of verification process largely depends on the scope of construction activity or change that occurred. For instance, for new line construction or a major line re-build, aerial based LiDAR is generally used. For smaller projects, ground based LiDAR or the use of other ground based measurement devices are used. Other tools are being used to capture as-built conditions as well. This includes blank forms that are included with construction plans which are used by construction personnel to record and document as-built measurements at every structure. Similar templates are used to record and document installed line tensions.

[9] In some cases, remediation activities are on-going.

2.2 ROW Encroachment Practices

ROW encroachment practices are procedures that are designed to manage the acceptable non-transmission uses and placements of various facilities or objects within ROWs to ensure the safe location of these facilities. The safe accommodation of such facilities typically requires an engineering analysis to ensure that transmission line clearance limitations and ratings are maintained.

Distribution

Properly managing new distribution or communication line crossings and under-builds is one of the key tasks needed to sustain adequate transmission conductor clearances of the baseline BES transmission system. Several entities have written processes to identify, communicate, evaluate and remediate internal and external distribution line encroachments on transmission ROWs as needed. One procedure includes a common design criteria guideline to ensure the proper height of distribution lines and reduce the likelihood of future discrepancies.

Typically, the procedures include the submittal of an application by the distribution or telephone/cable entity for proposed equipment or facility locations as well as associated drawings of the new or modified facilities that provide sufficient design details. The applications are then reviewed for modification or approval by transmission engineering staff. Field measurements are required after the approved work is completed to verify it was constructed according to the proper dimensions.

Private Easements

Another important aspect of ROW encroachment practices includes the management of land owner use of private property under transmission lines. Use of private lands in or near ROWs typically includes construction of residential housing, roadways, parking lots, lighting facilities and various other structures. For example, one entity has a real estate policy that specifies any proposed changes within the ROW be submitted for approval or rejection by the transmission line engineering department. In addition, any new residential home development plans within half a mile of a transmission line are required to be submitted to transmission line engineering for recording and tracking and to enable feedback to the developer. At a minimum, the feedback includes instructions for developers to contact transmission line engineering before moving any equipment or starting construction within a ROW. The policy also includes the requirement that all new easement rights include provisions to enable the company the right to prevent or remove any temporary or permanent buildings or structures from the easement.

Public Outreach

Public outreach refers to practices that are intended to educate to the public regarding the proper use of ROWs. The information provided includes vegetation-related guidelines as well as specifics on the proper use of ROW easements. For example, one entity has a newly designed public website that includes information on company policy related to ROW maintenance. It details vegetation management approaches and also includes a section on easements that reminds property owners of their responsibility to not introduce vegetation, buildings, or other objects in the ROW that could interfere with access to the lines or create safety clearance hazards. The “ROW Maintenance” section of the website includes a link to frequently asked questions that is intended to increase landowner knowledge regarding the allowed uses of the ROW. In addition, the entity includes a ROW fact sheet as part of “door-hanging” materials when notifying impacted customers of upcoming ROW work. The entity has future plans to include the more detailed ROW encroachment information contained in the fact sheet on their public website.

Encroachment Agents

Encroachment agents refers to the practice of designating entity staff to track and manage ROW encroachments. Assigning staff with this responsibility can be an important part of the method to ensure various ROW procedures are followed and to ensure that all encroachments are identified, tracked, and remediated. For example, several entities have specifically assigned staff to ensure protection of ROWs against encroachments. This responsibility

includes enforcement of ROW use guidelines, participation in public meetings and other outreach, and acting as the liaison between external agents and transmission engineering, among others.

2.3 Periodic Line Patrol Practices

Periodic line patrol practices are the practices routinely performed by entities to inspect transmission lines for vegetation growth and structural issues. The selected entities conduct line patrols using a combination of fixed wing aircraft, helicopters, and foot patrols, ranging from two to four times per year. Entities have indicated that the Alert has helped create an increased awareness of ROW encroachment concerns by line maintenance, construction, field operations, vegetation, and other relevant staff. This increased awareness has led to the enhancement of these existing routine line patrol practices to include a focus of identifying unauthorized ROW encroachments. The unauthorized encroachments can include deer stands, light poles, commercial signs, sheds, swimming pools, storage, and more. These practices typically include ground verification to confirm any reported issues.

While there has been excellent progress made by entities with increased feedback from field personnel and enhanced line patrol practices, the ROW team has not observed that these enhancements have been documented into related guidelines or procedures. As stated above, the ROW team concluded during the review of these practices that written procedures, guidelines, or both are important to ensure sustainability and continuity of ROW integrity, and provide another means of capturing the institutional knowledge regarding ROW sustainability that exists within each entity.

Documentation Tools

A key component of identifying and remediating discovered ROW issues includes documentation tools that are used to record, track, and communicate these findings. One entity has trained maintenance and construction personnel on the use of hand-held electronic tablets that interface with the internal asset management system. While these devices are primarily used to process work orders and record asset information from the field, they are also being used to collect inspection data and provide comments for future reference. The tablets can also be linked to a geographical information system (GIS) database to document various ROW issues, including the feature to upload photographs.

Another entity implemented a new mobile application to strengthen its ROW patrol program. The tools include the Esri Collector[10] application, which runs on a mobile hand-held tablet used during aerial patrols to collect and update ROW information. The tool directly associates the current location by populating corresponding GIS maps and enables real-time documentation and communication of ROW issues, including vegetation, structural, maintenance and encroachments.

Contractor Training

Contractor training enables the awareness and reporting of any suspected ROW encroachments. The use of contractors for vegetation maintenance and transmission construction is a very common industry approach. Since these external personnel may not have the same awareness of ROW concerns, training them can be another means to help identify and quickly remediate unauthorized ROW encroachments. For example, in addition to vegetation management procedures, one entity conducts training with all vegetation contractors on encroachment guidelines. The training includes a written procedure that contains instructions to notify system operations of any hazard trees or foreign structures that are within specific clearance zones. The clearance zones are shown in a table of acceptable vertical and horizontal clearance distances to the nearest conductor based on the voltage of the line.

[10] This application is used with a mobile device (smartphone or tablet) to "collect and update data in the field, log your current location, and put the data you capture to work….use maps anywhere to ground-truth your data, make observations, and respond to events…improve the efficiency of your field workforce and the accuracy of your GIS (http://doc.arcgis.com/en/collector/)."

2.4 Clearance Buffer Practices

Clearance buffer practices refers to the practice of incorporating conductor clearance sag heights above the minimum clearance requirements of the NESC (or other clearance requirements) when designing new or modified transmission structures and lines. Using clearance buffers, which are sometimes referred to as safety margins, is a long standing practice. It can provide insurance against unknown factors, such as the settlement of structures, the stretching of conductors due to severe mechanical loading, gradual land changes due to natural causes, installation variability, unauthorized encroachments, and other variables. Several selected entities have indicated that the large numbers of discrepancies discovered in response to the Alert have caused a re-evaluation of clearance buffers and resulted in a corresponding increase over past practices.

For example, one entity updated its design criteria for new and rebuilt construction to add a 10-foot buffer for 115kV conductor-to-ground clearance and a 9.5-foot buffer for 230kV conductor-to-ground clearance in addition to NESC guidelines. This is an increase of five feet over past practices. Another entity updated its criteria to add a five-foot buffer for conductor-to-ground clearance and a two-foot buffer for conductor-to-conductor clearance in addition to NESC guidelines.

2.5 Corporate Management Practices

Corporate management practices refers to the various organized management level support for remediating ROW clearance issues. Several selected entities established management teams that periodically meet to review and approve remediation projects associated with the Alert. These management teams are typically comprised of directors, managers and key-level staff from various internal groups or departments, including transmission and distribution engineering, system planning, transmission operations and maintenance, transmission and distribution construction, system operations, real estate, vegetation management, project management, and legal, among others. In some cases, these groups will continue functioning to provide direction on ROW encroachment mitigation and ratings sustainability as needed.

For example, one entity established a committee that has a written charter of responsibilities. The committee charter specifies overall responsibilities that include approval for all transmission ratings changes and making recommendations to executive management for approval of remediation projects. The committee has a process flow chart for project reviews from initiation to completion. These responsibilities also include voting and advisory membership roles. This group will continue to function and fulfill this role even after Alert remediation is completed.

2.6 Survey Frequency Practices

Survey frequency practices refers to the practice of conducting periodic transmission system surveys using aerial-based LiDAR. The intent of this practice is to supplement or, work in combination with the other good utility practices discussed above to ensure long-term ROW sustainability and line rating accuracy. The survey frequency of selected entities varies and appears to be dependent on the degree to which other ROW sustainability measures have been implemented.

For example, one entity plans to use the initial baseline LiDAR analysis combined with periodic annual aerial patrols to identify potential encroachments as a cost-effective way to verify and maintain adequate line clearances and ratings rather than periodic LiDAR surveys. Another entity has developed a procedure that dictates a LiDAR survey should be conducted on 20 percent of its transmission system every year, finishing the cycle every five years. A third entity has initiated a LiDAR pilot program with the goal of developing an ongoing strategic LiDAR program. The objectives are to provide increased assurances regarding possible errant trees or increased vegetation growing conditions, to provide for an increased ability to accurately quantify future work required for contract bid negotiations, to verify that new construction meets design standards, and to identify, inventory, and mitigate new ROW encroachments.

Chapter 3 – Conclusion

As a result of the ERO Enterprise assurance activity on the status of actions taken by industry in response to the Alert, this report was developed to share good utility practices with industry stakeholders. The good utility practices described in this report were based on the responses from 20 selected TOs to a voluntary data request that was conducted by NERC and the Regional Entities. These practices include as-built verification practices, ROW encroachment practices, periodic line patrol practices, clearance buffer practices, corporate management practices and survey frequency practices. The ROW team concluded that written procedures or guidelines are important to ensure implementation of these practices in the future.

The intent of this report was to publish relevant information for the industry that may be useful to the future development or enhancement of the best practices of registered TOs and GOs. The transmission systems of the selected entities in aggregate represents a significant portion of the total number high priority BES circuits that were assessed, evaluated, and remediated in response to the Alert. However, the good utility practices being implemented by the selected entities is not necessarily an all-inclusive list of the good industry practices available.

The ERO Enterprise acknowledges and expresses appreciation to the entities involved for their voluntary participation and open dialogue and sharing of information. The specific responses, related procedures and identities of the selected entities will remain confidential.