Long Beach July 2015 Secondary Network Outages RCE

Summary and Report

Table of Contents

Summary of SCE's Performance Review of the Long Beach July 2015 Secondary Network Outages

Background

Events of July 15 and July 30

On July 15, 2015, approximately 30,700 Southern California Edison (SCE) customers in Long Beach lost power after two electrical circuits shut down and fires started in three underground vaults. In the interest of public safety and to enable SCE crews to make repairs, SCE turned off the downtown electrical network and some adjacent circuits. Most of those customers, about 22,700, had power restored within an hour, but more than 6,500 customers were without power for more than 24 hours, and some customers were without power for nearly 72 hours. By July 18, all customers had power either through the grid or through generators. By July 20, all of the customers on generators were reconnected to the grid.

Less than two weeks later, on July 30, two different electrical circuits in Long Beach shut down and two fires occurred in underground vaults. SCE again turned off a large section of the Long Beach secondary network system, resulting in approximately 17,980 customers losing power for periods of between one and 72 hours (some customers were restored using mobile generation). By August 1, all customers had power either through generators or the grid, and by August 3, all customers were reconnected to the grid. Using lessons learned from the July 15 event, SCE was able to more quickly and effectively evaluate the system interruption issues, identify and isolate the damaged cable, and re-energize the network. The result was a more effective restoration effort, including a reduction of the number of customers impacted and a reduction in the duration of the outage time for the customers.

Internal Performance Review and Independent Review

Southern California Edison's primary mission is the safe delivery of reliable and affordable electric power. SCE's goal is to deliver power with 99.99 percent availability, meaning less than one hour of annual downtime on average per customer. The events of July 15 and July 30 did not meet SCE's standards for safe and reliable service. As a result, the company launched an internal independent review to identify the root causes of the events, and to recommend changes in those areas where SCE's performance before the events of July 15 and July 30 did not meet expectations. The report, "Performance Review Long Beach July 2015 Secondary Network Outages," is attached to this Summary, and contains the findings of that root cause investigation and recommendations for operational changes.

Root cause evaluations are intended to assure that conditions that contributed to performance issues are promptly identified and more effective, measures are suggested to improve performance. Root cause evaluations, like the one conducted by SCE here, are not intended to determine if any of the actions or decisions of management, vendors, internal organizations or individual personnel during an

event were reasonable or prudent based on the information available at the time and without the benefit of hindsight.

SCE also commissioned an independent, third-party review from Davies Consulting LLC, a utility industry consultant, to examine the cause of both events. However, Davies was asked to go beyond causation and also assess SCE's response to the outages, and to recommend improvements related to that response. The Davies report will be released separately.

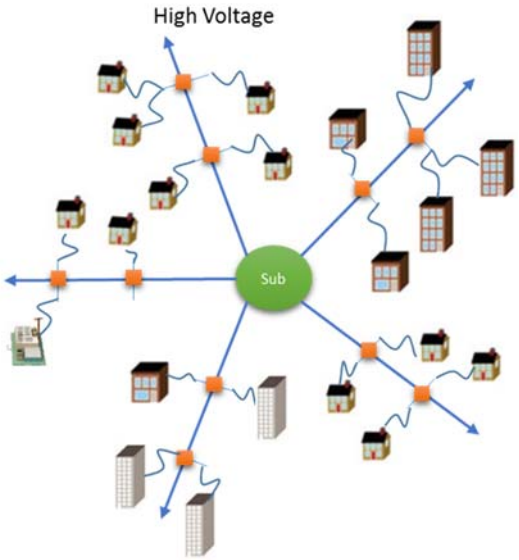
Long Beach Network

Southern California Edison (SCE), a subsidiary of Edison International, provides electric service to nearly 5 million customer accounts -- or about 14 million people -- across a 50,000-square-mile service territory in central, coastal, and southern California. SCE has provided electric service in the region for nearly 130 years. SCE's electric system includes 1.4 million power poles, 700,000 transformers and 103,000 miles of distribution and transmission lines.

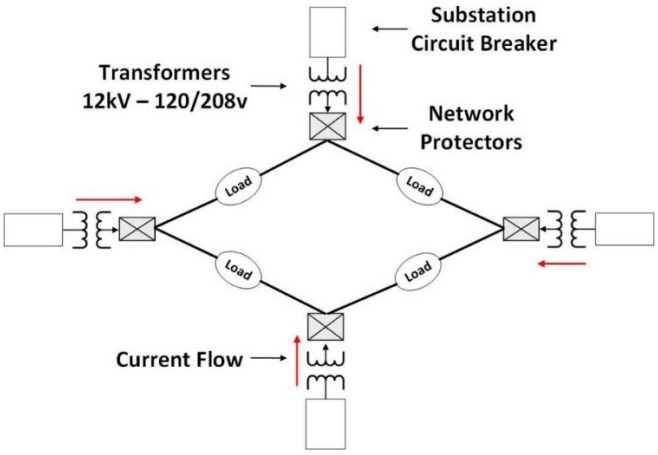
The city of Long Beach, with approximately 170,000 customer accounts within about 70 square miles, is the largest of the 180 municipalities served by SCE. Within SCE's Long Beach District is a section known as the Long Beach secondary network. The Long Beach secondary network was constructed in the mid-1920, and throughout the next several decades, and serves approximately 3,800 customers in about one square mile in the downtown area. The network's circuits are primarily underground, and are accessed through various manholes and underground vaults. Primary circuits feeding the secondary network serve approximately 26,000 additional customers. For many decades, the secondary network has operated with well above-average reliability.

The Long Beach network is unique in SCE's service territory. Most electrical distribution systems are constructed in a "radial" fashion, with power coming from a central source, such as a substation, and sent out through various circuits that end at customers' homes and businesses. Electrical current flows in only one direction in a radial system, and a failure along any one of those circuits typically results in a loss of power to the rest of that circuit, and that circuit only.

In contrast, a networked distribution system has multiple connections between substations and circuits, and current can flow in one direction or the other as needed to maintain voltage to all customers. The advantage to this configuration is that when one component in the network fails, current can be re-routed to prevent loss of power to other customers served from other parts of the network.



Radial System



Networked System

A key piece of equipment in a networked distribution system is known as a network protector[1], or NP. The network protector acts as a switch that can be on or off, either allowing current to flow through the circuit or breaking the circuit to stop the flow of power, as needed. The NP has three positions: Manual Closed, which allows current to pass through the switch to the circuit; Manual Open, which breaks the circuit and prevents current from flowing; and Automatic, which relies on a sensor known as an NP relay[2] to open the switch when voltage conditions in the circuit require it. These devices proved to be critical in the outage events of July 15 and July 30.

Root Cause

SCE's internal investigation determined that the triggering event[3] that led to the July 15 power outage was the failure of a cable splice in an underground vault at Ocean Blvd. and Pacific Ave. in downtown Long Beach. A cable splice is where two segments of electrical wires are joined by utilizing high voltage cable components that are then reinsulated to form a continuous cable. An independent review of the damaged cable splice by engineering consultants was unable to determine the cause of the splice failure because there was too little material remaining at the splice connection to analyze.

[1] Network Protector: An assembly comprising an air circuit breaker and its complete control equipment for automatically disconnecting a transformer from a secondary network in response to predetermined electrical conditions on the primary feeder or transformer, and for connecting a transformer to a secondary network either through manual control or automatic control response to predetermined electrical conditions on the feeder and the secondary network.

[2] Network Protector Relay (NP Relay): A relay or combination of relays that functions as a protective relay by opening a network protector when power is back-fed into the supply system and as a programming relay by closing the network protector when the poly-phase voltage phasors are within prescribed limits.

[3] Triggering event: The triggering event is any adverse human factor, equipment failure, or special condition (such as acts of nature) that sets a failure mechanism in motion. If not stopped by an effective barrier, it will result in a failure event.

The Failed Cable Splice

The failure of that single cable splice resulted in a cascade of events on July 15 leading to circuits automatically shutting off, fires in three adjacent underground vaults and the eventual loss of power for at least some period of time to more than 30,000 customers. The outage on July 30 was caused by the failure of a cable that had been degraded by overloading during the July 15 event. This event was also followed by a series of circuit shutoffs and vault fires. Under normal conditions, these events should not have occurred following the cable splice failure on July 15.

An examination of these events revealed a larger, systemic cause of the widespread outage. The root cause was found to be "Insufficient work processes and organizational structure to support continuous operation of the Long Beach secondary network."

In essence, the oversight and governance of the Long Beach secondary network was not sufficient to prevent, identify and address ongoing network vulnerabilities. For example, there was no standard design configuration of primary circuitry for the Long Beach secondary network, which included a combination of radial and networked systems. In addition, there was insufficient knowledge regarding the operation of the network protectors and there was limited automation and remote monitoring of those devices.

There were also field personnel failures in inspections and in installations of key electrical equipment because of gaps in the work management systems and processes that SCE used to monitor and maintain the Long Beach network. In several locations, network protectors were installed without required equipment, known as NP relays, which prevented them from operating as designed. Specifically, two network protectors had been left in the "manual closed" position without relays, which prevented them from shutting off current when necessary to keep circuits from backfeeding. SCE determined that in the July 15 event, some network protectors were not in a configuration to operate properly.

Certain NPs lacked relays for various reasons, among them: 1) some employees were unaware that NP relays were required for network protectors to perform their protective function because adequate training was not provided; and 2) the computer system that employees used to process work orders did not include NP relay installation as an item that could be requested, leading them to enter it into a non-descript category named "Special."

SCE also found that there was limited troubleshooting experience in the company on the Long Beach network because of its long history of reliability, the loss of personnel who had a working knowledge of the network due to attrition, the lack of formalized training on network operations, and because it's SCE's only network. When employees were transferred into the Long Beach District they were not always trained in the complexities of a network system. Additionally, system maps were not consistently updated, and proved to be inaccurate, and there was no network model. Finally, there was not a single

"owner" of the Long Beach network with overall responsibility -- rather it was shared by multiple departments within SCE, which led to certain items remaining unaddressed such as network map updates and transitioning Work Requests between organizations.

The investigation also found a specific, localized contributing cause: "A Network Protector inspection was closed out with no actions taken and without returning a complete Work Request."

Specifically, employees attempted to perform an inspection of a network protector in an underground vault in downtown Long Beach on March 15, 2013, but they could not access the vault due to nearby construction. The crew noted the circumstances for not performing the inspection and failed to complete the inspection when the access issues were resolved. That network protector failed to perform its protective function on July 15, 2015, allowing electrical current to flow into a failed cable splice, creating an overload that led to fires and additional circuits shutting down.

Chronology

The following sequence of events were relevant to - but occurred over several years before -- the Long Beach network outages of July 15 and July 30, 2015.

2007

- On December 17, 2007, a new network protector was installed in a vault at 3rd St. and N. Crystal Ct. by SCE crew. This is the Network Protector that eventually backfed into the primary circuit in July of 2015.

2008

- Sometime in 2008, that network protector's NP relay was removed and the handle left in the "manual open" position. Due to the subsequent transition in the work order management system to SAP, the records for the installation are not available. It is unknown when or why the NP relay was removed and why no action was taken to replace it.

2010

- On October 10, 2010, an SCE crew inspected the network protector at 3rd St. and N. Crystal Ct. and identified the missing NP relay on inspection notes, but no action was taken to install the NP relay.

2011

- In March 2011, a Long Beach Network Findings and Recommendations Report identified several system improvements. 25 Network Protectors were replaced; however, other recommendations were not implemented.

- On June 24, 2011, an SCE employee responding to a low voltage call found the network protector at 3rd and N. Crystal Ct. in the open position and with fuses not installed. A notification[4] was written to distribution apparatus to put the unit online.

- On July 1, 2011, a vault at Ocean Blvd. and Pacific Ave. was identified by SCE crew as deteriorated and a notification was written for replacement (See entry below for 8/4/2014).

2013

- On March 2, 2013, a network protector in a vault at 9th St. and Solana Ct. opened. The next day, a SCE employee responding to a low voltage call manually closed the network protector.

- On March 15, 2013, a SCE crew attempted to inspect a vault at 3rd St. and N. Crystal Ct., but the vault was inaccessible due to nearby construction and could not be inspected. The SCE crew closed the inspection, and did not return to complete it.

- On April 16, 2013, a network protector in a vault at 9th St. and Solana Ct. was found to be broken and would not close automatically. A notification was written to replace the network protector (See entry below for 7/31/2014).

2014

- On July 31, 2014, an SCE crew replaced the broken network protector at 9th St. and Solana Ct., but did not install the NP relay. The SCE crew manually closed the network protector to address low voltage issues.

- On August 4, 2014, a vault at Ocean Blvd. and Pacific Ave. was replaced by contractors. New cable splices and sections were replaced during the vault replacement.

2015

- On June 18, 2015, an SCE employee found a network protector to be out of service at 3rd St. and Crystal Ct. The employee wrote a notification to distribution apparatus to see why the network protector was not set on “automatic” or if it needed to be programmed. The employee manually closed the network protector to address low voltage issues.

The following sequence of events describes the Long Beach network outage of July 15-18, 2015:

July 15

- At 3:07 pm on July 15, a fault[5] in an underground vault at Ocean Blvd. and Pacific Ave. caused a primary circuit to shut down. At 3:32 a second circuit shut down.

[4] Notification: A notification in the SAP System (enterprise resource planning software) is a software notation that allows the business to record, process, and manage different types of work.
[5] Fault: A fault or fault current is any abnormal electric current.

- At 3:45 pm, a fire occurred in a manhole at 3rd St. and Chestnut Ave. Two adjacent underground vaults also started smoking.

- At 4:19 pm, an SCE employee responded to smoking vaults on 3rd St. and Chestnut Ave. and requested that the circuit be shut down. It was later determined that the network protector in a vault at that location was backfeeding[6] load onto that circuit, causing damage to a secondary network cable.

- At 4:31 pm, the Long Beach Fire Department responded to fires in underground structures at 3rd St. and Chestnut Ave.

- Between 5:59 and 6:21 pm, three more circuits were shut down by SCE, and one circuit relayed to lockout.

- At 7:00 pm smoke was reported at two manholes at 9th St. and Pine Ave. An SCE employee cut and isolated secondary cable between the two manholes.

[6] Backfeed: A condition by which the normal flow of power is reversed thereby allowing secondary low voltage to energize primary high voltage circuits through transformers connected to the energized secondary system.

July 16

- Between midnight and noon on July 16, SCE re-energized and de-energized[7] several circuits to isolate, troubleshoot, and make necessary repairs.
- At 12:31 pm, SCE re-energized the secondary network. At this time cable splice failures in a vault at Ocean Blvd. and Pacific Ave. were identified.
- At 12:51 pm, an SCE employee reported smoke in the vault at Ocean Blvd. and Pacific Ave.
- At 12:52 pm, SCE de-energized three primary circuits and opened primary circuit breakers to isolate the secondary network.
- Between 6:38 pm and 8:20 pm, partial service was restored to two primary circuits

July 17

- Between 2:58 pm and 4:27 pm, SCE re-energized and de-energized additional circuits to isolate, troubleshoot, and make necessary repairs.
- By 8:56 pm, full service was restored on six primary circuits.

July 18

Full service to customers was restored either through generation or through the grid.

The following sequence of events describes the Long Beach network outage of July 30-August 3, 2015:

July 30

- At approximately 4:00 pm, on July 30 a cable failed and caught fire in an underground vault at 9th St. and Pine Ave.
- At 4:43 pm, a manhole cover blew off of the vault at 9th St. and Pine Ave.
- At approximately 4:50 pm, another manhole cover blew off of the vault at 9th St. and Pine Ave.
- At 5:08 pm, field crew reported multiple fires in those two vaults, and requested de-energizing the entire Long Beach network.
- At 5:13 pm, seven primary circuits out of Seabright and State substations were de-energized for network reliability and safety.
- At 5:30 pm, SCE crew reported that an oil switch failed, causing an arc in the vault at 9th St. and Locust Ave.

[7] De-energized: The status of an electrical circuit following the operation of opening a switch, opening a circuit breaker, or otherwise disconnecting it from a source of supply.

- Between 6:35 pm and 7:44 pm, partial service was restored to some circuits and substations.
- Between 8:29 pm and 8:49 pm, partial service was restored to one more circuit and all service was restored on another circuit.
- At 8:55 pm, an SCE employee reported the extent of damage to a cable in the vault at 9th St. and Locust Ave.
- Between 9:12 pm and 10:59 pm, partial service was restored on three circuits.
- At 11:03 pm, one of those three circuits was de-energized in an emergency (unplanned) outage to address additional discovered damage.
- At 11:08 pm, all service was restored to that circuit.
- At 11:46 pm, clearance was issued for SCE crew to repair the bad cable in the vault at 9th St. and Locust Ave.

July 31

- At 3:32 am, another circuit was de-energized in an emergency (unplanned) outage to address additional discovered damage.
- At 5:08 am, partial service was restored on that circuit.
- Between 8:38 and 11:09 pm, all service was restored on two more circuits.

August 1

- At 3:00 pm, power was restored to all Long Beach customers either through generation or through the grid.

August 3

- At 3:28 pm, the last customer's power was restored.

Immediate, Interim, and Corrective Actions

Immediate Actions

The following immediate actions[8] were started after the July 15th event and completed after the July 30th events:

- Replaced and repaired primary and secondary cable and components damaged in both July 15th and July 30th events;
- To address potential failure risks, made various repairs to the secondary network identified through approximately 300 structure inspections;
- The Incident Management Team was activated to respond to the July 15th and July 30th events, and communicated with city officials and customers;
- Made repairs to or replaced network protectors found with limited function;
- Performed detailed inspections to identify the current status of all network protectors;
- Completed inventory of spare components, ordered critical material, and expedited shipment of cable, cable limiter (secondary fusing) and secondary connector bar junctions, network protectors, NP relays, and network transformers.

Interim Actions[9]

The following interim actions were undertaken as a result of the July 15th and July 30th events:

- Identify and order replacement of secondary network materials including cable, network protectors, and NP relays to replace materials from the July 15th and July 30th events;
- Update minimum and maximum inventory counts of Long Beach network protectors, and all associated material and components;
- Revise and implement Long Beach network restoration guidelines;
- Update Long Beach downtown secondary network map with the results of the network protector detailed inspections, Long Beach secondary network underground structure inspections, and repairs made from both July 15th and July 30th events;
- Verify and correct network maps with updated customer count;

[8] Immediate Action: Steps taken without delay to resolve situations or conditions involving safety or similar concerns requiring prompt attention.
[9] Interim Action: An action taken once a problem is discovered to prevent or mitigate the effects of the problem, and/or minimize the probability of a repeat problem.

- Appoint interim secondary network owner to identify key contacts to improve coordination of work on the secondary network;
- Utilize the secondary network map and key contacts, and provide clear direction to operating personnel regarding whom to contact before commencing work on the secondary network;
- Verify secondary network underground structure locations and secondary cable status through distribution crew inspections on secondary network underground structures;
- Electrically separate the north and south secondary network into sections to limit reliability impacts to the southern secondary network grid and improve operation to the northern secondary network;
- Conduct inspections of network protectors to ensure proper operation, including fuses, NP relays, and grounds, and schedule repairs of identified equipment deficiencies;
- Issue Long Beach secondary network operating bulletin to instruct crews on the installation and maintenance procedure for addressing network protectors;
- Replace network protectors or associated NP relays identified as non-operational[10];
- Model Long Beach network to determine potential overloading conditions and initiate replacement of potentially damaged components.

Corrective Actions[11]

SCE's root cause evaluation identified several steps that the company is taking to prevent future occurrences events like those of July 15 and July 30. Some of these steps have already been implemented, while others are scheduled to occur in the coming weeks or months. For example, SCE has identified a network owner (the Long Beach Distribution Business Line District Manager); updated documentation of the network; improved processes for identifying and replacing equipment; and enhanced training programs for field employees.

[10] Non-operational: A network protector that is unable to perform its designed function

[11] Corrective Action: Measures taken to correct an adverse condition and to minimize the potential for recurrence of the condition. Measures taken to alleviate symptoms of a problem or to eliminate or diminish causes of problems.

The following corrective actions will be taken as a result of the July 15th and July 30th events:

Lessons Learned	Corrective Actions
There were insufficient work processes and organizational structure to support continuous operation of the Long Beach secondary network,	Develop a specific organizational structure that is dedicated to the Long Beach secondary network. Become a participating member of a utility industry network forum such as at the Electric Power Research Institute to obtain lessons learned and best practices for secondary network design, construction, and maintenance. Initiate changes and corrective actions as identified.
The work management process was not adequately established to ensure that NP relays were ordered, tracked, and installed prior to placing a network protector in service. This includes an inadequate process established for capturing missing NP relays.	Develop a work management process to ensure proper handling of network protectors and associated relays. Establish a process to ensure all newly installed Network Protectors without the necessary components are physically tagged as “Out of Service” and a Notification that will prioritize the installation of a NP relay and/or other components is generated.
There was no standard design configuration of primary circuitry for the Long Beach secondary network, which included a combination of radial system and secondary network.	Develop and implement design configuration and planning criteria for secondary network distribution system. This includes configuration of primary circuitry, and loading criteria.
There was a lack of adequate knowledge of the vulnerabilities and operational importance of the network protectors, NP relays, and secondary network system. This lack of knowledge resulted in network protectors being placed in service that were not able to perform their intended function due to missing NP relays.	Instruct SCE crews on the installation and maintenance procedures for addressing network protectors including periodic refresher training.
A model of the Long Beach secondary network did not exist.	Create a computerized model of the secondary network for normal operation and contingencies.
After removal of asbestos fire/arc proofing insulation, alternative methods for insulating primary circuit cables were not sought.	Install fire protection wrap on cable splices.

Lessons Learned	Corrective Actions
The SCE crew closed out the network protector inspection with no actions taken and did not return to complete the work request.	Conduct an All Hands meeting with Distribution Apparatus Crew members to review lessons learned of the Long Beach outage events specifically addressing not closing out equipment inspections with no actions taken, documenting deficiencies in SAP, and notifying Distribution Apparatus supervision of inaccessibility to underground structures and rescheduling the equipment inspection.
There was a lack of consistent, updated mapping and no formal mapping process for network map corrections of the Long Beach secondary network.	Update Long Beach Downtown secondary network map with the results of the Network Protector detailed inspections, Long Beach secondary network underground structure inspections, and repairs made from both July 15th and July 30th events. Improve the process for all mapping updates for Long Beach secondary network to ensure they are submitted through Western Mapping Office at Lighthipe.
There was limited automation and remote monitoring capability of network protector's status within the Long Beach secondary network.	Install radio, antennas, and monitoring equipment on all Long Beach Network Protectors. Develop and implement an Outage Management System (OMS) graphic interface to monitor secondary load on secondary networks.

Exhibit A

Performance Review Long Beach July 2015 Secondary Network Outages

INCIDENT SUMMARY

A Performance Review Team conducted an investigation into the cause(s) of the July 15, 2015 and July 30, 2015 outages in Long Beach. The Performance Review Team concluded:

On July 15, 2015, at 1507, the Float 12kV primary circuit breaker relayed to lock out, which was followed by a lock out of the Steam 12kV primary circuit. The Float 12kV primary circuit failure was due to a failed splice on the Float 12kV primary circuit; this failed splice leading to a primary circuit failure was the triggering event for the July 15th Long Beach event. After the Float circuit breaker locked out, a secondary network cable began to overload and fail in underground structure 5133092, 3rd St. & Chestnut Ave. This overload was caused by an in-service network protector 20649 not operating properly because of a missing Network Protector relay (NP relay), and an increase in cable loading in this area due to an adjacent network protector open and non-operational . This condition (NP 20649 closed without a relay) allowed the secondary network to backfeed the primary cable fault on the Float 12kV primary circuit. As a result of this backfeeding, and subsequent overloading of the secondary network cable, fires occurred in three adjacent underground structures within the secondary network, causing the company to pro-actively de-energize three 12kV primary circuits- Cargo, Ocean, and Alamo- due to their proximity to the underground structure fires. SCE de-energized the entire Long Beach secondary network in the interest of public safety and secondary network integrity. The July 15, 2015 outage resulted in approximately 30,706 customers losing power. The SCE Incident Management Team (IMT) was activated to coordinate and manage restoration efforts to safely re-energize the Long Beach secondary network which was accomplished on July 18, 2015, at 1248. All customers were removed from generation and back on the network by July 20th at 1:02pm. This was initially completed by isolating damages and dividing the secondary network into smaller sections, then restoring power to a section at a time. Ultimately the circuits feeding the network were simultaneously energized once the failure points were safely isolated from the network.

On July 30, 2015, at approximately 1600, a secondary network cable failed in underground structure 5132757, 10th St. & Pine Ave, and caused damage to the associated 12kV primary circuits, Dusk and Hoback, which feed the Long Beach secondary network. This damage caused those primary circuits to relay and lock out, and two fires occurred in underground structures within the Long Beach secondary network. At 1713, SCE de-energized the State and Seabright substations, which feed the secondary network, to prevent further damage to the

secondary network. The July 30, 2015 outage impacted approximately 17,989 customers. The impact of the July 30th outage was less than the impact of the July 15th outage because secondary network isolation lessons learned from the July 15th event were applied. All customers had power restored by the night of August 1st, and were removed from generators and back on the grid on August 3rd, at 1528.

The July 30th outage was triggered by the failure of a secondary network cable. The network cable had degradation caused by high currents during the July 15th event when NP 28113 did not open to clear the backfeed current of radial connected load on the Cargo circuit. NP 28113 did not open due to the lack of the installation of an NP relay.

The overall restoration efforts for both outages required approximately 475 response personnel. Approximately 300 network structures were visually inspected and heat scanned, including the inspection of 62 Network Protectors. Approximately 4,500 feet of network cable was replaced and 428 individual tethers were installed in 278 structures.

BACKGROUND

Radial System

Distribution systems in the SCE service territory are generally designed “radially” where there is one source of power. Secondary electricity flows in one direction, and failure of a single component can result in electrical service disruptions.

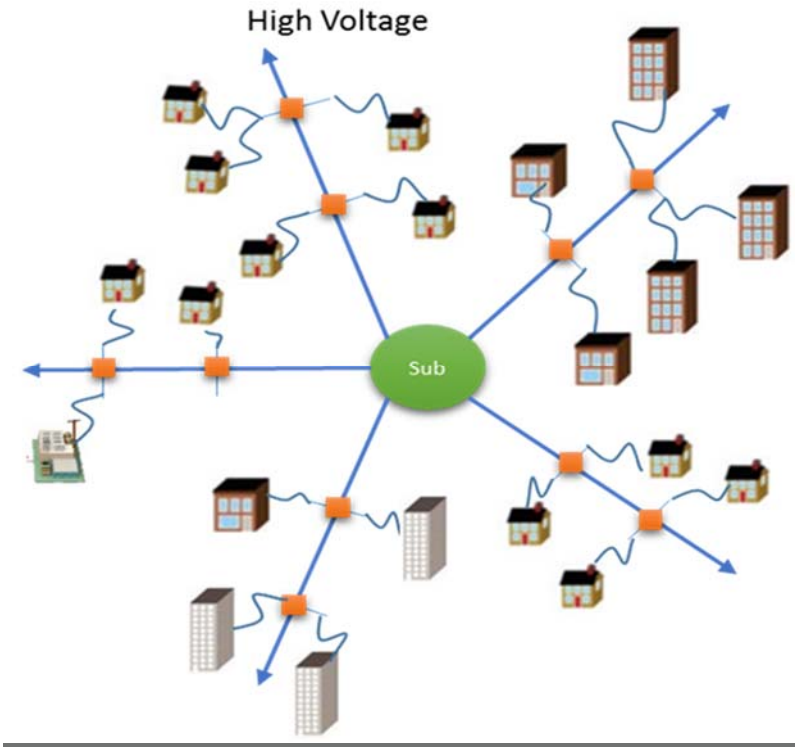


Figure 1: Radial System

Network System

Long Beach is the only city in the SCE service territory served by a secondary network. The secondary network is designed to meet the needs of approximately 3,800 customers within the Long Beach urban area. The Long Beach secondary network is designed to prevent service interruption due to the loss of one or more system components. It utilizes multiple sources of power and secondary electricity flows in multiple directions. Secondary cables are connected to multiple sources in a primarily underground secondary network of cables. The main components

of a secondary network system are: network transformers, network protectors, secondary cables, cable limiters, and secondary network connector bar junctions.

The Long Beach secondary network is served from multiple substations and primary circuits. In addition to the secondary network, 12kV primary circuits feeding the secondary network also serve approximately 26,000 additional customers via a traditional radial system.

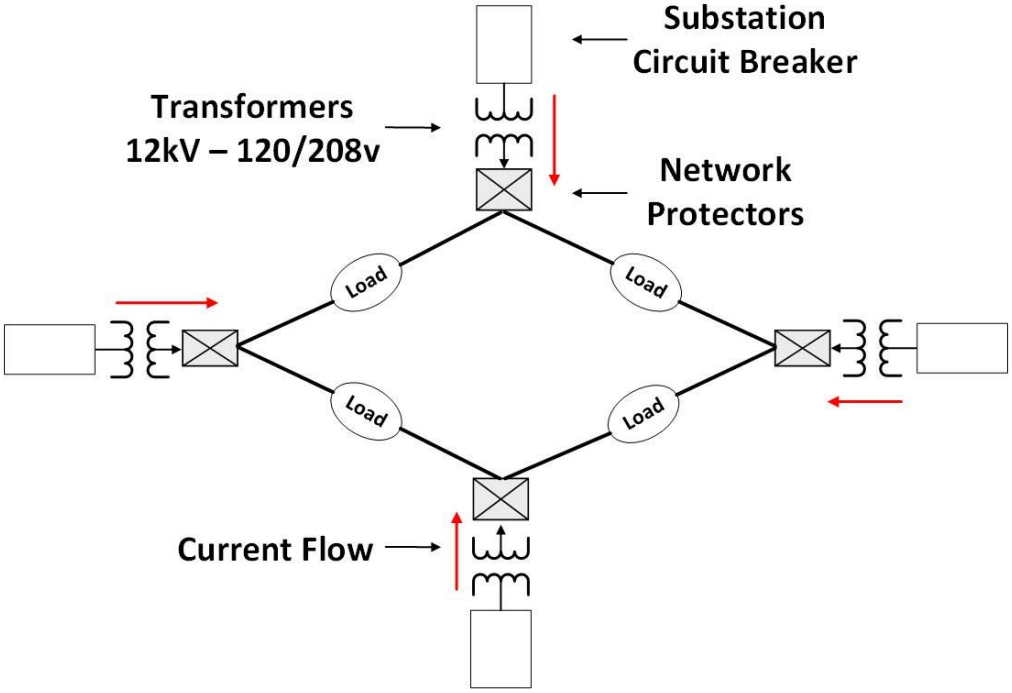


Figure 2: Network System

Network Protector

One of the major functions of the NP relay is to open a Network Protector, which automatically disconnects its associated power transformer from the secondary network, when current starts flowing in the reverse (unintended) direction. This function prevents the secondary network from backfeeding a fault, such as a cable splice failure on the primary feeder circuit, thus preventing the secondary cables from overloading and degrading until failure.

PROBLEM STATEMENT

Requirement

SCE is committed to providing safe, reliable, and affordable electric service to its customers.

Deviation

Beginning on July 15, 2015, and July 30, 2015, portions of the downtown Long Beach area experienced an extended unplanned power outage.

Consequences

Actual consequences included loss of electrical service to SCE customers and damage to SCE distribution equipment.

ANALYSIS AND CAUSES

Four primary analysis methodologies were used to determine causes. The primary analysis methods used were: (1) Event and Causal Factor Analysis (Attachment 3), (2) Barrier Analysis (Attachment 4), (3) Organizational & Programmatic Analysis, and (4) Process Flow Analysis (Attachment 5)

Event and Causal Factor Analysis

An Event and Causal Factor Chart Analysis (E&CF Analysis) was utilized in order to determine the Inappropriate Actions (IA), Equipment Failures (EF), and subsequent **Root and Contributing Causes** that led to the Long Beach secondary network outage events on July 15th and July 30th. These analyses identified the triggering event occurred during **Equipment Failure 1 and 2,** and four **Inappropriate Actions** were identified as the causes for the subsequent **Equipment Failures 3, 4, and 5**, all of which resulted in the Long Beach secondary network being de-energized on July 15th and July 30th. Removal of these Inappropriate Actions would have mitigated or prevented these events from occurring.

Detailed Equipment Failures & Associated Inappropriate Actions

On July 15, 2015, at 9:28 AM, to complete scheduled work to replace a Gas Switch, the Bow and Admiral 12kV circuits where transferred to the Float 12kV and Steam 12kV circuits respectively. Transferring circuits is a daily and routine activity that is completed in order to make repairs. The transfers resulted in the Float 12 kV circuit carrying approximately 270 Amps of the Bow 12kV circuit load to peak of 295 Amps. The Steam 12 kV circuit carried approximately 260 Amps of the Admiral 12kV circuit load to peak at 345 Amps. The loading on both of the circuits in this state was adequate for cable capacity, which was 550 Amps Planned Load Limit on the Float and Steam 12kV circuits.

At 1619, SCE personnel arrived at underground structure 5133093 (near 3rd St. and Chestnut Ave.) where secondary cables were burning in the underground structure. The Float and Steam 12kV primary circuits had previously locked out. Police and Fire departments were on the scene and pedestrian traffic was light. The Float and Steam 12kV primary circuits locking out and subsequent fires within structures throughout the secondary network were the result of **Equipment Failures 1, 2, 3 and 4.**

Equipment Failure 1 was a primary cable splice failure that caused a fault in underground structure 5134053 (Ocean Blvd. & Pacific Ave.) and locked out the Float 12kV circuit at 1507, on July 15th. The Float 12kV primary splice failure was the triggering event for the July 15th outage.

The visual inspection and dissection of the cable splice was conducted and certain risk factors were identified. The damage on the Float splice was significant and the cause of its failure was indeterminate.

Equipment Failure 2 occurred when a splice adjacent to the Float 12kV primary splice in the same underground structure on the Steam 12kV primary circuit failed and caused the Steam 12kV primary circuit breaker to relay 25 minutes after the Float 12kV circuit breaker relayed.

The single most significant risk factor identified on the Steam 12kV cable splice was craftsmanship. The conductive material and paper insulation interface were found to not have been removed from the splice as required by the manufacturer's installation instructions. Failure of the Float splice may have exposed the inherent internal weaknesses on the Steam splice due to craftsmanship. It is indeterminate what the impact of the Steam splice failure was to the overall events.

Equipment Failure 3 was a cable fire that occurred in underground structure 5133092 (3rd & Chestnut) at approximately 1545, as a result of overloading on the secondary network. The

overloading was caused by backfeeding from the secondary network into the Float 12kV primary circuit. Network Protector 20649 was not operating as designed which allowed current to backfeed into the failed Float splice fault, and any connected radial load on the Float 12kV primary circuit.

Network Protector 20649 was manually placed in service by a crew on June 18, 2015 while responding to low voltage in the area. The operating handle was in the "CLOSED" position, and the NP relay was not installed. Without the relay installed the Network Protector main contacts will not automatically open during reverse current flow in order to prevent backfeed onto the primary circuit. This condition was the result of **Inappropriate Actions 1 and 4.**

Inappropriate Action 1 was a missing NP relay in Network Protector 20649. The following critical actions led to this Inappropriate Action.

On December 17, 2007, a new Network Protector 20649 and NP relay were installed. At a later unknown date, the relay was removed and the operating handle was in the "OPEN" position. Due to the transition in the work management system to SAP, the records for the installation are not available. It is unknown when or why the NP relay was removed and why no action was taken to replace the NP relay.

When Network Protector 20649 was installed, the Apparatus Crew's records identified that additional wiring was needed to automate the Network Protector and complete the installation. The Network Protector was inspected in October 2008. This inspection does not identify the details of the Network Protector and if it was then in the "OPEN" or "CLOSED" position.

On October 15, 2010, a Distribution Apparatus Crew performed an inspection (3 year cycle) of Network Protector 20649 and documented in the notes that the relay was missing.

On March 15, 2013, a Distribution Apparatus Crew closed out the Network Protector inspection with no actions taken and did not return to complete the Work Request

During the inspections on October 15, 2010 and March 15, 2013, Distribution Apparatus personnel did not take the necessary steps to install the missing NP relay. Information was not programmatically captured to ensure equipment deficiencies were properly addressed. The Apparatus Crew did not generate a Notification to install the NP relay on either inspection date because their internal inspection notes were considered an acceptable practice for identifying discrepancies. There were no formal expectations established for capturing missing NP relays in SAP because that criteria was not established. The Apparatus Training & Qualification Program is based on conducting the inspections, and not how to create notifications. All

Apparatus Crews receive initial training on the Long Beach secondary network equipment regardless of their work location. There is no ongoing refresher training, and no retraining for those who are newly assigned to work at the Long Beach District.

On June 18, 2015, a Long Beach District Crew found Network Protector 20649 in the open position and wrote Notification 407095747 for Distribution Apparatus to assess why it was not in the automatic position, as expected, or if the Network Protector needed to be programmed. The Long Beach District Crew member selected Special Programs (Special/Special) because there was no specific NP relay installation Object Type in SAP, and added notes to the body of the Notification, then manually closed the Network Protector. A Distribution Apparatus Crew did not install the missing NP relay in Network Protector 20649 prior to July 15, 2015.

Distribution Apparatus had an informal process for tracking Network Protector installations and no ability to query for specific Network Protector Notifications pending in SAP. This means that the Distribution Apparatus SAP Gate Keeper has to query for pending work against Network Protectors and Notifications related to the underground structure and transformer associated with a Network Protector. This is an insufficient process to ensure that Notifications are being vetted in order to capture Network Protector related items. There is no visibility by the Apparatus Crew members of the District's schedule to replace Network Protectors and NP relay Work Orders are managed independently from District Work Orders.

Additionally, there is an internal document published by the Design Support Organization titled Work Orders, Issue 1B-09. This document outlines the Apparatus Equipment Work Order Process for the installation of new Distribution Apparatus equipment and Network Protectors. This process was not fully implemented to ensure formal roles and responsibilities were established for scheduling, planning, or installing Network Protectors or their relays.

Inappropriate Action 4 was placing Network Protector 20649 in service without a NP relay. It was determined that four critical actions led to this Inappropriate Action:

1. The NP relay was installed at the time the Network Protector was installed and later removed for unknown reasons,
2. The missing NP relay was identified as missing during the 3 year equipment inspections but never installed,
3. No signage or tags identifying the Network Protector as being non-operational, and
4. Priority was given to address customer low voltage issues over Network Protector protective function.

As described previously, on June 18, 2015, a Long Beach District Crew found the Network Protector 20649 operating handle in the open position and it was determined that, in order to address a low voltage call in the surrounding area, a Long Beach District Crew member, or Troubleman, placed the Network Protector in service (operating handle in closed position). There was no process present to prevent Long Beach District Crew members from placing a Network Protector in service. Appropriate signage or tags stating “Not OK for Service” would have identified the Network Protector as being non-operational and pending NP relay installation. The District’s immediate concern was to address the customer low voltage problem. At that time, there were no established expectations for the Long Beach District Line Crews to place tags identifying the Network Protector as being “Out of Service”.

Network Protectors were not identified as a critical protection device for the secondary network as well as the primary circuitry feeding the secondary network, ensuring safety and reliability. This knowledge was not established as an expectation and the Long Beach District personnel were not provided sufficient training about Network Protectors.

Equipment Failure 4 was a cable fire that occurred in underground structures 5132734 and 5132735 (9th St. & Pine Ave). During the fire previously described in **Equipment Failure 2**, additional underground structures were being affected due to the spreading of fire through the associated duct banks. At 1619, a Troubleman responded to smoking underground structures 5133093 and 5133091 (3rd St. & Chestnut Ave.) and requested No Test Orders (NTO) on the Cargo 12kV primary circuit. Unable to access underground structure 5133092 and contain the spread of the fire, the Troubleman requested Grid Operations de-energize the Cargo 12kV primary circuit.

After de-energizing, the Cargo 12kV primary circuit began experiencing backfeed from the secondary network due to the loss of this primary feeder circuit. The backfeed was a result of **Inappropriate Action 3,** which was Network Protector 28113 being in the manual closed position, and **Inappropriate Action 2,** a NP relay not being installed. This allowed current to flow from the secondary network onto the Cargo 12kV primary circuit. The Network Protector 28113 was found by a Distribution Apparatus Crew with the operating handle in the closed position and the Network Protector main contacts in the closed position. Without the NP relay installed, the Network Protector main contacts cannot automatically open to prevent backfeed.

Inappropriate Action 2 was the missing NP relay in Network Protector 28113, which eventually caused the degradation to the secondary network cables that lead to the Long Beach outage on July 30th. The following critical actions led to this Inappropriate Action.

Network Protector 28113 was installed on July 31, 2014 without a NP relay, and was placed in service not able to perform its intended protection function.

A chronology outlining the history of Network Protector 28113 is as follows:

On March 3, 2013 a Troubleman responded to a low voltage call and determined that Network Protector 20710 would not close when in the “Auto” position. To correct the low voltage condition, the Troubleman manually closed Network Protector 20710 which fixed the low voltage issue and Notification 405044601 was created for Distribution Apparatus to repair. On April 16, 2013, Distribution Apparatus was unable to make the repairs and generated Notification 405147182 to replace Network Protector 20710 with a new Automated Network Protector[12].

[12] Automated network protectors operate the same as non-automated network protectors. The automation provides current and voltage measurements to Operators, and in most cases the automation provides operational status of the network protector relay, the ability to trip open the network protector, and the Open/Closed status of the Network Protector.

On July 31, 2014 Long Beach District Crew installed the new Automated Network Protector 28113, replacing 20710, and informed Distribution Apparatus via a phone call that the NP relay still needed to be installed. An SAP Notification was not generated and there was no option in SAP to create a specific, separate Notification to install, repair, or replace a NP relay. When SAP was implemented in 2008 the NP relays were not formally identified as a required component that would be installed separately from the Network Protection, by two different groups, before it could be placed in service.

At the time of the event, a phone call or email to Distribution Apparatus after the Network Protector was installed was an accepted practice. The process outlined in DSU 1B-09 stated that Distribution Apparatus Crews were to be notified three weeks in advance before scheduling the work. This practice led to inadequate communication standards between the District Crews and Distribution Apparatus.

Inappropriate Action 3 was placing Network Protector 28113 in service without a NP relay. It was determined that the following two critical actions led to this Inappropriate Action:

1. Apparatus did not install NP relay at time the Network Protector was installed.
2. Immediate concern was addressing customer low voltage.

On July 31, 2014, a Long Beach District Crew replaced Network Protector 20710 with a new Automated Network Protector 28113. At the time of installation, the existing Network Protector 20710 was placed in service (manual closed position) to mitigate the low voltage issue in the area. The District Crew installed the new Network Protector without a NP relay and placed it in the closed position as their immediate action was to address the customer low voltage problem.

Network Protectors were not consistently identified as critical protection devices and proper training was not given to implement that expectation.

Equipment Failure 5 was a secondary cable that failed resulting in a fire that developed in underground structure 5132757 on July 30th, at approximately 1600 - 1643. This was a result of high heating in the secondary network cabling due to backfeeding of the primary radial load on the Cargo 12kV circuit during the July 15th event. During the July 15th event, a Troubleman had Grid Operations de-energize the Cargo 12kV primary circuit. Doing so caused the remaining network transformers to pick up load dropped by the Cargo network transformers. Unknown at the time, this caused cable degradation between underground structures 5132757 and 5132758 as this was the main path of travel of the backfeed during the July 15th event. As a result, the run between underground structures 5132758 to 5132760 was also damaged due to high

loading. During the restoration, District Crews were unable to pull new cable between underground structures 5132758 to 5132760 due to a damaged duct bank section between these structures.

After de-energizing, the Cargo 12kV circuit began experiencing backfeed from the secondary network as a result of **Inappropriate Action 3** which was Network Protector 28113 being in the manual closed position, and **Inappropriate Action 2** which was a NP relay not being installed. This allowed current to flow from the secondary network onto the primary circuitry and led to high loading on the secondary cables on 9th and 10th Streets, which led to cable degradation. Eventually, these secondary cables began to fail and catch fire in underground structure 5132757, burning the Dusk and Hoback 12kV primary circuits and the Oregon 4kV circuit resulting in the Long Beach July 30th outage event.

Potential Causes (refuted):

The following potential causes were considered and evaluated and determined to not have contributed to equipment failures associated with the Long Beach outage events:

Equipment Failure 1 (EF-1): A fault in underground structure 5134053

- Secondary equipment failure causing fault duty
- Design changes by manufacture to splice design JJ507 (Joints & Junction)
- Overloading to primary circuit
- Previous backfeed on the Float 12kV primary circuit
- Other internal electrical factors
- Any other potential external factors such as natural disasters, animals, vandalism, etc.

Equipment Failure 3 (EF-3): Fire occurs in underground structure 5133092

- Secondary connection failure
- Primary cable failed in vault 5133092
- Other external factors
- Connector-bar equipment failure of incorrect cable-limiter size
- Connector-bar excessive cable -limiter heat
- Any other potential external factors such as natural disasters, animals, vandalism, etc.

Equipment Failure 5 (EF-5): Secondary cables fail and catch fire in underground structure 5132757

- Primary cable failed (fault duty)
- Any other potential external factors such as natural disasters, animals, vandalism, etc.
- Grid was jeopardized because cable that ran south of the fault was taken out of service
- Connector-bar, limiter bus failure contributed to the fire
- Bad connector due to LB1 incident (weakened connection)

Barrier Analysis

The effectiveness of each existing barrier was considered, and apparent barriers that failed, and the cause of those failures were identified.

These findings were compared to the E&CF analysis to ensure alignment. The five barriers that were determined ineffective were: Installation, Inspections, Records, Operating Procedures, and

Configuration Control. Had these barriers existed, they would have helped prevent the Long Beach secondary network outages on July 15th and July 30th.

Process Flow Analysis

The existing process for managing Network Protectors was reviewed. Five Network Protectors were installed without NP relays, and one was configured incorrectly and unable to perform its intended function. Two of the Network Protectors missing NP relays were found in the closed position (NP 20649 & 28113), unable to perform their intended protective function, and allowed the secondary backfeed on the primary circuits during the Long Beach outage events.

The "Installation of Network Protectors (NP) Process Flow Analysis" chart (Attachment 5) describes the process of installing a Network Protector with a NP relay and placing it in service. The chart also identifies deficiencies in the existing process that were attributed to the **Root Cause**. All of the deficiencies have also been captured within the Event and Causal Factors analysis (E&CF Analysis).

The following deficiencies were identified:

- Network Protector can be inadvertently ordered without NP relay
- Informal process for Long Beach District Crew to communicate Network Protector status to Field Apparatus
- No SAP NP relay option in Notification Object Type
- No formal SAP Notification process for installing a NP relay
- Long Beach District does not formally schedule Distribution Apparatus when installing Network Protector
- Informal tracking of NP relay after installation of Network Protector by district
- Inadequate communication process between Long Beach District and Distribution Apparatus
- Work Orders which provided the documents (i.e. maps, timesheets, permits, etc.) necessary to complete the work were managed independently
- Inadequate district crew training of Network Protectors
- Work Requests which provided a notification of work to be completed were managed outside of SAP

Organizational & Programmatic Analysis

The team concluded the following Root Cause led to the July 15th and July 30th events.

Root Cause (RC): Insufficient work processes and organizational structure to support continuous operation of the Long Beach secondary network.

The following details were the basis for the Root Cause:

- Oversight and governance over the Long Beach secondary network was not sufficient to preempt and address ongoing network vulnerabilities. Conditions included:
    - Lack of consistent, updated mapping and no formal mapping process for network map corrections of the Long Beach secondary network
    - No standard design configuration of primary circuitry for the Long Beach secondary network (e.g. combination radial system and secondary network circuits)
    - Limited automation and remote monitoring capability of Network Protectors status within the Long Beach secondary network
    - A model of the Long Beach secondary network did not exist
    - After removal of asbestos fire/arc proofing insulation, alternative methods for insulating primary circuit cables were not pursued
- The work management process was not adequately established to ensure that NP relays were ordered, tracked, and installed prior to placing a Network Protector in service. This includes an inadequate process for not capturing the missing NP relays.
- Lack of adequate knowledge of the vulnerabilities and operational importance of the Network Protectors, NP relays, and secondary network system. This lack of adequate knowledge resulted in Network Protectors being placed in service that were not able to perform their intended function due to missing components(NP relays).

In regards to the process aspect of the **Root Cause,** the Long Beach District and the Distribution Apparatus Organization developed independent work processes which did not coincide, and a lack robust coordination between the two processes contributed to the Long Beach outage events. The process for ordering, tracking, and installing Network Protectors by the Long Beach District Crews was independent from the process for Distribution Apparatus to track and install NP relays, and to place them in service. An expectation for Long Beach District Crews to follow up with the Distribution Apparatus Organization once the Network Protector was installed was not established. Once the Network Protector was installed the District Crew would close the Notification and associated Work Order. Then the Distribution Apparatus Organization would have to create and charge to its own Work Order. The process for ensuring NP relays are installed prior to placing Network Protector in service was not effective and did not include a

specific process for communicating a Network Protector was missing a NP relay. Other Network Protectors identified as being out of service and missing a NP relay were identified as Priority 2 in SAP with a due date of up to 2 years.

The Long Beach District Crew's process for ordering and installing Network Protectors was to notify Distribution Apparatus via a phone call or email stating that a NP relay needed to be installed after the installation a Network Protector. The manager or supervisor taking the call would document the request which was managed informally through logs and files. Steps were not taken to implement a work management process, or formalize communication between the Long Beach District and the Distribution Apparatus Organization.

In regards to the knowledge aspect of the **Root Cause,** the historic reliability of the secondary network reduced the focus on network maintenance by the Long Beach District. Additionally, Subject Matter Experts left the district without conducting detailed knowledge transfers. As network experts left, the knowledge gaps were not filled.

Long Beach is the only city in the SCE service territory with a secondary network. This is a unique system with unique equipment, such as Cable-Limiters and Network Protectors. However, Network Protector training is only offered to members of the Distribution Apparatus crew during their initial training. Apparatus Crew members can go years without seeing or working on a Network Protector but would be expected to perform inspections, routine maintenance, or emergent work on Network Protectors upon entering the Long Beach district.

District Crew members may receive limited training about the secondary network if they complete their Lineman Apprenticeship Training while working at the Long Beach District. District Crew members who have transferred from other districts and complete their Lineman Apprenticeship Training outside of the Long Beach District may not receive training at all. Without proper training, District Crews may not be aware of the repercussions of putting a Network Protector in service without a NP relay. There is a knowledge gap in both the Long Beach District Crews and Distribution Apparatus Crews as to the vulnerabilities and operational importance of the Network Protectors, NP relays, and secondary network System.

In addition, other factors supported the Root Cause, such as a fragmented responsibility and accountability for Network Protectors within the Long Beach secondary network. A lack of a specific secondary network organization made it difficult to implement a process unique to the secondary network which would include elements such as preventative maintenance and improved visibility of equipment inspections affecting secondary network reliability.

Another indicator of the Root Cause is that System Operating Bulletin 310 (SOB310) was not designed to address issues within the secondary network. There was no specific secondary network organizational driver to develop and implement new restoration processes for other scenarios. Related deficiencies included:

- No Outage Management System (OMS, graphic interface for Grid Operations management of the network system) and insufficient network Oversight & Management (Long term planning for automation program). Lack of automation was previously identified as an issue, however, there was insufficient follow-through to correct this.
- A lack of adequate monitoring of the Long Beach network. Without a specific secondary network organizational structure, the monitoring initiative was not completed as individual network experience left the Long Beach district
- Lack of consistent, updated mapping and no formal mapping process for network map corrections of the Long Beach secondary network allowed the opportunity for personnel to make decisions without the most accurate information.

A 2011 PowerPoint presentation titled “Long Beach Network System Update” outlines a summary of findings and recommendations for ongoing restoration of the Long Beach secondary network. The key recommendations in the report suggested upgrading some (25) of the network protectors, to further evaluate the network system requirements, refresh the current contingency plan, order spare equipment for emergency purposes, and to consider new fusing materials. The Network Protectors were ordered and installed, one spare transformer and two spare Network Protectors were ordered and in the inventory. However, other recommended actions were not taken.

Over the years, a situation developed of limited oversight in implementing Long Beach secondary network recommendations provided by subject matter experts as some recommendations have either not been initiated or completed. The loss of visibility over these recommendations is an indicator of the fragmented responsibility and accountability over the Long Beach secondary network.

Design Support Update Issue 1B-09 (DSU 1B-09) is an internal process developed by Design Support to address the Apparatus Equipment Work Order Process. This Work Management process was insufficient to ensure the completion of proper installation of NP relays in Network Protectors. The process encompassed multiple organizations, and there were communication gaps between these groups due to the lack of a specific secondary network organizational structure that can define, drive, and oversee an effective Work Management process.

Extended Lessons Learned

Other areas of exposure similar to those presented by the informal work management process- specifically the informal communication process (via email or phone call) between the District Crew and Distribution Apparatus Crew- that allowed critical NP relays not to be installed in Network Protectors. Informal communications also exist for the installation of other protective equipment located outside the secondary network, such as Automatic Reclosers and Vacuum Fault Interrupters. This will be corrected by expanding the corrective action to implement a formal Work Management process for installation of NP relays to include the following secondary network components: Automatic Reclosers and Vacuum Fault Interrupters (See **Corrective Action CA-2**)

In addition, there were not adequate parts/supplies to immediately restore the system. There were not enough cable limiters and NP relays available. Many of the equipment needed to restore the network were specialized and applied to the Long Beach network only. Although availability of parts and supplies did not directly contribute to the cause of the event, it was important to capture in order to ensure effective restoration efforts in the event of another outage and Interim Actions 1 and 2 **(IA-1 and IA-2)** were implemented to address this.

IMMEDIATE ACTIONS TAKEN

The following Immediate Actions were steps taken without delay to resolve situations or conditions involving safety or similar concerns requiring prompt attention. These were completed after the July 15th and July 30th events:

Network Field Recovery Activities

- Immediate Action 1: Replaced and repaired primary and secondary cable and components damaged in both July 15th and July 30th events
- Immediate Action 2: Made repairs to potential risks to the secondary network identified through approximately 300 secondary network structure inspections
- Immediate Action 3: Made repairs to or replaced Network Protectors found with limited function

Network Inspection

- Immediate Action 4: Performed detailed inspections to identify the current status of all Network Protectors

Reporting

- Immediate Action 5: Reported both July 15th and July 30th incidents to the California Public Utilities Commission (CPUC)

Material

- Immediate Action 6: Completed inventory of spare components, ordered critical material, and expedited shipment (cable, cable limiter and connector bar components, Network Protectors, NP relays, and Network Transformers)

INTERIM ACTIONS

Interim Actions are taken between the time a problem is discovered and when the final actions are complete to prevent or mitigate the effects of the problem, and/or minimize the probability of a repeat problem. The following Interim Actions were taken as a result of the July 15th and July 30th events:

Material Acquisition

- Interim Action 1: Identify and order replacement of secondary network materials (e.g., cable, Network Protector, NP relays) to replace materials from the July 15th and July 30th.
- Interim Action 2: Update minimum and maximum inventory counts of Long Beach Network Protectors, and all associated material and components.

Mapping & restoration guidelines

- Interim Action 3: Revise and implement Long Beach Network Restoration Guideline.
- Interim Action 4: Update Long Beach Downtown secondary network map with the results of the Network Protector detailed inspections, Long Beach secondary network underground structure inspections, and repairs made from both July 15th and July 30th.
- Interim Action 5: A) Complete interim Transformer Load Management (TLM) map to update customer count. B) TLM map verification and correction.

Ownership & Process

- Interim Action 6: Appoint interim secondary network owner to identify key contacts to improve coordination of work on the secondary network.
- Interim Action 7: Utilize the secondary network map and key contacts, and provide clear direction to operating personnel regarding whom to contact before commencing work on the secondary network.
- Interim Action 11: Issue Long Beach secondary network Operating Bulletin to instruct T&D crews on the installation and maintenance procedure for addressing Network Protectors.

Inspection & field verifications

- Interim Action 8: Verify secondary network underground structure locations and secondary cable status through Distribution Crew inspections on secondary network underground structures.

Operational improvements

- Interim Action 9: Electrically separate the North and South secondary network into sections to limit reliability impacts to the southern secondary network grid and improve operation to the northern secondary network.
- Interim Action 10: Conduct inspections of Network Protectors to ensure proper operation, including fuses, NP relays, and grounds, and schedule repairs of identified equipment deficiencies.
- Interim Action 12: Replace Network Protectors or associated NP relays in Network Protectors identified as non-operational.
- Interim Action 13: Model affected areas of the secondary network to determine potential overloading conditions and initiate replacement of potentially damaged components.

EXTENT OF CONDITION

With respect to the July 15th and July 30th Long Beach secondary network events, the Performance Review Team concluded that the following potential issues could lead or contribute to a similar event. These potential issues led to Immediate, Interim, and Other Actions described above:

- EOCo 1: Vulnerabilities on the secondary network. The secondary network was vulnerable because of outstanding and unidentified repairs and unverified circuit maps. Interim Actions 4, 8, 10, and 13, were implemented to address these conditions.
- EOCo 2: Non-operational Network Protectors. Network Protectors that are non-operational, and the causes for and effect of their non-operation, have been identified. Interim Actions 10, 11, 12, and 13 address this condition.
- EOCo 3: Outdated mapping for secondary network. Out-of-date mapping for the secondary network has hindered decision-making ability when addressing secondary network issues. Interim Actions 4, 5, and 8 were implemented to correct this condition.
- EOCo 4: Insufficient coordination and visibility of secondary network operations and maintenance. The lack of a single contact, gatekeeper, and/or owner for work on the secondary network reduced and hindered coordination of work on the secondary network. Interim Actions 6 and 7 were implemented to address these conditions.
- EOCo 5: Lack of fire protection on the splice of primary cables. Corrective Action 27 (CA-27) was implemented to mitigate this condition.
- EOCo 6: System Operating Bulletin (SOB) 310 is a System Operating Bulletin used by Grid Operations to restore power to the Long Beach Network. It was not designed to address failures of multiple circuits feeding the Long Beach secondary network or failure

within the Long Beach secondary network. Interim Actions 3 and 9 were implemented to address this condition.

- EOCo 7: Insufficient secondary network related material stocks. Critical material stocks were not sufficient to enable repairs needed on the secondary network. Interim Actions 1 and 2 were implemented to correct this condition.

BENCHMARKING SECONDARY NETWORK

Electric Power Research Institute (EPRI) has a deep body of work in secondary networks. Their 10 year effort has been driven by industry participants, such as Consolidated Edison, Pacific Gas & Electric, Southern Company, and a number of others operating secondary networks. They perform everything from full scale testing to deep technical classroom style theory training.

SCEs recent participation, prior to the July 15th and July 30th events, with EPRI in this Network Group was limited.

Benchmarking was performed by the Performance Review Team to initially help understand the events and develop initial actions in response to the events. Additionally, SCE participated in the Electric Power Research Institute's (EPRI) Urban Network Practice Inventory 2015 Survey with those in the industry.

There were a total of 103 questions documented in the EPRI survey response. Of the 103 questions, SCE was in line with the industry in 64 of the questions, SCE was different from the industry in 36 of the questions, and three questions did not apply. The area that SCE most conflicted with the industry was in design.

An analysis of the SCE and industry responses showed some of the following significant items to consider where SCE differed from the industry:

- Network monitoring capabilities
- Primary feeder circuits having tie points with other feeder circuits
- Dedicated primary feeder circuits
- Fire wrapping of primary cables

In addition, members of the team participated in a 90 minute conference call with EPRI Senior Program Managers and a Georgia Power Principal Engineer to discuss best practices for secondary network system automation, inspection cycles, dedicated primary circuit feeders, and sectionalizing the secondary network.

DISCLAIMER

Consistent with the SCE philosophy that all problems are thoroughly understood, this cause evaluation evaluates, through the use of an after-the-fact hindsight-based analysis, conditions adverse to quality and the causes of those conditions. The information identified in this cause evaluation was discovered and analyzed using all information and results available at the time it was written. These results and much of the information considered in this evaluation were not available to the organizations, management, or individual personnel during the time frame in which relevant actions were taken and decisions were made. Cause evaluations have been established as a means to document and assure that problems are identified and corrected.

This cause evaluation does not attempt to make a determination as to whether any of the actions or decisions taken by management, vendors, internal organizations, or individual personnel at the time of the event were reasonable or prudent based on the information that was known or available at the time they took such actions or made such decisions. Any statements or conclusions included in the evaluation as to whether errors may have been made or improvements are warranted are based upon all of the information considered, including information and results learned after the fact and evaluated in hindsight after the results of actions or decisions are known, and do not reflect any conclusion or determination as to the prudence, reasonableness, or negligence of actions or decisions at the time they were made. SCE is not disclosing the contents of any privileged communications and does not intend to waive attorney client privilege or attorney work product protection by virtue of any disclosure of this cause evaluation.

The reason for the addition of this information is to make clear to outside reviewers that the cause evaluation is not a “reasonableness” or “prudence” review or a liability assessment, and to prevent statements and conclusions included in cause evaluations from being used out of context.

This language does not change how we do cause evaluations, but reflects current practice. In particular, cause evaluations should continue to be critical, thorough, and accurate in identifying the reasons why adverse conditions or events occurred and what corrective action is needed to address them and, as appropriate, to prevent recurrence.

ATTACHMENT 1: Corrective Action Matrix

NOTE: As of October 19, 2015, entering the corrective actions status and/or closure date will not be made in this report. All tracking and closure dates will be entered into a separate spreadsheet titled “Long Beach Outages Corrective Actions” and is available by contacting any one of the sponsors, leads, or team members identified in this report. The Corrective Action spreadsheet is considered the formal document for tracking corrective actions.

ATTACHMENT 1: Corrective Action Matrix

Cause Evaluation Element	Description
Problem Statement SCE is committed to providing safe, reliable, and affordable electric service to its customers. Beginning on July 15, 2015, and July 30, 2015, portions of the downtown Long Beach area experienced an extended unplanned power outage.	On July 20, 2015 and August 3, 2015 respectively, SCE Long Beach customers affected by these two outages had power restored. Conduct a Cause Evaluation.
Root Cause (RC): Insufficient work processes and organizational structure to support continuous operation of the Long Beach secondary network.	CA-1: Develop a specific Long Beach secondary network organizational structure that is dedicated to the Long Beach secondary network system, with the following attributes: Network Owners Group, meeting structure with defined agenda items, performance monitoring criteria, industry engagement expectations, etc., and periodic reports sent to the T&D VP. This action can be closed by documenting the approval of this standard by the Long Beach Network Owners Group to the T&D VP.

Cause Evaluation Element	Description
Root Cause (RC): The work management process was not adequately established to ensure that NP relays were ordered, tracked, and installed by Distribution Apparatus prior to placing a Network Protector in service.	CA-2: Develop and implement a documented Work Management Process that captures the details and responsibilities of the Distribution Apparatus Organization and the Long Beach District for inspecting, identifying, capturing, ordering, tracking, and installing Network Protectors, NP relays, and any other critical components necessary for safe and effective operation of the Long Beach Network. These to include; • Workflow steps for identifying equipment being non-operational Updated Apparatus Inspection Checklist in e-Mobile (CMS) • Field Apparatus to be consulted before closing Network Protector Work Orders • District Production Specialist to include Apparatus Technicians during scheduling for work orders that include apparatus equipment
	CA-3: Assign one (1) dedicated Apparatus Crew to support the Long Beach District. Suggested crew make up: • 3 Apparatus Technicians • 1 Apparatus Foreman This action can be closed when the first Work Order is completed using the Dedicated Apparatus crew, include a copy of the completed WO

Cause Evaluation Element	Description
Root Cause	CA-4: Document that Distribution Operations Center (DOC) personnel understand the expectation to Call Duty Engineer & Apparatus Duty Supervisor when a Network Protector fails. Callout process should model the “Wire Down” policy. This action can be closed by a signed document stating the Call Duty Engineer & Apparatus Duty Supervisor understand their expectations when a Network protector fails
	CA-5: Complete SAP change request to DIMP to include “Install NP relay” as a selection in Object Type. This action can be closed by documenting the first SAP change request using “Install NP relay” as an object type
	CA-6: Field Apparatus to work with IT to modify the Field Tool to include mandatory fields for capturing Apparatus Equipment inspections to ensure actions are completed before closing Work Order • CMS, SAP Measuring Point, DIMP, and e-Mobile This action can be closed when the first inspection is performed and Work Order successfully tests for closure using one of these mandatory fields in the Field Tooling

Cause Evaluation Element	Description
Root Cause	CA-7: Apparatus Technicians to go through an initial formal SAP/Field Tool Training on how to generate Notifications when identifying Apparatus equipment using the updated NP Relay Object Type when performing the following work • Apparatus Inspections • Find & Fixes This action can be closed when the first training class is completed
	CA-8: District Lineman, and Troubleman out of Lighthipe sector, to go through an initial formal SAP/Field Tool Training on how to generate Notifications when identifying Apparatus equipment using updated NP Relay Object Type when performing the following work • New Network Protector Installations • Trouble Calls This action can be closed when the first training class completed

Cause Evaluation Element	Description
Root Cause	CA-9: Apparatus Field Technician to be scheduled by District Production Specialist with District Line Crew when planning work for the new installation or replacement of Network Protectors per the Design Support Update. This action can be closed when the first Network Protector Relay is installed by the Apparatus Field Technician using this new scheduling process
	CA-10: Modify the Network Protectors ordering compatible unit process to ensure that NP relays are ordered by the District Planners. This action can be closed when the first NP is ordered by a District Planner using this new process
	CA-11: Establish a process to ensure all newly installed Network Protectors without the necessary components are physically tagged as “Out of Service” by District Lineman & Troubleman, and a Notification to install a NP relay and/or other components is generated to Distribution Apparatus. This action can be closed when Long Beach District Lineman & Troubleman have been documented as having read and understood this expectation

Cause Evaluation Element	Description
Root Cause (RC): Lack of adequate knowledge on the vulnerabilities and operational importance of the Network Protectors, NP relays, and secondary network system.	CA-12: T&D Training Organization to develop and implement three (3) distinct training curriculum (initial and refresher) that would address secondary networks and the Work Management Process that captures the details and responsibilities of the Distribution Apparatus Organization and the Long Beach District for critical components Network (as described in **CA-1**), • Detailed Training for Distribution Apparatus Technicians • Functional Training for Long Beach District Lineman, and Troubleman who work on the secondary network • Operational Training for Grid Operators who work on the secondary network This action can be closed when the first initial training class for each of the following groups is completed (Apparatus Technicians, Long Beach District Lineman & Troubleman and Grid Operations) and the refresher training material have been developed and refresher classes have been scheduled.

Cause Evaluation Element	Description
Root Cause	CA-13: On a periodic re-qualification cycle (as determined by T&D Training Organization), T&D Training Organization to conduct training for Apparatus Technicians and Foreman on the Network Protector detailed training material that covers • Network Protectors being a priority and treated like a protection device • How Network Protectors work, their function, and how they support the secondary network • Identifying and troubleshooting Network Protector issues through On the Job Training (OJT) • Recent Industry Events and Lessons Learned Reinforcement of Work Management Process that captures the details and responsibilities of the Distribution Apparatus Organization and the Long Beach District for critical components Network (as described in **CA-2**), Training to be initiated for all current Apparatus Technicians and foreman, and for all new Apparatus Technicians and foreman being on boarded. This action can be closed when the first training class for each of the following groups is completed (Apparatus Technicians, and Apparatus Technician foremen)

Cause Evaluation Element	Description
Root Cause	CA-14: On a periodic re-fresher training cycle (as determined by T&D Training Organization), T&D Training Organization to conduct training for Long Beach District Lineman, and Troubleman out of Lighthipe sector, on the Network Protector functional training material that covers • A general understanding of Network Protectors • How Network Protectors are protection devices • Outline the callout process • Recent Industry Events and Lessons Learned Training to be initiated for all current Long Beach District Lineman and Troubleman, and for all new Lineman and Troubleman being on boarded This action can be closed when the first re-fresher class for Long Beach District Lineman & Troubleman completed

Cause Evaluation Element	Description
Root Cause	CA-15: On a periodic re-fresher training cycle (as determined by T&D Training Organization), T&D Training Organization to conduct training for Grid Operators out of Lighthipe sector, on the Network Protector operational training material that covers • A general understanding of Network Protectors • How Network Protectors are protection devices • Outline the callout process • Recent Industry Events and Lessons Learned Training to be initiated for all current Grid Operators out of Lighthipe sector, and for all Grid Operators out of Lighthipe sector being on boarded This action can be closed when the first re-fresher class for Grid Operators completed

Cause Evaluation Element	Description
Contributing Cause (CC): The Distribution Apparatus Crew closed out Network Protector inspection with no actions taken and did not return to complete the Work Request (July 15, 2015 Network Protector 20649).	CA-16: Coach & counsel Distribution Apparatus individuals involved in closing out Network Protector inspection with no actions taken and not returning to complete the Work Request.
	CA-17: Conduct an All Hands meeting with Distribution Apparatus Crew members to review lessons learned of the Long Beach outage events specifically addressing not closing out equipment inspections with no actions taken, documenting deficiencies in SAP, and notifying Distribution Apparatus supervision of inaccessibility to underground structures and rescheduling the equipment inspection.

Cause Evaluation Element	Description
Organizational & Programmatic	CA-18: Create a Model of the secondary network for normal operation and any critical contingencies. This action can be closed by documenting the approval of this model by the Engineering Director
	CA-19: Implement a secondary network monitoring tool. Model real time status of the secondary network. Automation of all Network Protectors. This action can be closed by documenting the presentation presented to the Long Beach Network Owners Group concerning the modeling tool
	CA-20: Develop and implement a Distribution Underground Standard for the Long Beach Network. Standard to include acceptable cable replacement criteria, aluminum to copper connections, splice connector types, connector bar, cable limiters, fire wrap, secondary network specific equipment, and Network Protectors. This action can be closed by documenting the approval of this standard by the Long Beach Network Owners Group

Cause Evaluation Element	Description
Organizational & Programmatic	CA-21: Develop and implement design configuration and planning criteria for secondary network distribution system. Configuration of primary circuitry, loading criteria, and number of Network Protectors. This action can be closed by documenting the presentation presented to the Long Beach Network Owners Group concerning the design configuration and planning criteria for secondary network distribution system
	CA-22: Improve the process for all mapping updates for Long Beach secondary network to ensure they are submitted through Western Mapping Office at Lighthipe. This action can be closed by documenting the presentation presented to the Long Beach Network Owners Group concerning a mapping update process
	CA-23: Develop and implement an Outage Management System (OMS) graphic interface to monitor secondary load on secondary networks. This action can be closed by demonstrating to the Long Beach Network Owners Group the OMS interface to monitor secondary load on secondary network
	CA-24: Update and implement Emergency Operating Bulletin to match the current design of the secondary network and improve restoration response of the Long Beach secondary network. This action can be closed by attaching a copy of the revised bulletin

Cause Evaluation Element	Description
Organizational & Programmatic	CA-25: Become participating member (annual fees paid) of the industry utility network forum such as EPRI - secondary networks to obtain lessons learned and best practices for secondary network design, construction, and maintenance. Initiate changes and corrective actions as identified. This action can be closed once SCE participates in at least one EPRI Network event and provided documented lessons learned from this event to the Long Beach Network Owners Group
	CA-26: Install radio, antennas, and monitoring equipment on all Long Beach Network Protectors. This action can be closed when each non spot Network Protector has an installed radio, antenna and monitoring equipment
	CA-27: Fire wrap splices on the Float and Steam circuits in vault 5134053 (location of Float & Steam circuit failure).

Cause Evaluation Element	Description
Extended Lessons Learned	CA-28: Develop and implement a documented Work Management Process that captures the details and responsibilities of the Distribution Apparatus Organization and the Long Beach District for inspecting, identifying, capturing, ordering, tracking, and installing Automatic Recloser and Vacuum Fault Interrupter necessary for safe and effective operation outside of the Long Beach Network. These to include; • Workflow steps for identifying equipment being non-operational Updated Apparatus Inspection Checklist in e-Mobile (CMS) • Field Apparatus to be consulted before closing Network Protector Work Orders District Production Specialist to include Apparatus Technicians during scheduling for work orders that include apparatus equipment
	CA-29: Remove three additional spices in vault 5134053 and have them analyzed by IMCorp. This action will be considered complete when a final report is received from IMCorp.

Cause Evaluation Element	Description
Interim Actions	Interim Action 1: Identify and order replacement of secondary network materials (e.g. - cable, Network Protector, NP relays) to replace from the July 15th and July 30th events.
	Interim Action 2: Update minimum and maximum counts of Long Beach Network Protectors, and all associated material and components.
	Interim Action 3: Revise and implement Long Beach Network Restoration Guideline.
	Interim Action 4: Update Long Beach Downtown secondary network map with the results of the Network Protector detailed inspections, Long Beach secondary network underground structure inspections, and repairs made from both July 15th and July 30th events.
	Interim Action 5: A) Complete interim Transformer Load Management (TLM) map for more accurate customer count. B) TLM map verification and correction.
	Interim Action 6: Appoint interim secondary network owner to identify key contacts to improve coordination of work on the secondary network.
	Interim Action 7: Utilize the secondary network map and key contacts, and provide clear direction to operating personnel regarding whom to contact before commencing work on the secondary network.

Cause Evaluation Element	Description
Interim Actions	Interim Action 8: Verify secondary network underground structure locations and secondary cable status through Distribution Crew inspections on secondary network underground structures.
	Interim Action 9: Electrically separate the North and South secondary network into sections to limit reliability impacts to the southern secondary network grid and improve operation to the northern secondary network.
	Interim Action 10: Conduct inspections of Network Protectors to ensure proper operation, including fuses, NP relays, grounds, and schedule repairs of identified equipment deficiencies.
	Interim Action 11: Issue Long Beach secondary network Operating Bulletin to instruct T&D crews on the installation and maintenance procedure for addressing Network Protectors.
	Interim Action 12: Replace Network Protectors or associated NP relays in Network Protectors identified as non-operational.
	Interim Action 13: Model affected areas of the secondary network to determine potential overloading conditions and initiate replacement of potentially damaged components.

Cause Evaluation Element	Description
Other Actions	OA-1: Installed vault lid tethers 278 to minimize lifting during a failure.
	OA-2: Provide to the Long Beach Network Owners Group a recommendation for frequency of apparatus inspections within the Long Beach Network. Current industry practices should be included as a basis for the recommendation. This action can be closed by documenting the presentation recommendation and completion of changed frequency of inspections (as required) by the Long Beach Network Owners Group
	OA-3: Provide to the Long Beach Network Owners Group a recommendation for Fire wrap of splices on Primary splices in the Secondary Network. Current industry practices should be included as a basis for the recommendation.
	OA-4: Evaluate Current guidance for the number of primary circuits in an underground structure. Current industry practices should be included as a basis for the recommendation.

ATTACHMENT 2: Corrective Action Closure Process

Corrective Action Closure Process

for the Long Beach Network Outages
July 15th and July 30th, 2015

Scope:

The purpose of this guideline is to provide direction to the Corrective Action owners on the criteria and documentation to ensure proper closure and adequate documentation in completing these RCE Corrective Actions. Also, to provide direction on how to archive these documents for future reference and proof for completing the corrective actions.

Corrective Action Review Team:
Key organizational leaders and network owners.

- DBL Region Manager
- Long Beach District Manager
- Grid Operations Region Manager
- Apparatus Senior Engineer
- Distribution Engineering
- Apparatus Manager

Documentation Archiving:
T&D Oversight and Quality Assurance, Quality Oversight group (T&D O&QA)

- Supervisor
- Technical Specialist

In the event of any job changes then the person leaving from any of the above roles should be replaced by the person filling their position.

Corrective Action Owner:

Understand the scope and deliverables required for each corrective action. Complete the action as written or contact the Corrective Action Review Team if the action cannot be completed as written. Provide thorough, legible, and complete documentation to the review team upon completion of the assigned corrective. Meet assigned corrective action due dates and keep the review team apprised as soon as possible of any delays or challenges in meeting the corrective action due date.

Responsibilities:

Corrective Action Review Team:
The team is to ensure the actions that are completed meet the description and intent of that corrective action assigned. They are to validate that all completed documentation proves and justifies the actions taken to complete the corrective action. They forward all final documentation to T&D O&QA for archiving. Electronic documents are preferred for e-filing onto the server.

If the action criteria is not met the team is to provide feedback to the action owner to ensure they meet all corrective action closure expectations. The review team also tracks the progress and due dates of the actions to ensure the action owners are meeting due date expectations, and provide assistance to the owner as needed to overcome any challenges.

The review team is the reviewer and approver of all completed actions. The review team sponsor has final authority to accept, reject, or challenge Corrective Action closures.

T&D Oversight and Quality Assurance:

Responsible for organizing and archiving the corrective action documentation. They provide internal access to the cause evaluation SharePoint folder as needed, and ensure the records are readily available and accessible. Provide documentation associated with this cause evaluation to internal and external entities upon request.

Documentation:

The following are examples and are not all inclusive. Documenting each action will vary. The goal is to provide proof that can be referenced and demonstrates the completion and quality of the action. Any documentation questions should be directed to the review team.

Requirement	***Documentation***
Training	Copy of the Lesson Plan including revision date
	Signed and dated attendance sheet
	Dated Name list of all employees required to complete the training
	Dated Plan with next scheduled training date that ensures all required employees will complete the training
	All class survey/feedback documents
Inspections	Completed inspection forms with dates and names
	Results, actions, tracking documents, package numbers
Job Assignments	Names, title, dates
	Organization chart, work location
Work Process Changes	Guideline, bulletins with dates and/or revision numbers
	Meeting dates, attendance sheets, agenda
	Program screen shots with dates

ATTACHMENT 3: Effective Review (EFR) Action Matrix

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Root Cause (RC): Insufficient work processes and organizational structure to support continuous operation of the Long Beach secondary network.	EFR-1: Randomly select six underground structures with Primary Circuits and Network Protectors. Physically inspect and document review for the following: • Secondary network map reflects actual infield conditions • Verify Network Protector (s) in these structures have NP relays installed • Verify a Long Beach Distribution Apparatus inspection has been performed on the frequency required, inspection form properly completed and next inspection is scheduled on the frequency required • Verify Network Protector (s) in this structure has an installed radio, antennas, and monitoring equipment • Verify components in these structures include acceptable cable replacement, aluminum to copper connections, splice connector types, connector bar, cable limiters, fire wrap, and secondary network specific equipment • Verify Network Protectors out of service have “Out of Service” tag and Notification written to correct the condition Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 12 **Short Term EFR**	EFR-2: Verify the three training programs were developed for initial training addressing Network Protectors and the Work Management Process for: • Apparatus Technicians - Detailed Network Protector operation including NP relay, operating positions of Network Protectors and Work Management Process • Long Beach District Lineman & Troubleman out of Lighthipe sector - Network Protector Functional Training and Work Management Process • Grid Operators (Distribution Operations Center personnel) - understand the expectation to Call Duty Engineer & Apparatus Duty Supervisor when a Network Protector fails (modeling "Wire Down" policy) and Network Protector Operational Training Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 13 **Short Term EFR**	EFR-3: Verify the Apparatus Technicians training program was implemented for initial training addressing Network Protectors and the Work Management Process by: • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Distribution Apparatus organization to verify completion of the initial training (by review of training records). Acceptance criteria should be 100% of those sampled has completed training. • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Distribution Apparatus organization through interview or test to assure understanding of the distinct initial training topics for that organization. Acceptance criteria should be that greater than 90% of those interviewed understand the training topics. Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 14 **Short Term EFR**	EFR-4: Verify the Long Beach District Lineman, and Troubleman out of Lighthipe sector, training program was implemented for initial training addressing Network Protectors and the Work Management Process by: • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Long Beach District Lineman, and Troubleman out of Lighthipe sector, organizations to verify completion of the initial training (by review of training records). Acceptance criteria should be 100% of those sampled has completed training. • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Long Beach District Lineman, and Troubleman out of Lighthipe sector, organizations through interview or test to assure understanding of the distinct initial training topics for that organization. Acceptance criteria should be that greater than 90% of those interviewed understand the training topics. Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 15 **Short Term EFR**	EFR-5: Verify the Grid Operators out of Lighthipe sector training program was implemented for initial training addressing Network Protectors and the Work Management Process by: • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Grid Operators out of Lighthipe sector to verify completion of the initial training (by review of training records). Acceptance criteria should be 100% of those sampled has completed training. • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Grid Operators out of Lighthipe sector through interview or test to assure understanding of the distinct initial training topics for that organization. Acceptance criteria should be that greater than 90% of those interviewed understand the training topics. Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 12 **Long Term EFR**	EFR-6: Verify the three training programs were developed for re-training addressing Network Protectors and the Work Management Process for: • Apparatus Technicians - Detailed Network Protector operation including NP relay, operating positions of Network Protectors and Work Management Process • Long Beach District Lineman & Troubleman out of Lighthipe sector - Network Protector Functional Training and Work Management Process • Grid Operators (Distribution Operations Center personnel) - understand the expectation to Call Duty Engineer & Apparatus Duty Supervisor when a Network Protector fails (modeling "Wire Down" policy) and Network Protector Operational Training Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 13 **Long Term EFR**	EFR-7: Verify the Apparatus Technicians training program was implemented for re-training addressing Network Protectors and the Work Management Process by: • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Distribution Apparatus organization to verify completion of the initial training (by review of training records). Acceptance criteria should be 100% of those sampled has completed training. • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Distribution Apparatus organization through interview or test to assure understanding of the distinct initial training topics for that organization. Acceptance criteria should be that greater than 90% of those interviewed understand the training topics. Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 14 **Long Term EFR**	EFR-8: Verify the Long Beach District Lineman, and Troubleman out of Lighthipe sector, training program was implemented for re-training addressing Network Protectors and the Work Management Process by: • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Long Beach District Lineman, and Troubleman out of Lighthipe sector, organizations to verify completion of the initial training (by review of training records). Acceptance criteria should be 100% of those sampled has completed training. • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Long Beach District Lineman, and Troubleman out of Lighthipe sector, organizations through interview or test to assure understanding of the distinct initial training topics for that organization. Acceptance criteria should be that greater than 90% of those interviewed understand the training topics. Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 15 **Long Term EFR**	EFR-9: Verify the Grid Operators out of Lighthipe sector training program was implemented for re-training addressing Network Protectors and the Work Management Process by: • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Grid Operators out of Lighthipe sector to verify completion of the initial training (by review of training records). Acceptance criteria should be 100% of those sampled has completed training. • Sampling 5% (or a minimum of 3 individuals) of persons (in the job for more than 3 months) in the Grid Operators out of Lighthipe sector through interview or test to assure understanding of the distinct initial training topics for that organization. Acceptance criteria should be that greater than 90% of those interviewed understand the training topics. Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 1 **Long Term EFR**	EFR-10: Attend three Long Beach Secondary Network Owners Group meetings over a 6 month period. Verify these meetings are occurring regularly and 2/3 of the members attend. Verify at a minimum the following items are included in the meeting: • Defined agenda items and approved meeting minutes • Discussion of Long Beach secondary network performance monitoring criteria and actions for criteria not meeting expectations • Review of the status of training on the Long Beach secondary network for - Apparatus Technicians, Long Beach District Lineman, Troubleman out of Lighthipe sector, and Grid Operators • Review of Long Beach secondary network project(s) status (must include tether or lid project) and status of open actions • Review of status of industry engagement lessons learned open actions • Review status of Long Beach Secondary Network Owners Group open actions. Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 3: Effective Review (EFR) Action Matrix

Effective Review (EFR) Action	Description
Corrective Action - 2 **Long Term EFR**	EFR-11: Through sampling of 5 Work Orders (WO) requiring installation or repair of apparatus equipment (i.e. AR, VFI, with at least one WO for a NP relay). Verify Apparatus Technicians are included in the WO process with written verification of Apparatus Technician completion of work prior to the District WO closure. Acceptance criteria should be 100% Apparatus Technicians are included in the WO process with written verification of Apparatus Technician completion of work prior to the District WO closure: Summarize the overall rationale and basis used in the determination of the effectiveness review. Present results to the Long Beach Secondary Network Owners Group. Unacceptable results requires action to address the specific failed criteria.

ATTACHMENT 4: Definitions Page

Definitions Page

All Load Up (ALU): The term used when service has been restored to all of the customers on a circuit, substation or system.

Barrier Analysis: The barrier analysis is a process used to identify physical, administrative, procedural controls, and other barriers that should have prevented the inappropriate action from happening.

Corrective Action: Measures taken to correct an adverse condition and to minimize the potential for recurrence of the condition. Measures taken to alleviate symptoms of a problem or to eliminate or diminish causes of problems.

Event & Causal Factor Chart: The Event and Causal Factor Chart is an effective way to show the sequence of events and the contributing factors to a negative event.

Extent of Condition: Extent of Condition is to determine where else within the Long Beach secondary network could the same or similar problem exist.

Fault: A fault or fault current is any abnormal electric current.

Ground relay target: Ground relays are designed to prevent damage and protect personnel from the dangerous fault currents that develop when a conductor contacts the ground (or a structure that allows current to flow to ground). Ground relays quickly de-energize a grounded conductor in order to protect individuals, prevent equipment damage, and prevent fires.

Handle Positions: Automatic, Opened, and Closed: There are three positions for the operating handle: "Open", "Automatic", and "Closed". The position functions are listed below:

A. Automatic Position: When the network protector operating handle is in the "Automatic" position, the relay commands the trip coil and closing motor to automatically open or close the network protector. Upon the detection of reverse current, based on the network protector relay settings, the network protector relay will respond to open the network protector main contacts. When the poly-phase voltage phasor measurements are within the predefined relay settings for closing the protector the Network Protector Relay will respond to close the network protector main contacts.
B. Open Position: Manually moving the operating handle to the "OPEN" position will open the main contacts of the network protector. The network protector main contacts will

remain open when the handle is in the "Open" position, disabling the network protector relay's capability from automatically operating the network protector main contacts.

C. Closed Position: Manually moving the operating handle to the "CLOSE" position closes the Network Protector main contacts. Upon the detection of reverse current, based on the network protector relay settings, the network protector relay will respond to open the network protector main contacts. The handle in the "CLOSE" position disables the network protector relay's capability from automatically operating the network protector main contacts to closed.

Immediate Action: Steps taken without delay to resolve situations or conditions involving safety or similar concerns requiring prompt attention.

Interim Action: A temporary action taken between the time a problem is discovered and when the final actions are complete to prevent or mitigate the effects of the problem, and/or minimize the probability of a repeat problem.

Limited Function: A Network Protector with the main contacts in the closed position which does not have the network protector relay(s) installed or operating properly, and therefore eliminating the functions provided by the Network Protector relay(s).

Network Protector: An assembly comprising an air circuit breaker and its complete control equipment for automatically disconnecting a transformer from a secondary network in response to predetermined electrical conditions on the primary feeder or transformer, and for connecting a transformer to a secondary network either through manual control or automatic control response to predetermined electrical conditions on the feeder and the secondary network.

Network Protector Relay (NP Relay): A relay or combination of relays that functions as a protective relay by opening a network protector when power is back-fed into the supply system and as a programing relay by closing the network protector when the poly-phase voltage phasors are within prescribed limits.

No Test Order (NTO): A No Test Order is a formal statement issued and recorded under a prescribed procedure, by an authorized person to a Qualified Electrical Worker (QEW), declaring that in case certain specified energized distribution line(s) or substation equipment of 33 kV or below become de-energized, said equipment shall not be re-energized, by any method, until the No Test Order has been released by the person to whom the No Test Order was issued.

ATTACHMENT 4: Definitions Page

The purpose of the No Test Order is to provide a formal procedure by which a qualified person could request and receive a guarantee that a line or equipment shall not be re-energized when the nature of the work is such that the re-energizing would be hazardous to personnel.

Non-operational: A Network Protector configured with the operating handle in the open position.

Part Load Up (PLU): A term used when service has been restored to a portion of the customers on a circuit, substation, or system.

Problem Statement: The Problem Statement defines the issue being evaluated and briefly describes what happened and the consequences to SCE in terms of the governing requirement or standard, the deviation or defect, and the consequences of the deviation or defect.

Process Flow Analysis: A process analysis is used to understand the breakdowns in a process and related barriers. This analysis can be used to gain a better understanding of each failure in a series of events related to NP relay installations. The failed, or missing, steps are marked with diamonds and a summary of the overall issues within the process are identified below.

Triggering event: The triggering event is any adverse human factor, equipment failure, or special condition (such as acts of nature) that sets a failure mechanism in motion. If not stopped by an effective barrier, it will result in a failure event.

ATTACHMENT 5: Sequence of Events

Background: Dates prior to the event taking place on July 15, 2015 are provided as informational data to lend a point of reference for the underground structures involved in the event.

- 12/17/2007 - New NP 20649 installed in Vault 5134205 by Long Beach District Crew and was later removed in 2008 (unknown reason why)
    - **NP Circuit:** Float
    - **Other Vault Circuits:** Cargo, Steam, Mitchell, Alamo, and Ocean
    - **Location:** 3rd and N. Crystal Ct.

      IA-1 - NP relay not installed in NP 20649 in Vault 5134205

- 10/15/2010 - Apparatus Crew inspected NP 20649 installed in Vault 5134205 and identified the missing NP relay on inspection notes, no action was taken to install NP relay.
    - **NP Circuit:** Float
    - **Other Vault Circuits:** Cargo, Steam, Mitchell, Alamo, and Ocean
    - **Location:** 3rd and N. Crystal Ct.

      IA-1 - NP relay not installed in NP 20649 in Vault 5134205

- 6/24/2011 - Troubleman respond to low voltage call and found new NP 20670 in Vault 5133091 with fuses not installed & the NP in the open position. Notification 403775927 written to apparatus group to put NP unit online

- 7/1/2011 - Vault 5134053 identified by District Crew as deteriorated and Notification 404614518 written for replacement
    - **Circuits:** Cargo, Chestnut, Mitchell, Float, and Steam 12kv
    - **Location:** Ocean Blvd. and Pacific

- 2/8/2012 - Vault 5133091 inspected by UDI during routine inspection cycle (3 years) No issues noted
    - **Circuits:** Ocean, Steam, Mitchell, Float, and Cargo
    - **Location:** 3rd and Magnolia

- 5/21/2012 - Vault 5132733 inspected by UDI during routine inspection cycle (3 years) No issues noted
    - **Circuits:** Hoback and Cargo
    - **Location:** 9th and Solana Ct.

- 5/25/2012 - Vault 5133093 inspected by UDI during routine inspection cycle (3 years) No issues noted
    - **Circuits:** Ocean, Steam, Mitchell, Float, and Cargo
    - **Location:** 3rd and Magnolia

- 6/07/2012 - Vault 5134053 inspected by UDI during routine inspection cycle (3 years) No issues noted

- **Circuits:** Chestnut, Float, and Steam
- **Location:** Ocean Blvd. and Pacific

- 7/20/2012 - Vault 5133092 inspected by UDI during routine inspection cycle (3 years) No issues noted
  - **Circuits:** Ocean, Steam, Mitchell, Float, and Cargo
  - **Location:** 3rd and Magnolia

- 3/2/2013 - Station interruption out of Seabright substation opening up load side bank breakers de-energizing 12kv tripping off NP 20710 in Vault 5132733
  - **Circuits:** Hoback and Cargo
  - **Location:** 9th and Solana Ct.

- 3/3/2013 - Troubleman responds to low voltage call, per Notification 405044601, and closed in NP 20710 in Vault 5132733
  - **Circuits:** Hoback and Cargo
  - **Location:** 9th and Solana Ct.

- 3/15/2013 - NP 20649 in Vault 5134205 inaccessible due to nearby construction and could not be inspected. Apparatus Crew closed inspection and did not return to complete the inspection
  - **NP Circuit:** Float
  - **Other Vault Circuits:** Cargo, Steam, Mitchell, Alamo, and Ocean
  - **Location:** 3rd and N. Crystal Ct.

  IA-1 - NP relay not installed in NP 20649 in Vault 5134205

- 4/16/2013 - NP 20710 found to be broken after relaying on 3/2/2013 and would not close automatically. Notification 405147182 written to replace NP 20710 in Vault 5132733
  - **NP Circuit:** Cargo
  - **Other Vault Circuit:** Hoback
  - **Location:** 9th and Solana Ct.

- 7/31/2014 - NP 28113 in Vault 5132733 installed by district crew replacing NP 20710
  - **NP Circuit:** Cargo
  - **Other Vault Circuit:** Hoback
  - **Location:** 9th and Solana Ct.

- 7/31/2014 - Incorrect equipment ID for NP 28113 entered in SAP. NP serial number was used and not the NP number
  - **NP Circuit:** Cargo
  - **Other Vault Circuit:** Hoback
  - **Location:** 9th and Solana Ct.

  IA-2 - NP relay not installed in NP 28113 in Vault 5132733

- 7/31/2014 - District crew closed in NP 28113 in Vault 5132733 to address low voltage issues
  - **NP Circuit:** Cargo
  - **Other Vault Circuit:** Hoback

- **Location:** 9th and Solana Ct.

  IA-3 - NP 28113 in Vault 5132733 closed in service without NP relay

- 8/4/2014 - Vault 5134053 replaced by Asplundh (contractor) and a new 12kV cable spliced into existing primary Float circuit by Petrelli (sub-contractor)
  - **Circuits:** Cargo, Chestnut, Mitchell, Float, and Steam
  - **Location:** Ocean Blvd. and Pacific

- 6/18/2015 - District Foreman found NP 20649 in Vault 5134205 to be out of service. Foreman wrote Notification 407095747 to Apparatus to see why NP was not on Auto or if it needed to be programmed
  - **NP Circuit:** Float
  - **Other Vault Circuits:** Cargo, Steam, Mitchell, Alamo, and Ocean
  - **Location:** 3rd and N. Crystal Ct.

- 6/18/2015 - District Foreman closed in NP 20649 in Vault 5134205 to address low voltage issues.
  - **NP Circuit:** Float
  - **Other Vault Circuits:** Cargo, Steam, Mitchell, Alamo, and Ocean
  - **Location:** 3rd and N. Crystal Ct.

  IA-4 - NP 20649 in Vault 5134205 closed in service without NP relay in Vault 5

Long Beach 1 Event - 7/15/2015

- 0928 - Bow circuit load transferred onto Float circuit & Admiral circuit load transferred onto Steam circuit to isolate Gas Switch in Vault 5408333
    - **Circuits:** Admiral and Bow
    - **Location:** Aquarium Way

- ~1230 - Gas Switch 6635 being replaced in Vault 5408333 with NTO on Float & Steam 12kV circuits
    - **Circuits:** Admiral and Bow
    - **Location:** Aquarium Way

- 1507 - Float 12kV primary circuit relayed to lock out

    EF-1 - A fault in underground structure 5134053 (Ocean Blvd. & Pacific Ave.)

- 1507 - 4 Network Protectors no longer feeding the secondary network because the Float primary circuit breaker opened

- 1515 - Grid Operations cancels NTO on the Float circuit and performs a manual test

- 1519 - Float circuit tested bad and locks out a second time

- 1532 - Steam circuit relayed with NTO and locked out

    EF-3 - ~15:45 Fire occurs in manhole 5133092 (3rd & Chestnut)

- ~1545 - Adjacent underground structures 5133093 & 5133091 also smoking

- 1619 - Troubleman responds to smoking structures on 3rd & Chestnut and requests NTOs on Cargo circuit

- 1622 - Troubleman requests operator to de-energize Cargo circuit. Cargo circuit de-energized

    EF-3 - NP 28113 in Vault 5132733 is backfeeding load on Cargo primary circuit causing damage to secondary network cable

- 1629 - Troubleman requests NTOs on Alamo circuit

- 1631 - Troubleman requests operator to de-energize Alamo circuit. Alamo circuit de-energized

Long Beach 1 Event - 7/15/2015

- 1631 - Fire Department responds to fires in structures on 3rd & Chestnut
- 1759 - NTO's initiated on Chestnut, Loop, Tribune, and Ocean circuits
- 1820 - Ocean circuit locks out in Vault 5133091
- 1821 - Operations de-energizes the Chestnut, Loop, and Tribune circuits to de-energize the source of the failed cable
- 1821 - Primary circuits Chestnut, Loop, Mitchell, Steam, Float, Ocean, and Cargo are fully de-energized
- ~1900 - Low voltage calls in area of manhole 5132758 (Pine & 9th)
- ~1900 - Report of smoke at manhole 5132761 & 5132758 (Pine & 9th)
- ~1900 - Troubleman cut & isolate secondary cable between 5132761 & 5132758 (Pine & 9th)

Long Beach 1 Event - 7/16/2015

- 0003 - 1252 - Operations re-energizes and de-energizes the Loop, Float, and Chestnut Circuits to isolate, troubleshoot, and make necessary repairs
- 0100 - 1231 - Communications with city officials delayed work to accommodate commuter traffic conditions
- 1231 - Operations energized the secondary network for testing
- 1231 - At this time cable splice failures in Vault 5134053 was discovered
- 1250 - Troubleman reports smoke in vault 5134053 @Pacific & Ocean
- 1252 - Operations open de-energizes Chestnut, Loop, and Tribune primary circuits
- 1253 - Operations open Tribune & Alamo primary circuit breakers to isolate the secondary network
- 1256 - Operations closed circuit breakers energizing State Street, Seabright, and Cherry substations
- 1838 - 2020 - PLU status assigned by Operations on the Steam & Cargo Circuits

Long Beach 1 Event - 7/17/2015

- 1458 - 1627 - Operations re-energizes and de-energizes the Tribune & Loop Circuits to isolate, troubleshoot, and make necessary repairs
- 2051 - 2056 - ALU status assigned by Operations on the Cargo, Float, Ocean, Loop, Tribune, and PLU Steam Circuits

Long Beach 1 Event - 7/18/2015

- 0034 - 0231 - ALU status assigned by Operations on the Steam Circuit
- 1240 - 1248 - ALU status assigned by Operations on the Chestnut Circuit
- 1248 - Long Beach secondary network is fully re-energized

Long Beach 1 Event - 7/20/2015

- 1302 - All customers are removed from generation and connected to the network

Long Beach 2 Event - 7/30/2015

- 1600 - Customer no lights calls around vault 5132757 but no circuit interruption

  EF-4 - ~1600 - 1643 - Secondary cable fail and catch fire in Vault 5132757

- 1643 - Dusk Primary Circuit relayed to lockout
- 1643 - Lid cover blows off of vault 5132757 (YouTube video)
- 1645 - Oregon Circuit relayed and tests good
- 1650 - Hoback Circuit relayed to lockout
- ~1650 - Lid cover blows off of manhole 5132758
- 1650 - Oregon Circuit relayed and tests good
- 1653 - Operations makes Dusk and Hoback Circuit reclosers solid
- 1708 - Field crew reports multiple fires in vaults (5132757 & 5132758)
- 1708 - Field crew requests de-energizing the entire Long Beach network out of Seabright & State Street substations

- 1708 - 1712 - Seabright & State Substation Operations makes #1 & 2 Bank re-closers solid and closes parallel Banks
- 1713 - Operations de-energizes Seabright and State Street Subs (feeding Daisy sub)
- 1713 - Primary circuits Chestnut, Loop, Mitchell, Steam, Float, Ocean, and Cargo are fully de-energized
- 1720 - Oregon circuit relayed to lockout
- 1730 - Field crew reports OS elbows failed/flashed over in Vault 5208242
- 1741 - Operations makes Oregon circuit re-closers solid
- 1835 - 1944 - PLU status assigned by Operations on the Oregon Circuit (Locust Sub), Hoback Circuit (Cherry sub), Seabright Sub, and State Street Sub (including Daisy Sub)
- **1944 - PLU Energized Long Beach network - Main grid picked up Seabright & State Street**
- 2029 - 2049 - PLU status on the Cargo Circuit (Seabright sub) and ALU status assigned by Operations on the Oregon Circuit (Locust Sub)
- 2055 - Troubleman reports all damage is beyond POS 5 OS4900 in Vault 5208242
- 2112 - 2259 - PLU status assigned by Operations on the Dusk, Hoback, and Cargo Circuits
- 2303 - Cargo circuit de-energized (emergency outage)
- 2308 - ALU status assigned by Operations on the Cargo Circuit (Seabright Sub)
- 2346 - Clearance issued for Line crew to repair bad cable beyond open pos. 5 to OS in Vault 5208242

Long Beach 2 Event - 7/31/2015

- 0000 - 0300 - Work completed in Vault 5132745 with discovered asbestos
- 0332 - Dusk circuit de-energized (emergency outage)
- 0508 - PLU status assigned by Operations on the Dusk Circuit (Cherry Sub) picking up affected customers
- 2038 - 2309 - ALU status assigned by Operations on the Dusk and Hoback Circuit

Long Beach 2 Event - 8/1/2015

- 0300 - ALU status assigned by Operations on the Cargo Circuit (Seabright Sub)

Long Beach 2 Event - 8/2/2015

- 1835 - Most customers are off generation and connected to the grid

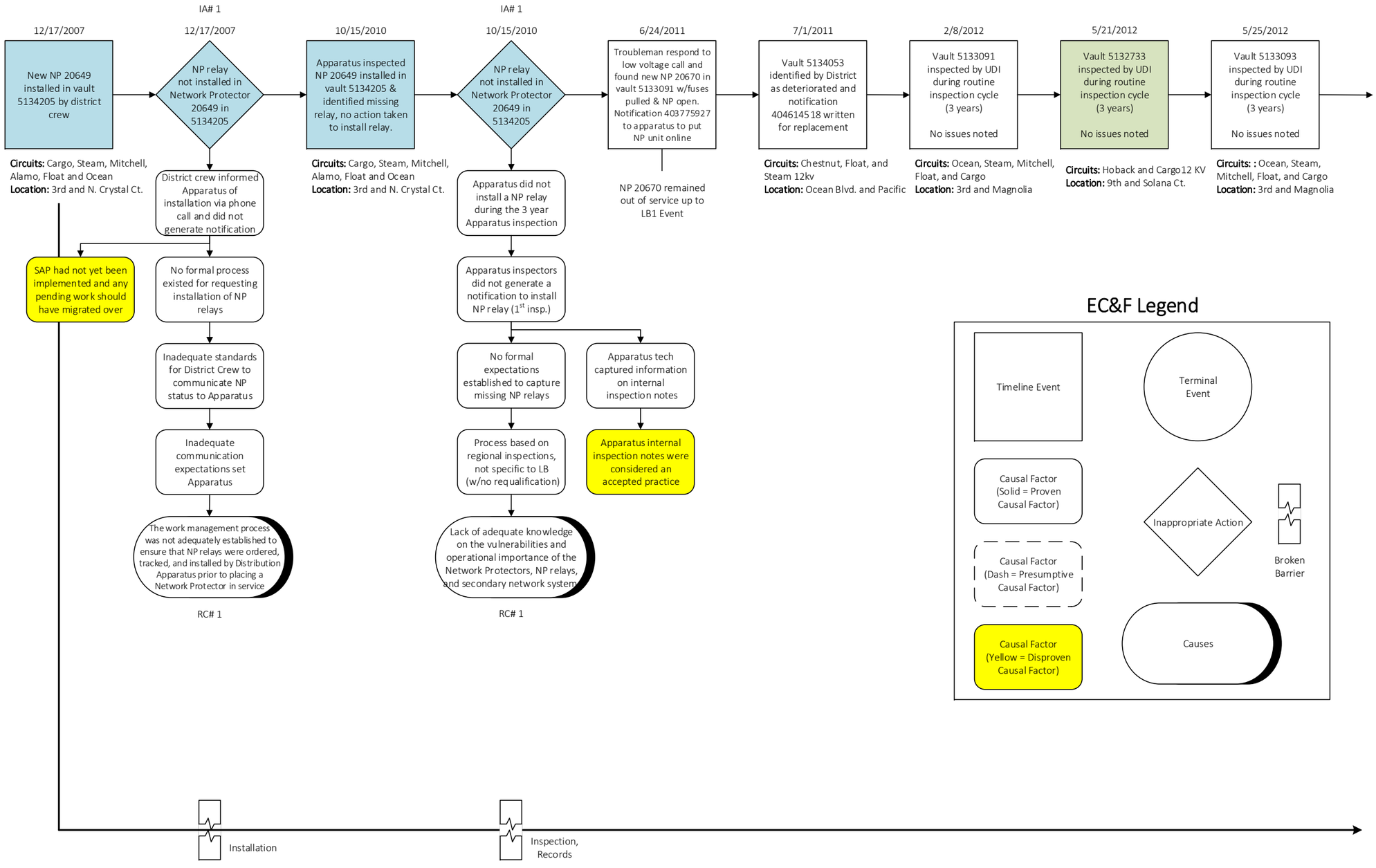
Long Beach 2 Event - 8/3/2015

- 1528 - Final customer is connected to the grid

ATTACHMENT 6: Event and Causal Factor Chart

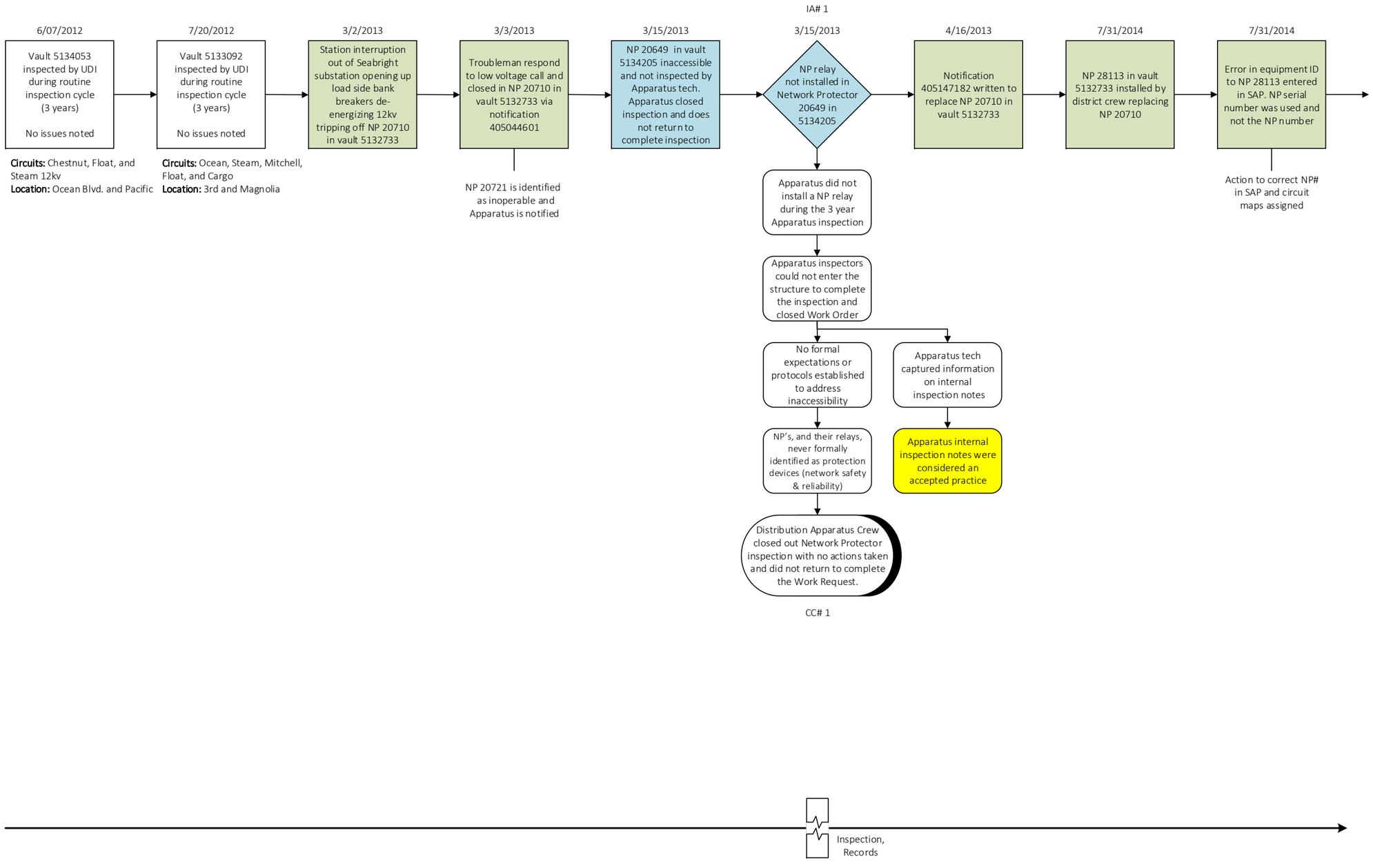
ATTACHMENT 6: Event and Causal Factor Chart

BACKGROUND: 4/2010 – 5/2012



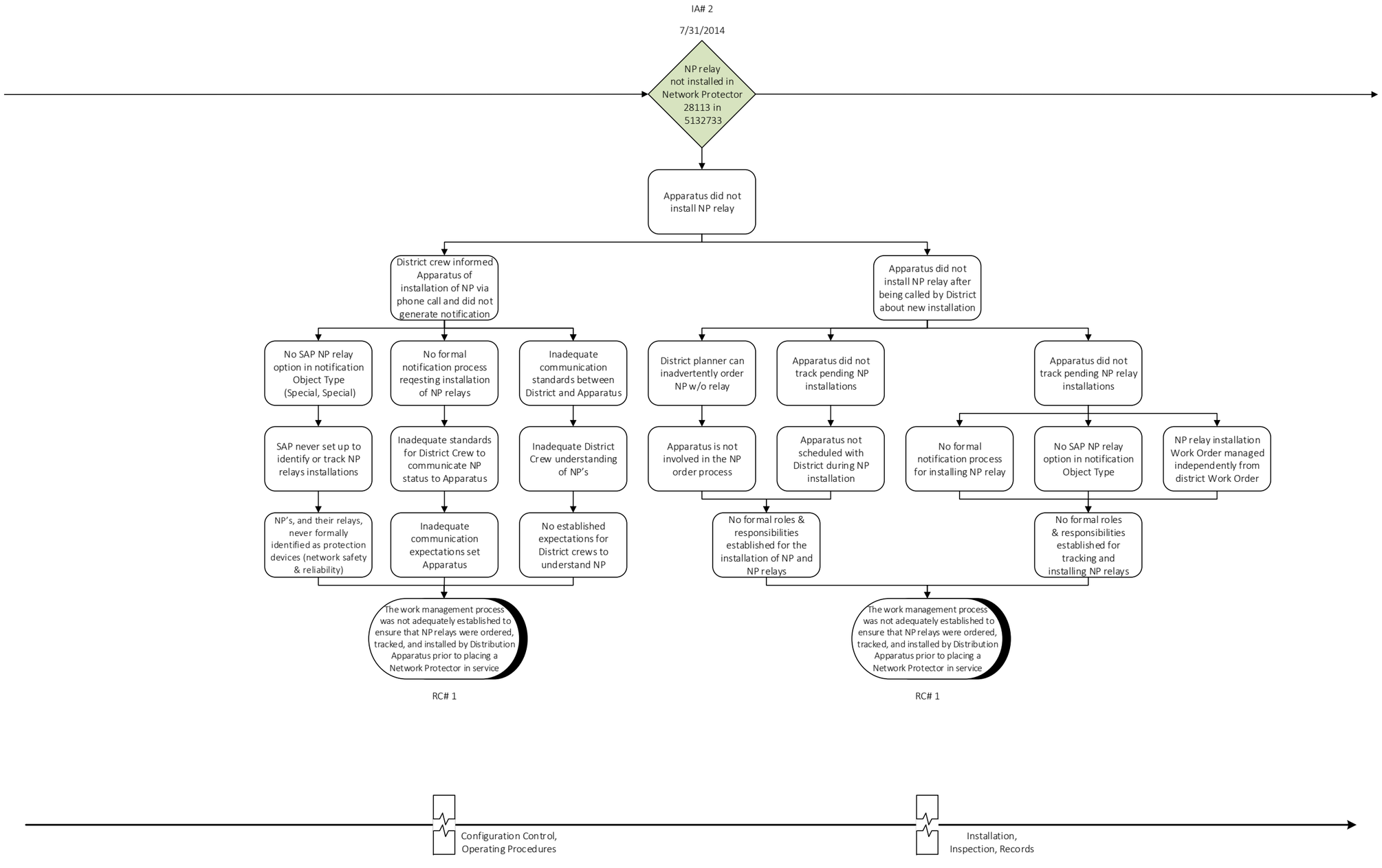
ATTACHMENT 6: Event and Causal Factor Chart

BACKGROUND: 6/2012 – 7/2014



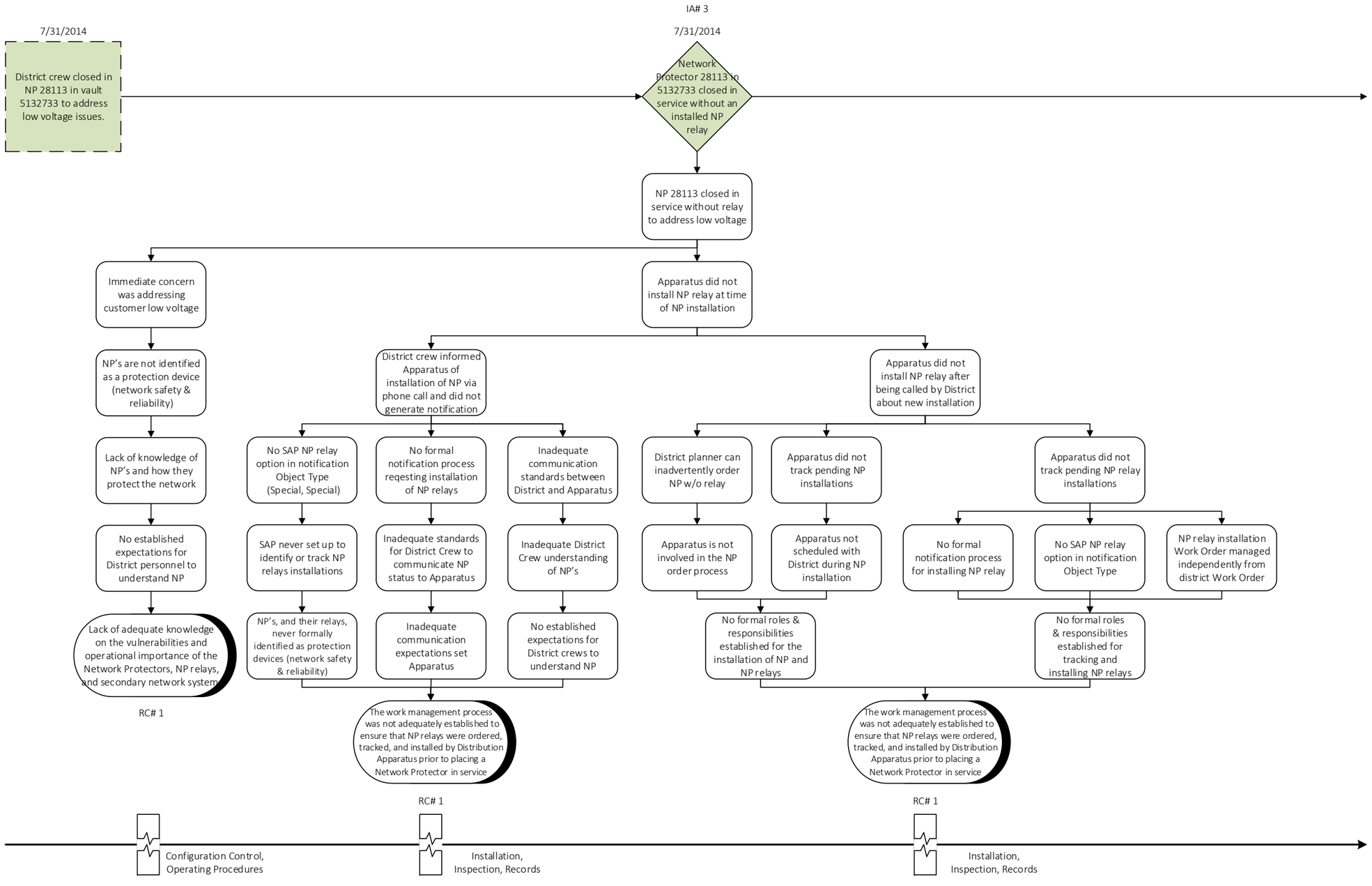
ATTACHMENT 6: Event and Causal Factor Chart

BACKGROUND: 6/2012 – 7/2014



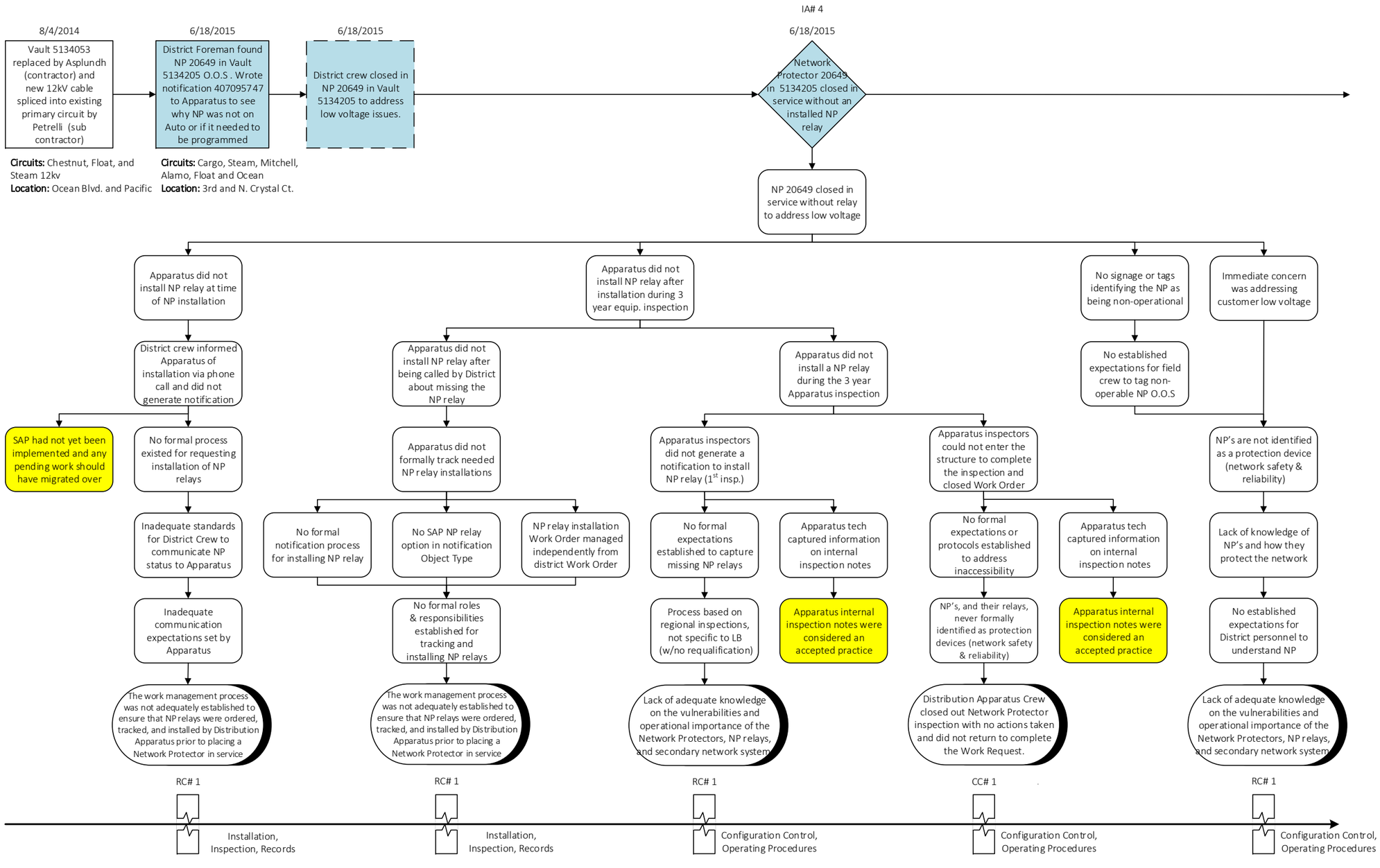
ATTACHMENT 6: Event and Causal Factor Chart

BACKGROUND: 6/2012 – 7/2014



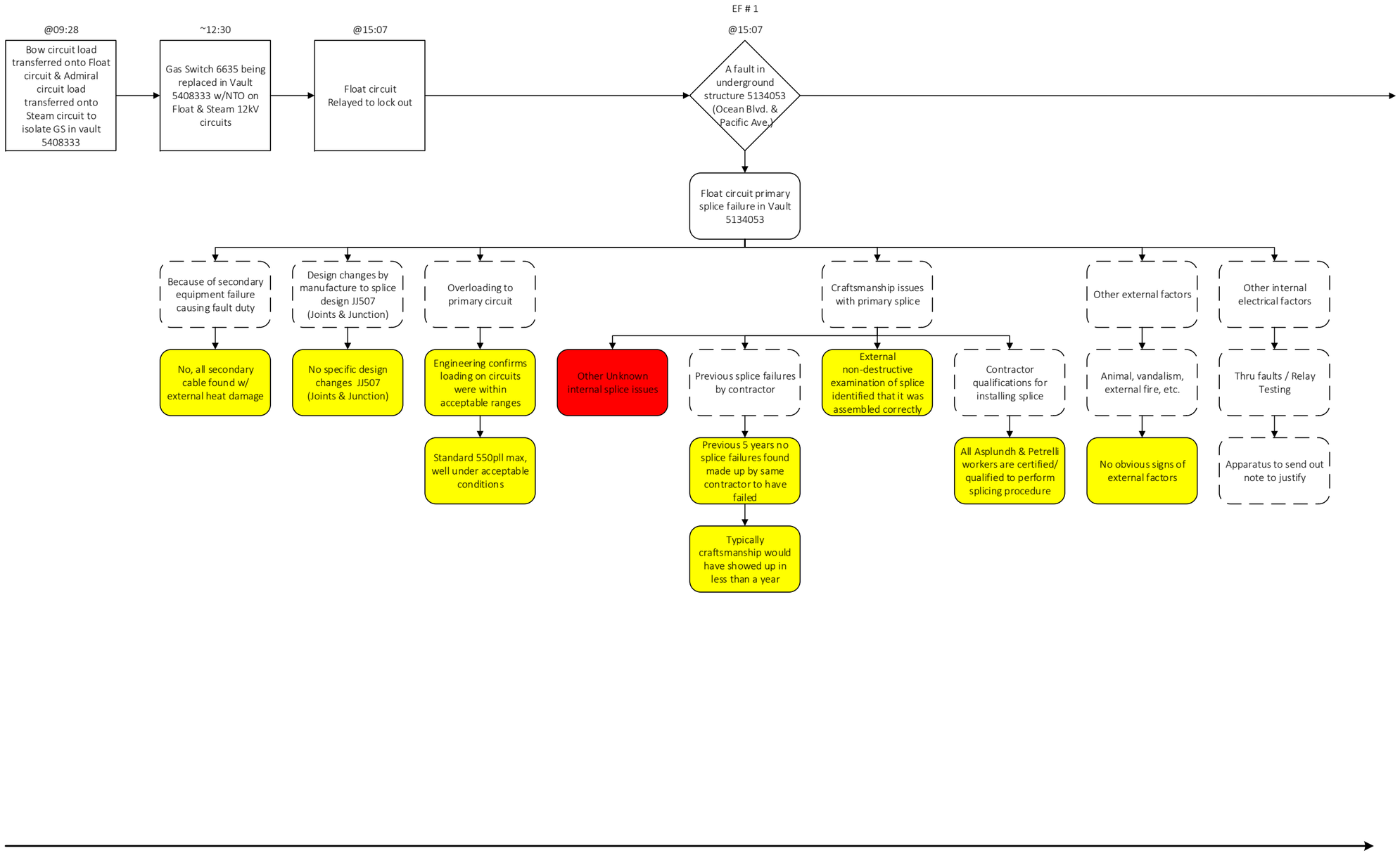
ATTACHMENT 6: Event and Causal Factor Chart

BACKGROUND: 8/2014 – 6/2015



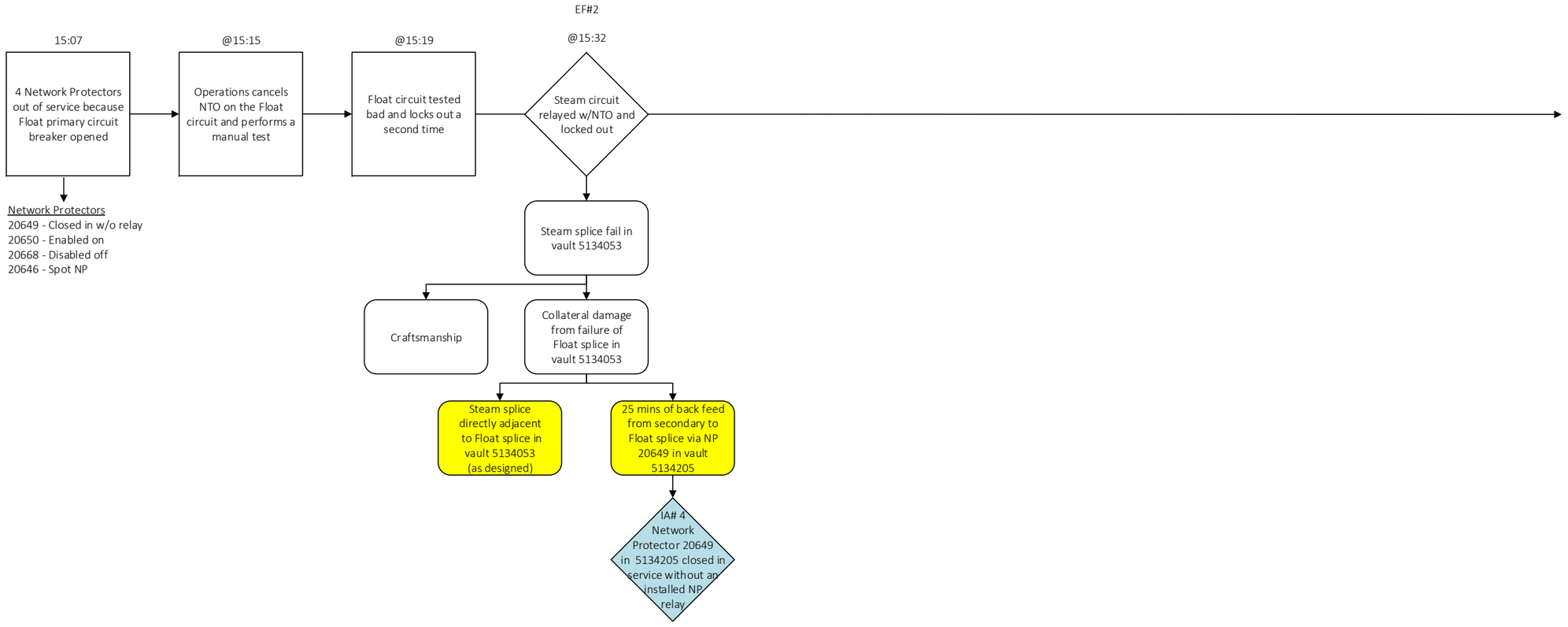
ATTACHMENT 6: Event and Causal Factor Chart

Long Beach 1 Event - 7/15/2015



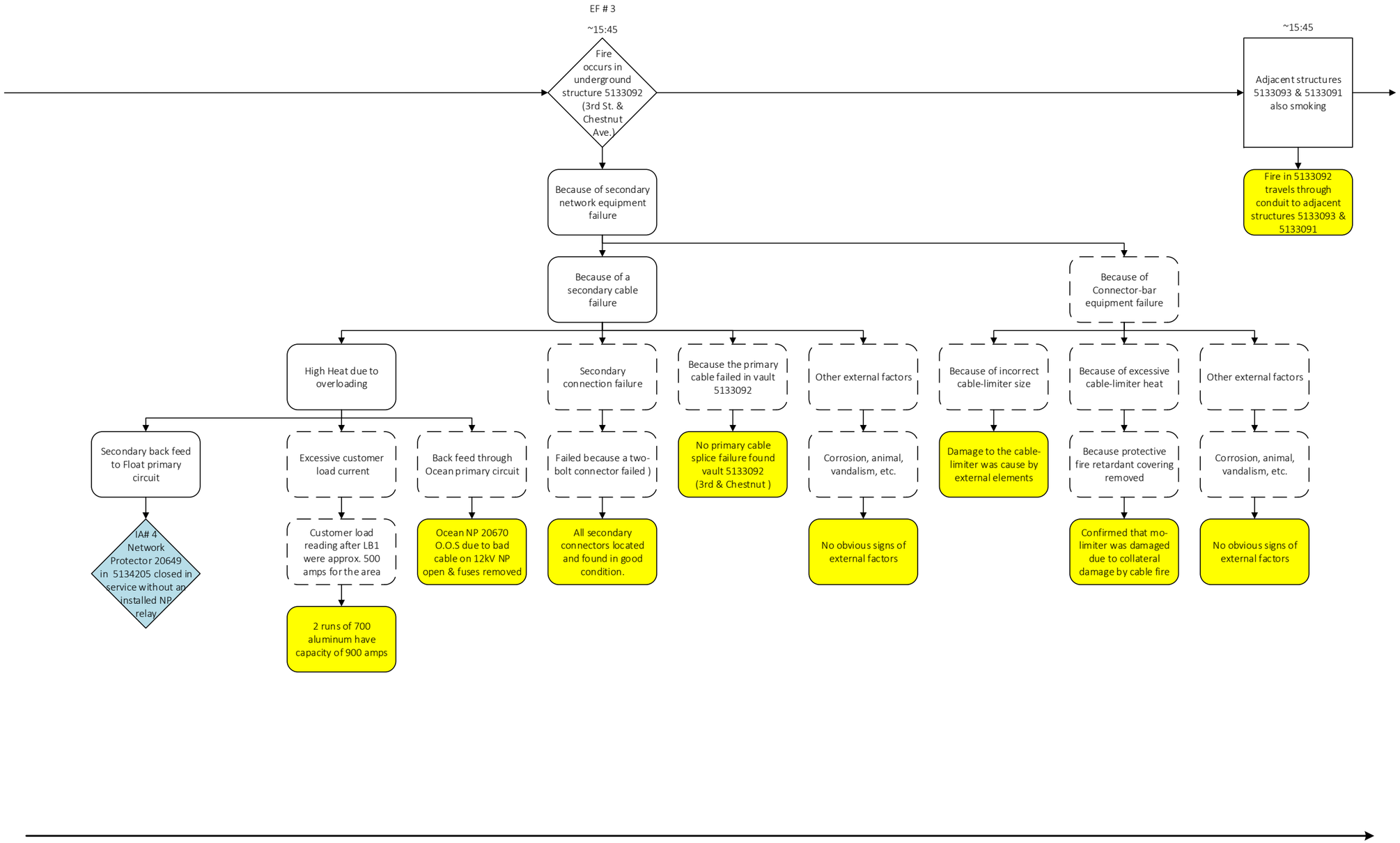
ATTACHMENT 6: Event and Causal Factor Chart

7/15/2015



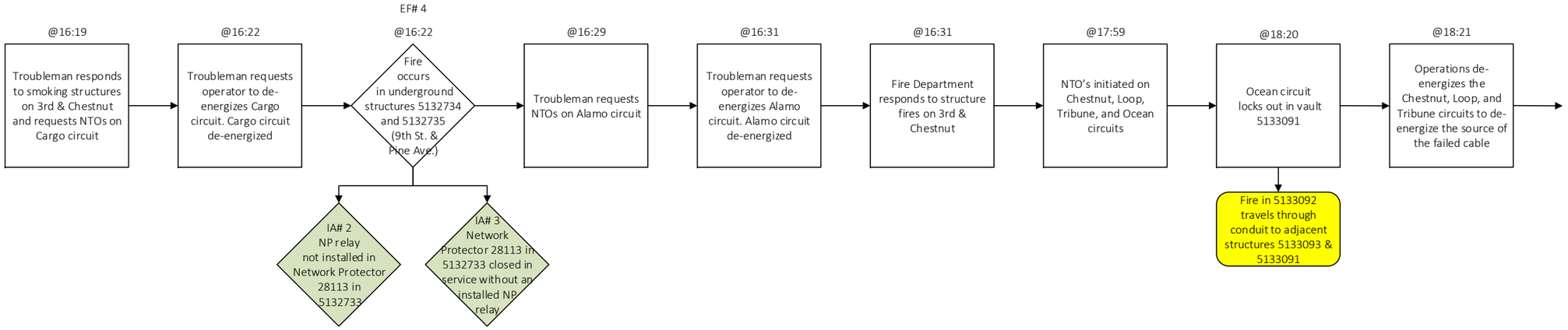
ATTACHMENT 6: Event and Causal Factor Chart

7/15/2015

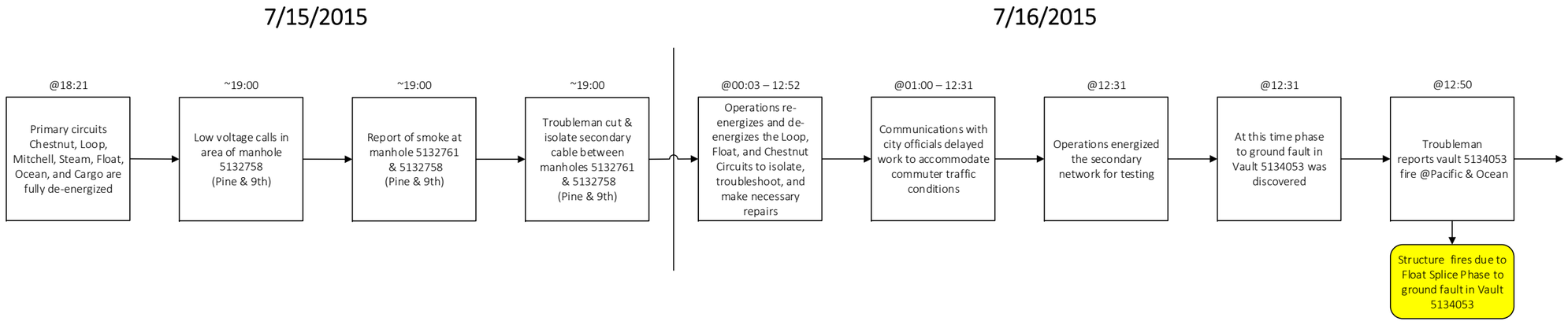


ATTACHMENT 6: Event and Causal Factor Chart

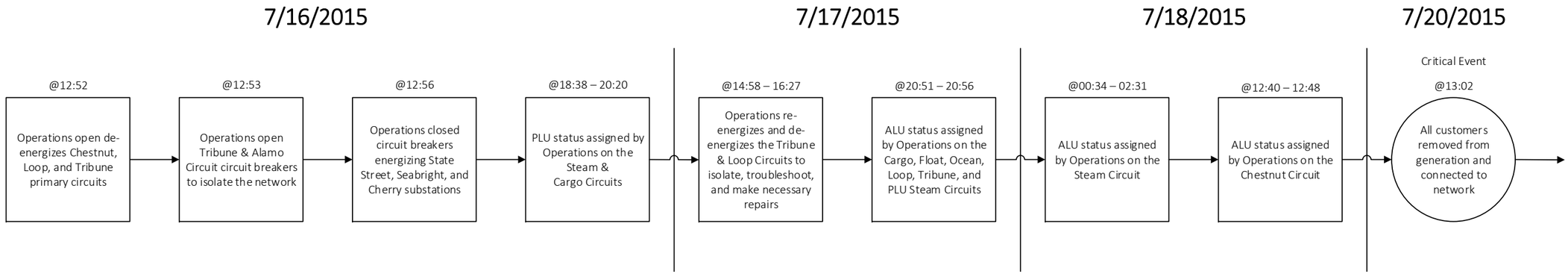
7/15/2015



ATTACHMENT 6: Event and Causal Factor Chart

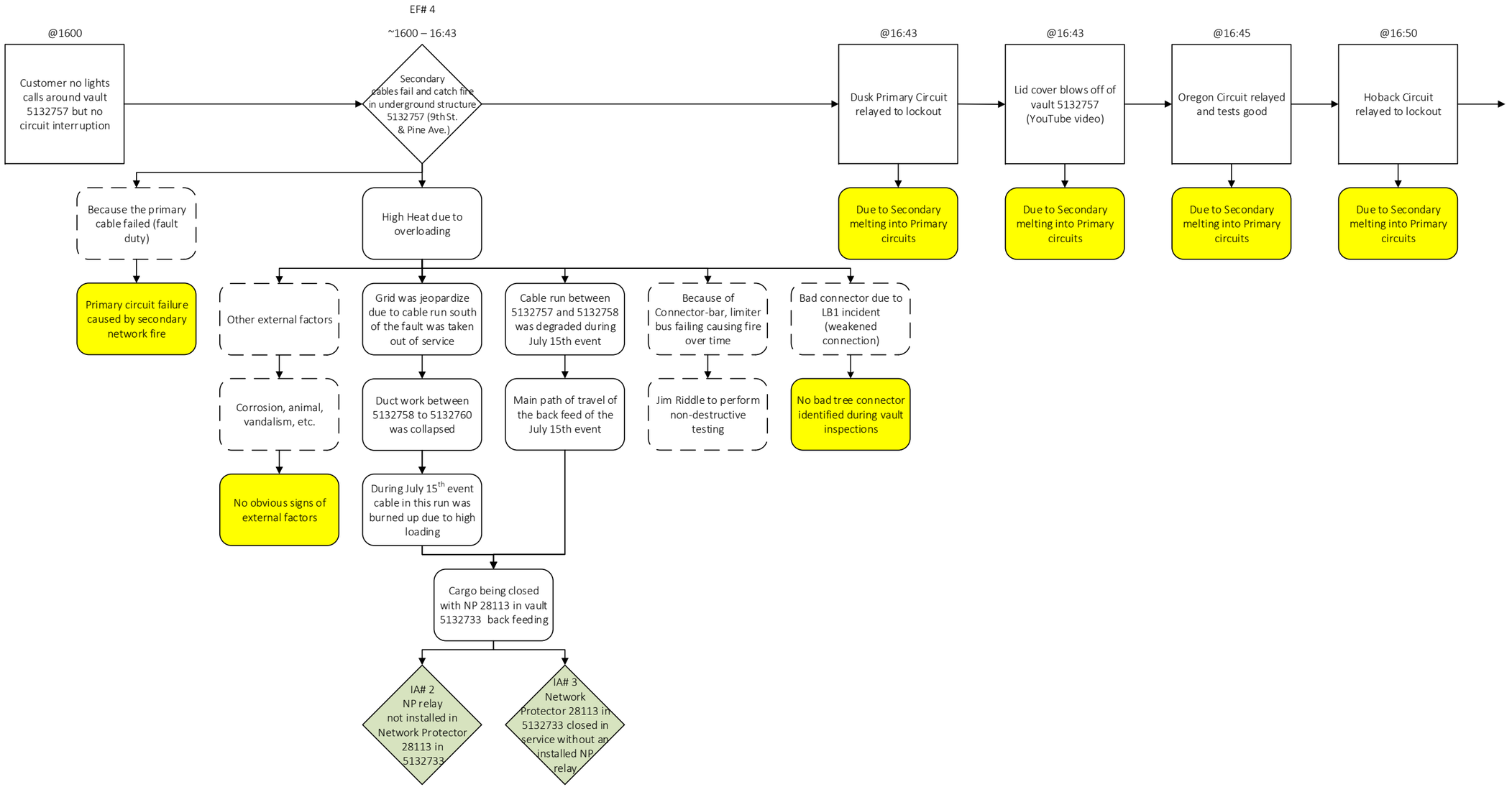


ATTACHMENT 6: Event and Causal Factor Chart



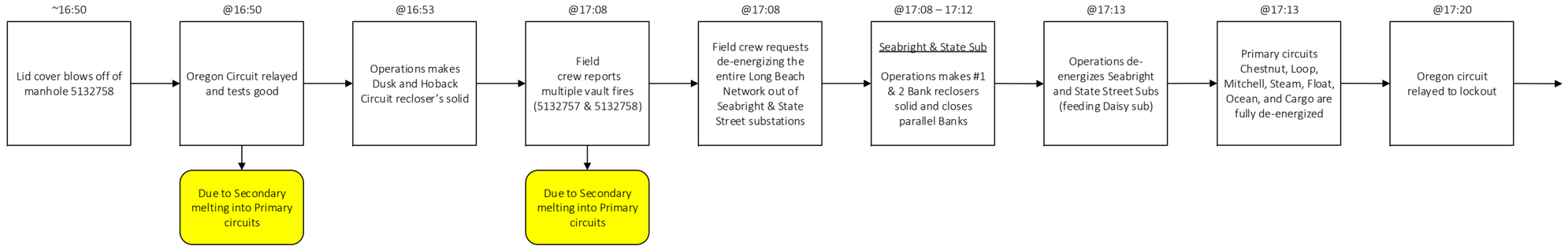
ATTACHMENT 6: Event and Causal Factor Chart

Long Beach 2 Event - 7/30/2015

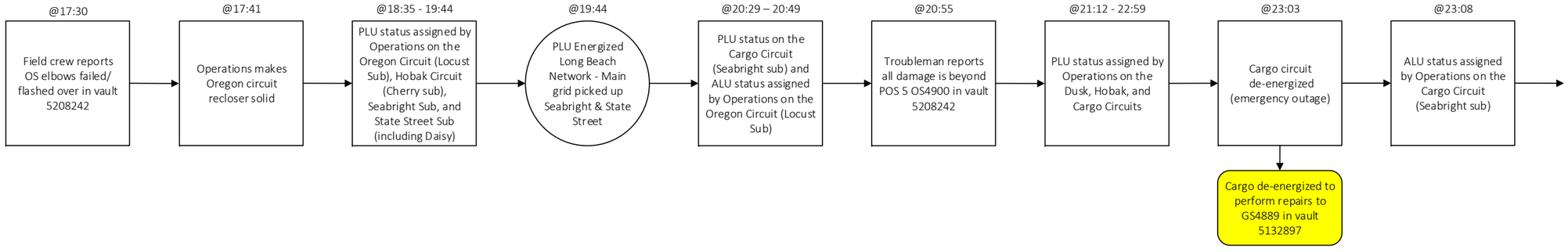


ATTACHMENT 6: Event and Causal Factor Chart

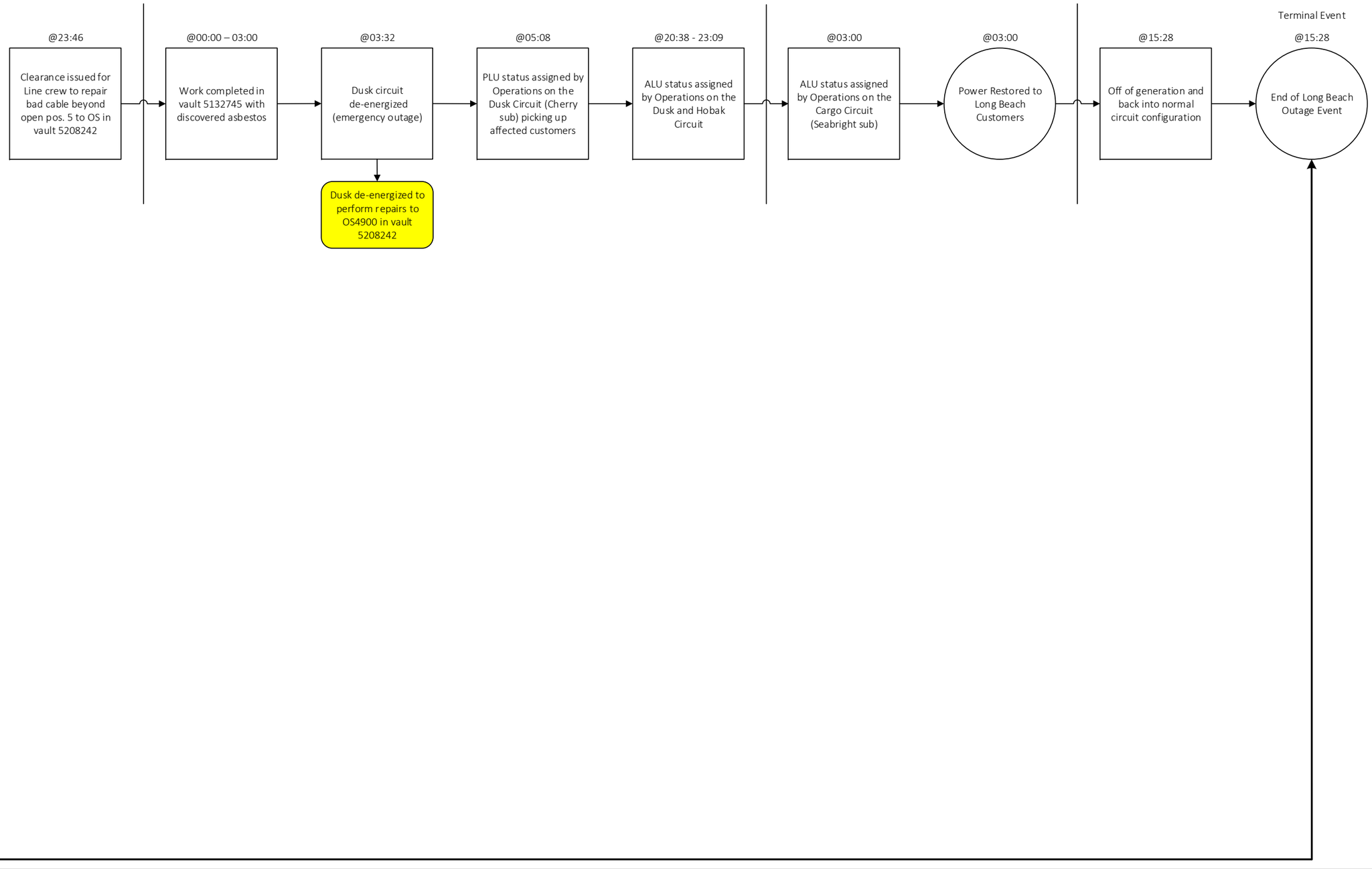
7/30/2015



ATTACHMENT 6: Event and Causal Factor Chart



ATTACHMENT 6: Event and Causal Factor Chart



ATTACHMENT 7: Barrier Analysis

Failure Mode Categories	Failure Mode	Associated Inappropriate Action / Equipment Failure	Failed Barrier Yes or No	Basis	Actions
Design	Selection of Materials	EF-1: Cable splice failure in structure 5134053	No	Materials were within the latest JJ507 standards (Joints & Junction)	N/A
	Dimensional Issues	EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	No	Structure design and circuit proximity within acceptable industry standards	N/A
	Single Point Vulnerability Issues	EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	No	Multiple feeder circuits were in same structure when splice failed, lost 2 network feeders. Acceptable to have up to 4 primary circuits within one structure.	N/A
	Operating Experience	IA-1: Relay not installed in NP 20649 in structure 5134205 IA-2: Relay not installed in NP 28113 in structure 5132733 IA-3: NP 28113 in structure 5132733 closed in service without Relay IA-4: NP 20649 in structure 5134205 closed in service without Relay	No	Previous Network Protector failures within the last 10 years have failed due to equipment malfunction. No known Operating Experience on Network Protectors missing relay and closed in service	N/A
	Standards	EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	No	Other utilities (ConEd and PG&E) have circuits and substations dedicated only to the Secondary Network. SCE Secondary Network equipment maintenance is performed within the Industry standards (IEEE or other)	N/A

ATTACHMENT 7: Barrier Analysis

Failure Mode Categories	Failure Mode	Associated Inappropriate Action / Equipment Failure	Failed Barrier Yes or No	Basis	Actions
Maintenance	Parts	EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	No	Failed splice undergoing further forensic analysis. All parts utilized for the fabrication and maintenance of the equipment involved in the event were within the industry standards.	N/A
	Assembly	EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	No	Failed splice undergoing further forensic analysis. Assembly of all other equipment involved in the event were done within the industry standards.	N/A
	Installation	IA-1: Relay not installed in NP 20649 in structure 5134205 IA-2: Relay not installed in NP 28113 in structure 5132733 EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	Yes	Relay does not happen at the point of Network Protector installation. No clear communication path. Failed splice undergoing further forensic analysis. Installation of all other equipment involved in the event were done within the industry standards.	CA-1 & 8
	Preventative Maintenance	EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	No	Preventative Maintenance of all equipment involved in the event were done within the industry standards.	N/A
Programmatic	Inspections	IA-1: Relay not installed in NP 20649 in structure 5134205	Yes	Apparatus inspections did not adequately capture the missing relay. No reporting of the missing relay.	CA-11 & 12

Failure Mode Categories	Failure Mode	Associated Inappropriate Action / Equipment Failure	Failed Barrier Yes or No	Basis	Actions
	Records	IA-1: Relay not installed in NP 20649 in structure 5134205 IA-2: Relay not installed in NP 28113 in structure 5132733 IA-3: NP 28113 in structure 5132733 closed in service without Relay IA-4: NP 20649 in structure 5134205 service without Relay closed in	Yes	Inadequate record keeping in SAP. Loss of visibility of Network Protector status. Inability to track Network Protector Relay by Distribution Apparatus	CA-1 & 4
Operations	Operating Procedures and Practices Appropriate for this Equipment Or System	IA-1: Relay not installed in NP 20649 in structure 5134205 IA-2: Relay not installed in NP 28113 in structure 5132733 IA-3: NP 28113 in structure 5132733 closed in service without Relay IA-4: NP 20649 in structure 5134205 closed in service without Relay EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	Yes	No operating procedure existed for adequately addressing the operation & restoration of the Long Beach Secondary Network System	CA-22
	Configuration Control	IA-1: Relay not installed in NP 20649 in structure 5134205 IA-2: Relay not installed in NP 28113 in structure 5132733 IA-3: NP 28113 in structure 5132733 closed in service without Relay IA-4: NP 20649 in structure 5134205 closed in service without Relay	Yes	Inadequate oversight over Network Protector configuration (missing relay).	CA-11 & 12
Environmental	Weather & Temperature	EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	No	Weather not a factor, no high heat reported	N/A

ATTACHMENT 7: Barrier Analysis

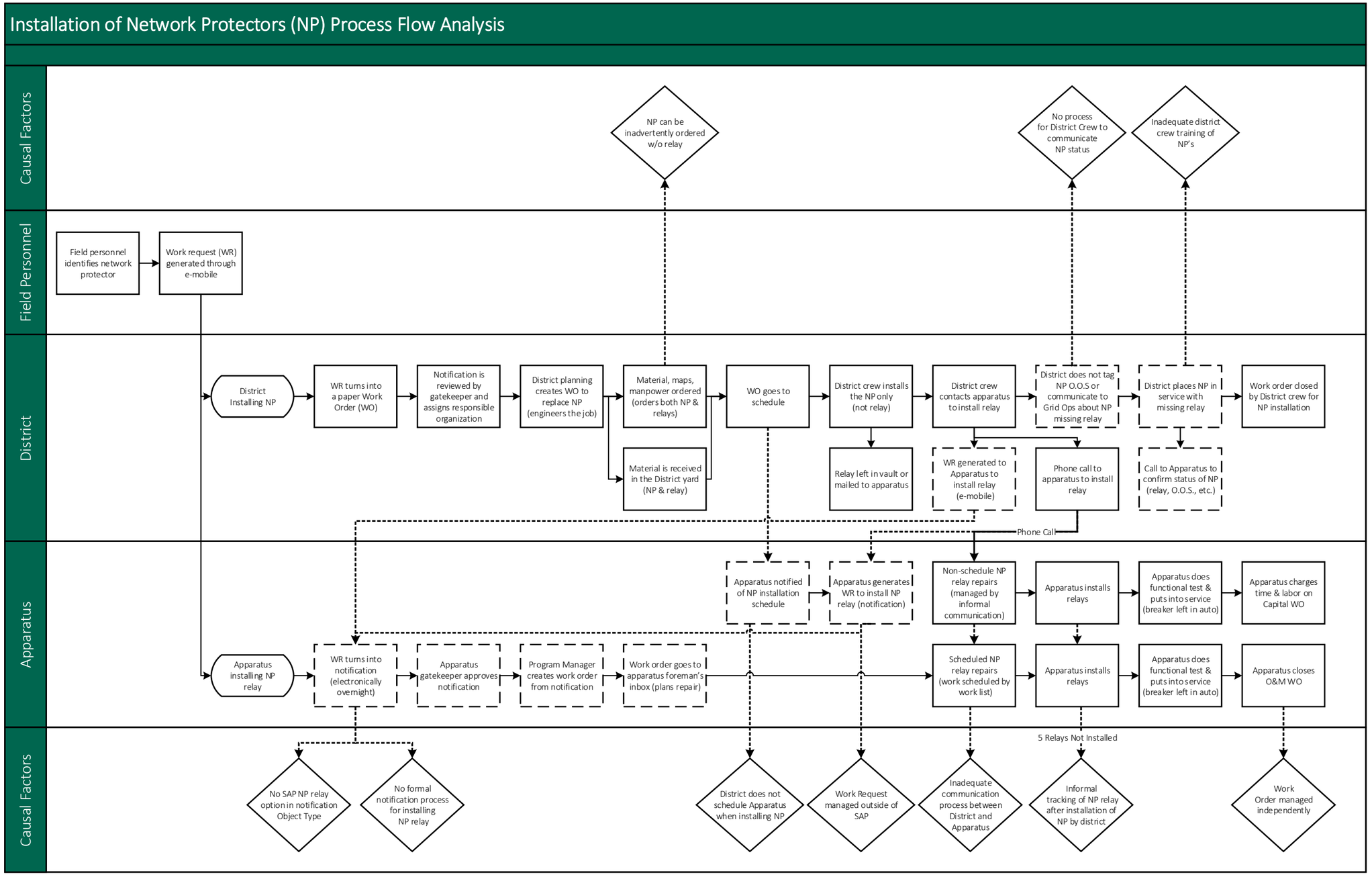
Failure Mode Categories	Failure Mode	Associated Inappropriate Action / Equipment Failure	Failed Barrier Yes or No	Basis	Actions
Equipment	Animal & Human Interaction	EF-1: Cable splice failure in structure 5134053 EF-2: Structure fire occurs in structure 5133092 EF-3: NP 28113 in structure 5132733 is back feeding load on Cargo primary circuit causing damage to secondary network cable EF-4: Secondary cables fail and catch fire in structure 5132757	No	No evidence of Animal or Human Interaction with the equipment to have caused equipment failures	N/A
	Fatigue	EF-1: Cable splice failure in structure 5134053 EF-4: Secondary cables fail and catch fire in structure 5132757	No	No obvious sign of Fatigue, forensic analysis to be performed to determine cause of failure.	N/A
	Temperature Embrittlement	EF-1: Cable splice failure in structure 5134053 EF-4: Secondary cables fail and catch fire in structure 5132757	No	No obvious sign of Temperature Embrittlement, forensic analysis to be performed to determine cause of failure.	N/A
	Interferences	EF-1: Cable splice failure in structure 5134053 EF-4: Secondary cables fail and catch fire in structure 5132757	No	No obvious sign of Interferences, forensic analysis to be performed to determine cause of failure.	N/A
	Corrosion	EF-1: Cable splice failure in structure 5134053 EF-4: Secondary cables fail and catch fire in structure 5132757	No	No obvious sign of Corrosion, forensic analysis to be performed to determine cause of failure.	N/A
	Capacity formation	EF-1: Cable splice failure in structure 5134053 EF-4: Secondary cables fail and catch fire in structure 5132757	No	No obvious sign of Capacity formation, forensic analysis to be performed to determine cause of failure.	N/A
	Contamination	EF-1: Cable splice failure in structure 5134053 EF-4: Secondary cables fail and catch fire in structure 5132757	No	No obvious sign of Contamination, forensic analysis to be performed to determine cause of failure.	N/A
	Wear	EF-1: Cable splice failure in structure 5134053 EF-4: Secondary cables fail and catch fire in structure 5132757	No	No obvious sign of Wear, forensic analysis to be performed to determine cause of failure.	N/A
	Foreign Material	EF-1: Cable splice failure in structure 5134053 EF-4: Secondary cables fail and catch fire in structure 5132757	No	No obvious sign of Foreign Material, forensic analysis to be performed to determine cause of failure.	N/A

ATTACHMENT 7: Barrier Analysis

Failure Mode Categories	Failure Mode	Associated Inappropriate Action / Equipment Failure	Failed Barrier Yes or No	Basis	Actions
Equipment	Cold Flow - distortion, deformation or dimensional change under load causing deformation influencing performance.	EF-1: Cable splice failure in structure 5134053 EF-4: Secondary cables fail and catch fire in structure 5132757	No	No obvious sign of Cold Flow, forensic analysis to be performed to determine cause of failure.	N/A

ATTACHMENT 8: Installation of Network Protectors (NP) Process Flow Analysis

ATTACHMENT 8: Installation of Network Protectors (NP) Process Flow Analysis



ATTACHMENT 9: Splice Dissection Results

50 Utopia Road • Manchester, CT 06042
860.783.8000 • www.imcorp.com

October 7, 2015

Attention: Jim Riddle
Jim.Riddle@sce.com

Subject: PILC Transition Joints Dissection Report

Dear Jim,

This summary describes IMCORP's findings during the dissection of the two Southern California Edison Company (SCE) joint samples received on 9/28/2015. The samples consisted of two faulted TE Connectivity (Raychem) trifurcating transition joints. See Table 1, Figure 1 (Steam joint), and Figure 9 (Float joint) for sample identification. The samples were dissected according to the procedure in Attachment 1. As with most cable and accessory failures, much of the evidence was destroyed but in each case risk factors were observed. During the dissection several stress enhancement and void type risk factors were identified. Stress enhancements and air voids in the presence of high voltage electrical stress can lead to an erosion process associated with partial discharge and eventually cause an insulation rupture.

Steam Joint
On the basis of the dissection observations, the single most significant risk factor to the premature failure of the sample labeled by SCE as "Steam" (Figure 1) is conductive material layer that was not removed from the joint and paper insulation interface as required by the manufacturer's installation instructions (Figures 5-8).

The risk factors identified in the Steam joint that represent significant deviations from the manufacturers' instructions include the amount of stress relief material (SRM) around the conductor (Figure 2), white markings on the inside of the red insulating tube (Figure 4), and carbon papers extending past the conductive material cutback length (Figures 5-8). The SRM around the connector is supposed to fill air voids under the stress control tube. Insufficient material can lead to air voids exposed to high voltage stress. White markings on the inside of the red insulating tube have been known to be an indication of air voids, partial discharge, and its associated erosion process. The carbon papers extending beyond the conductive material cutback length likely provided a high voltage stress enhancement near the conductor connector. In addition to these risk factors, the Steam joint was assembled using a Raychem 'trifurcating transition reducing splice' kit. According to the joint manufacturer representative attending the dissection, this kit was not necessary and the added parts complicated the installation and provided more risk for installation error.

Float Joint

There was very little material left near the middle of the joint SCE as labeled as “Float” (Figure 9) and, while some risk factors were identified in the remaining materials, none appear to be significant enough to conclude what caused the failure. Only one risk factor identified during the dissection of the Float joint represents a significant departure from the manufacturer’s instructions. A dimple (Figure 10) in the oil barrier tube was found in the high stress interface between the tube and the paper insulation. This risk factor did not cause the failure but would likely expose an air void to high electrical stress.

IMCORP appreciates the opportunity to support SCE and its cable reliability efforts. If you have any questions or comments, please do not hesitate to contact me at +1 (860) 783 - 8008.

Kind regards

Ben Lanz
Director, Applications Engineering
IMCORP

Table 1: Sample label and description

Sample	Description
Steam	3 EPR 500kcmil copper cables spliced to 1, 3-core sector shaped paper insulated lead covered (PILC) cable
Float	3 EPR 500kcmil copper cables spliced to 1, 3-core belted round conductor PILC cable

Steam Joint

Figure 1: Steam joint as received and unpackaged at IMCORP

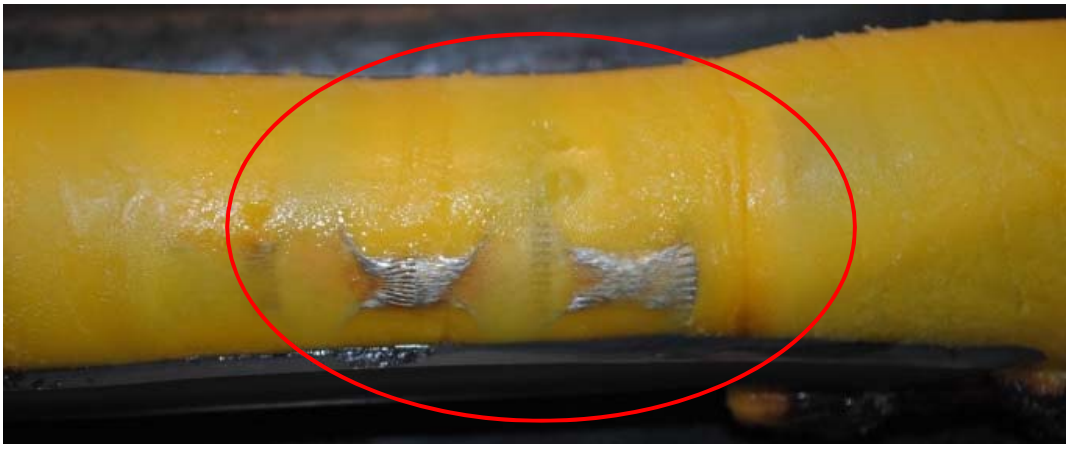


Figure 2: Red phase potentially insufficient stress relief material (SRM) mastic on the connector per the manufacturers' instructions (step 32)

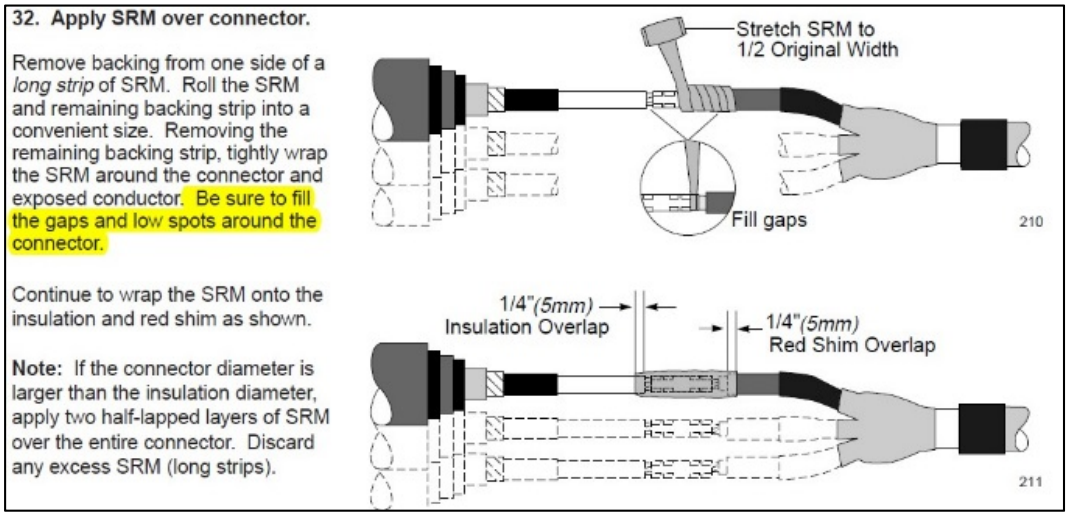


Figure 3: SRM application per manufacturers' instructions (IMCORP highlights)

Figure 4: Red phase white marks on the red insulating tube indicating likely erosion activity associated partial discharge activity in voids due to insufficient shrinkage. Disregard pry marks from the dissection effort on the right side of the oval.

Figure 5: Red phase dimensions of conductive material (black carbon paper tape) layer extending from the lead sheath cutback to near the conductor connector (yellow mastic over connector area starting at about 13 inches). Copper tapes ending approximately at the 6.5 inch mark. Brown insulating paper tape shown below black carbon paper.

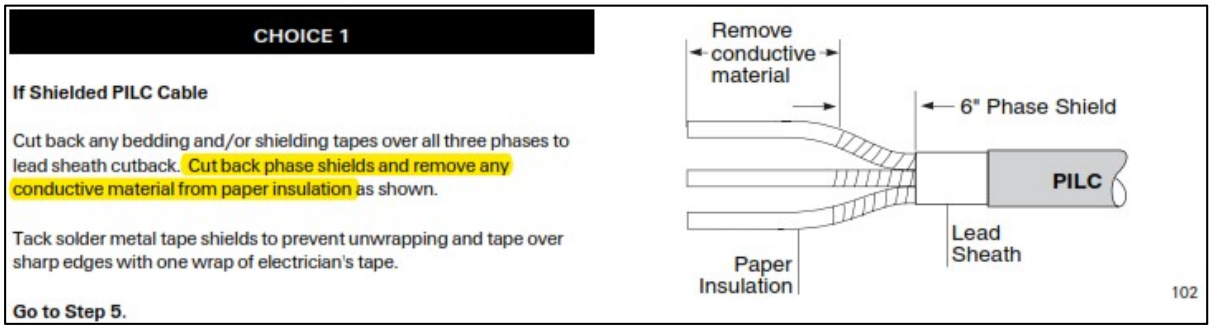


Figure 6: Dimensions of conductive material cutback per the manufacturers' instruction (step 7) (IMCORP highlight) Conductive materials including copper tape and black carbon paper tape must be removed to within 6 inches of the lead sheath.

Figure 7: Blue phase copper tapes ending at approximately 6.5 inches from the lead sheath cutback reference point (grey mark on jacket). Black carbon paper tape extending well beyond the 6 inch mark heading towards the conductor connector.

Figure 8: Blue phase close up of black carbon paper tape extending well beyond the 6 inch mark heading towards the conductor connector.

Float Joint

Figure 9: Float joint as received and unpackaged at IMCORP. Most of the insulating material around the conductor connectors is missing suggesting where the fault may have originated.

Figure 10: Evidence of uneven shrinkage of the oil barrier tube leaving an air void at insulation interface.

ATTACHMENT 10: All Areas That Were Impacted By One or More Outages

Customer Outages

July 15-19 - 30,705 customers

- 22,763 customers without service less than 1 hour
- 1,414 customers without service between 1-24 hours
- 6,528 customers without service over 24 hours

July 30 – Aug 3 - 17,790 customers

- 181 customers without service less than 1 hour
- 17,378 customers without service between 1-24 hours
- 231 customers without service over 24 hours