SoCalGas
A Sempra Energy utility®

Risk Assessment Mitigation Phase

(Chapter SCG-8)

Storage Well Integrity Event

November 27, 2019

TABLE OF CONTENTS

SoCalGas
A Sempra Energy utility®

Risk: Storage Well Integrity Event

I. INTRODUCTION

The purpose of this chapter is to present the Risk Mitigation Plan for Southern California Gas Company's (SoCalGas) Storage Well Integrity Event (Storage) risk. Each chapter in this Risk Assessment Mitigation Phase (RAMP) Report contains the information and analysis that meets the requirements adopted in Decision (D.) 16-08-018 and D.18-12-014, and the Settlement Agreement included therein (the SA Decision).[1]

SoCalGas has identified and defined RAMP risks in accordance with the process described in further detail in Chapter RAMP-B of this Report. On an annual basis, SoCalGas' Enterprise Risk Management (ERM) organization facilitates the Enterprise Risk Registry (ERR) process, which influenced how risks were selected for inclusion in the 2019 RAMP Report, consistent with the SA Decision's directives.

The purpose of RAMP is not to request funding. Any funding requests will be made in SoCalGas' General Rate Case (GRC). The costs presented in this 2019 RAMP Report are those costs for which SoCalGas anticipates requesting recovery in its Test Year (TY) 2022 GRC. SoCalGas' TY 2022 GRC presentation will integrate developed and updated funding requests from the 2019 RAMP Report, supported by witness testimony.[2] For the 2019 RAMP Report, the baseline costs are the costs incurred in 2018, as further discussed in Chapter RAMP-A. This 2019 RAMP Report presents capital costs as a sum of the years 2020, 2021 and 2022 as a three-year total; whereas, O&M costs are only presented for TY 2022.

Costs for each activity that directly addresses each risk are provided where those costs are available and are within the scope of the analysis required for this RAMP Report. Throughout this 2019

---

1 D.16-08-018 also adopted the requirements previously set forth in D.14-12-025. D.18-12-014 adopted the Safety Model Assessment Proceeding (S-MAP) Settlement Agreement with modifications and contains the minimum required elements to be used by the utilities for risk and mitigation analysis in the RAMP and GRC.

2 *See,* D.18-12-014 at Attachment A, A-14 ("Mitigation Strategy Presentation in the RAMP and GRC").

RAMP Report, activities are delineated between controls and mitigations, which is consistent with the definitions adopted in the SA Decision's Revised Lexicon. A "Control" is defined as a currently established measure that is modifying risk. A "Mitigation" is defined as a measure or activity proposed or in process designed to reduce the impact/consequences and/or likelihood/probability of an event.

As discussed in Chapter RAMP-D, Risk Spend Efficiency (RSE) Methodology, no RSE calculation is provided where costs are not available or not presented in this RAMP Report (including costs for activities that are outside of the GRC or certain internal labor costs). Additionally, SoCalGas did not perform RSE calculations on mandated activities. Mandated activities are defined in this report as control activities conducted in order to meet a mandate or law, such as a Code of Federal Regulation (CFR), Public Utilities Code statute, or General Order. Activities with no RSE score presented in this 2019 RAMP Report are identified in Section VII below.

SoCalGas has also included a qualitative narrative discussion of certain risk mitigation activities that would otherwise fall outside of the RAMP Report's requirements, to aid the California Public Utilities Commission (CPUC or Commission) and stakeholders in developing a more complete understanding of the breadth and quality of SoCalGas' mitigation activities. These distinctions are discussed in the applicable control/mitigation narratives in Section V. Similarly, a narrative discussion of certain "mitigation" activities and their associated costs is provided for certain activities and programs that may indirectly address the risk at issue, even though the scope of the risk as defined in the RAMP Report may technically exclude the mitigation activity from the RAMP analysis. This additional qualitative information is provided in the interest of full transparency and understandability, consistent with guidance from Commission staff and stakeholder discussions.

A. Risk Definition

For purposes of this 2019 RAMP Report, the Storage risk is defined "as the risk of an uncontrolled release of gas that occurs over an extended period due to a storage well structural integrity issue that requires complex well control operations resulting in gas reliability issues, extensive customer impacts, injuries and/or fatalities."

B. Summary of Elements of the Risk Bow Tie

Pursuant to the SA Decision,[3] for each control and mitigation presented herein, SoCalGas has identified which element(s) of the Risk Bow Tie the mitigation addresses. Below is a summary of these elements.

Table 1: Summary of Risk Bow Tie Elements

ID	Description of Driver/Trigger and Potential Consequence
DT.1	Internal/external corrosion
DT.2	Aging asset infrastructure
DT.3	Incorrect/inadequate asset records
DT.4	Outside forces (natural disasters, landslides)
DT.5	Human error
PC.1	Serious injuries[4] and/or fatalities
PC.2	Property damage
PC.3	Uncontrolled release in high consequence area
PC.4	Loss of storage injection and withdrawal capacity
PC.5	Loss of stored gas
PC.6	Adverse litigation
PC.7	Diminished public confidence
PC.8	Penalties and fines
PC.9	Environmental impacts

---

3 D.18-12-014 at Attachment A, A-11 ("Bow Tie").

4 As defined by Cal/OSHA as "any injury or illness occurring in a place of employment or in connection with any employment which requires inpatient hospitalization for a period in excess of 24 hours for other than medical observation or in which an employee suffers a loss of any member of the body or suffers any serious degree of permanent disfigurement, but does not include any injury or illness or death caused by the commission of a Penal Code violation, except the violation of Section 385 of the Penal Code, or an accident on a public street or highway." 8 California Code of Regulations (CCR) § 330(h).

C. Summary of Risk Mitigation Plan

Pursuant to the SA Decision,[5] SoCalGas has performed a detailed pre- and post-mitigation analysis of controls and mitigations for each risk selected for inclusion in RAMP, as further described below. SoCalGas' baseline controls for this risk consists of the following programs/activities:

Table 2: Summary of Controls

ID	Control Name
SCG-8-C1	Well Construction Requirements and Dual Barrier System
SCG-8-C2	Well Abandonments
SCG-8-C3	Pressure Monitoring and Alarming
SCG-8-C4	Wellhead Leak Detection and Repair
SCG-8-C5	Integrity Management for Gas Storage Operations
SCG-8-C6	Integrity Demonstration, Verification, and Monitoring Practices

SoCalGas will continue the baseline controls identified above. Finally, pursuant to the SA Decision,[6] SoCalGas presents considered alternatives to the mitigation plan for the Storage risk and summarizes the reasons the alternatives were not included in the mitigation plan in Section VIII.

II. RISK OVERVIEW

Gas storage wells are a necessary and critical component of California's reliable gas delivery infrastructure because gas storage provides supply to over 21 million customers and half the electric generation in SoCalGas' territory. SoCalGas operates four underground gas storage fields: Aliso

---

[5] D.18-12-014 at Attachment A, A-11 ("Definition of Risk Events and Tranches").

[6] *Id.* at 33.

Canyon, La Goleta, Honor Rancho, and Playa del Rey with a current combined working capacity of approximately 84.4 Bcf.[7,8]

- Aliso Canyon is in Northern Los Angeles County and is the largest of the four gas storage fields that delivers gas to the Los Angeles pipeline loop. Aliso Canyon has a design working capacity of approximately 86 Bcf .[9,10] Aliso Canyon has 78 injection/withdrawal/observation wells[11] and was designed for a maximum withdrawal rate of approximately 1.8 Bcf per day.[12]
- Honor Rancho is also located in Northern Los Angeles County, approximately ten miles north of Aliso Canyon, with a working capacity of approximately 27 Bcf and delivers to the Los Angeles pipeline loop. Honor Rancho has 35 gas injection/withdrawal wells and is designed for a maximum withdrawal capability of 1.0 Bcf per day. [13]
- La Goleta is in Santa Barbara County and provides service to the northern coastal area of the SoCalGas territory. La Goleta has a working capacity of approximately 21 Bcf. La

---

7 The volumetric capacity of a natural gas storage field reservoir is measured in units of billion cubic feet (Bcf).

8 Aliso Canyon is currently restricted to a working gas capacity of 34 Bcf, per CPUC July 6, 2018 report: Aliso Canyon Working Gas Inventory, Production Capacity, Injection Capacity, and Well Availability for Reliability, Summer 2018 Supplemental Report.

9 *Id.*

10 PHMSA Underground Natural Gas Storage Facility Annual Report for Calendar Year 2018 Supplemental Report.

11 PHMSA Underground Natural Gas Storage Facility Annual Report for Calendar Year 2018 – Supplemental Report, submitted May 20, 2019.

12 Withdrawal capacity is dependent on well availability and inventory.

13 PHMSA Underground Natural Gas Storage Facility Annual Report for Calendar Year 2018 – Supplemental Report, submitted May 20, 2019.

Goleta has 21 gas injection/withdrawal/observation wells and is designed for a maximum withdrawal capability of 0.4 Bcf per day.[14]

- Playa del Rey, located in central Los Angeles County, has a working capacity of approximately 2.4 Bcf. Playa del Rey has 39 gas injection/withdrawal/observation wells.[15] Playa del Rey is designed for a maximum withdrawal rate of 0.4 Bcf per day to meet residential, commercial and industrial loads throughout the western part of Los Angeles, including electric generators and oil refineries.

This chapter considers risks associated with the following storage field components: process and well servicing operations, well design, casing, tubing, and annulus or tree/wellhead for SoCalGas' four active underground gas storage facilities: Aliso Canyon, Honor Rancho, La Goleta, and Playa del Rey.

On October 23, 2015, SoCalGas' Aliso Canyon SS-25 well failed, causing a gas leak at the Aliso Canyon gas storage facility in Los Angeles, California. Ultimately, a relief well was drilled to permanently plug the leaking well on February 18, 2016. The event prompted heightened awareness of underground gas storage operations risks, and new federal and state regulations were introduced in 2016, 2017, and 2018, which include:

- U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration's (PHMSA) Underground Storage regulations, 49 Code of Federal Regulations (CFR) § 192.12 Interim Final Rule (IFR), effective January 18, 2017, adopts American Petroleum Industry (API) Recommended Practice 1171, Functional Integrity of Natural Gas Storage in Depleted Hydrocarbon Reservoirs and Aquifer Reservoirs, as a mandatory regulation, among other things.
- Division of Oil, Gas, and Geothermal Resources (DOGGR) established 14 California Code of Regulations (CCR) §1726 California Underground Gas Storage regulations effective October 1, 2018, which includes among other things, requirements for operators

---

14 *Id.*

15 *Id.*

to submit project-specific Risk Management Plans, Emergency Response Plans, project data requirements, a Records Management Program, well construction requirements, mechanical integrity testing requirements, and monitoring and reporting requirements.

- California Air Resources Board (CARB) established an Oil & Gas Rule regulation effective October 1, 2017, which describes monitoring requirements for natural gas underground storage facilities. SoCalGas has developed and received approval from CARB and the local air districts for an underground storage facilities monitoring plan and leak detection protocol. These include installation of continuous ambient methane monitoring at the wellheads and associated lateral piping.

SoCalGas has implemented activities and measures to comply with new federal and state regulations at an accelerated pace, and has incorporated additional industry leading safety enhancements and improvements. These activities and measures are part of the implementation of SoCalGas' Storage Integrity Management Program (SIMP). SoCalGas' SIMP was modeled after the federally mandated distribution and transmission integrity management programs, and was designed to provide a forward-looking, methodical, and structured approach, using state-of-the-art inspection technologies and risk management disciplines to address storage reservoir and well integrity issues.

SoCalGas proposed SIMP in 2014, before federal and state underground gas storage regulations were promulgated, and has an accelerated pace of completing its SIMP assessments for storage wells at all four storage fields from its original plan of six years to four years. SoCalGas has completed over 90% of its baseline assessments and abandonments for injection/withdrawal gas storage wells to date, considerably ahead of the PHMSA requirement to complete baseline assessments within three to eight years.[16]

---

[16] Furthermore, for well integrity casing thickness demonstration for underground storage, SoCalGas goes beyond the DOGGR regulations by performing both magnetic flux leakage ("MFL") and ultrasonic ("UT") inspection technology to detect corrosion or metal loss, even though only one method is required by regulation.

SoCalGas has also introduced a suite of advanced leak-detection technologies and practices that allow for early detection of leaks and help quickly identify anomalies, such as changes in well pressure. These enhancements include:

- Around-the-clock monitoring of the pressure in all wells from our 24-hour operations center;
- Continuous upwind/downwind ambient air monitoring and meteorological stations at each storage facility;
- Either daily well inspections or continuous/real-time wellhead monitoring; and
- Enhanced training for our employees and contractors.

SoCalGas also continues to support industry experts in their research efforts to advance underground storage safety.

III. RISK ASSESSMENT

In accordance with the SA Decision,[17] this section describes the Risk Bow Tie, possible drivers, and potential consequences of the Storage risk.

A. Risk Bow Tie

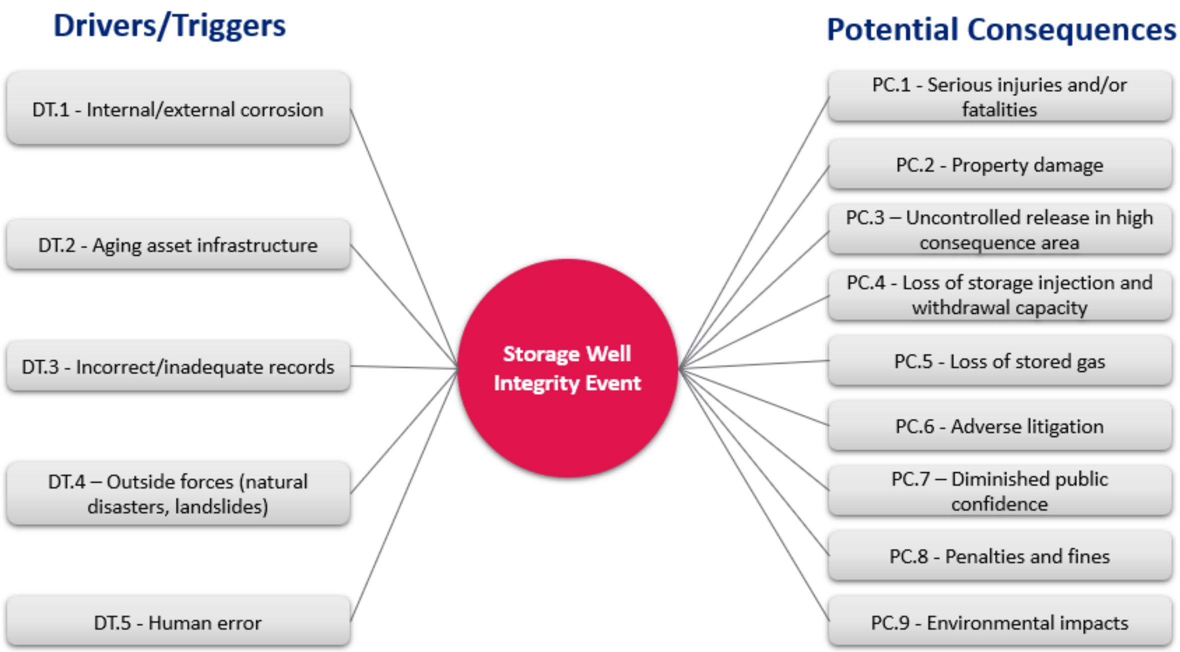
The Risk Bow Tie shown in Figure 1 below is a commonly-used tool for risk analysis. The left side of the Bow Tie illustrates drivers that lead to a risk event and the right side shows the potential consequences of a risk event. SoCalGas applied this framework to identify and summarize the information provided above. A mapping of each Control/Mitigation to the element(s) of the Risk Bow Tie addressed is provided in Appendix A.

---

[17] D.18-12-014 at 33 and Attachment A, A-11 (“Bow Tie”).

SoCalGas
A Sempra Energy utility

Figure 1: Risk Bow Tie



B. Asset Groups or Systems Subject to the Risk

The SA Decision[18] directs the utilities to endeavor to identify all asset groups or systems subject to the Storage risk. The four underground storage fields work in conjunction with the SoCalGas transmission pipeline and distribution delivery network. This interconnected system consists of high-pressure pipelines, compressor stations, and underground storage fields, designed to receive natural gas from interstate pipelines and local production sources. The integrated system enables deliveries of natural gas to customers or into storage field reservoirs, depending on market demands.

C. Risk Event Associated with the Risk

The SA Decision[19] instructs the utility to include a Risk Bow Tie illustration for each risk included in RAMP. As illustrated in the above Risk Bow Tie, the risk event (center of the bow tie) is a storage well integrity event, which may result in any of the Potential Consequences listed on the right.

---

[18] *Id.* at Attachment A, A-11 ("Definition of Risk Events and Tranches").

[19] *Id.* at Attachment A, A-11 ("Bow Tie").

The Drivers/Triggers that may contribute to this risk event are further described in the section below. The Risk Scenario (i.e. a potential reasonable worst-case scenario used to assess the residual risk impacts and frequency), as assessed for SoCalGas' 2018 Enterprise Risk Registry, considers a well integrity event, leading to damage and considers any direct consequences of gas deliverability reduction, gas inventory loss, environmental impacts, penalties or fines, serious injuries or fatalies, property damage, and adverse litigation associated with a single well.

D. Potential Drivers/Triggers[20]

The SA Decision[21] instructs the utility to identify which element(s) of the associated bow tie each mitigation addresses. When performing the risk assessment for Storage risk, SoCalGas identified potential leading indicators, referred to as Drivers or Triggers. These include, but are not limited to:

DT.1 – Internal/ external corrosion: The risk driver is based on the potential for corrosion on the inside or outside of tubing and buried steel casing. Internal corrosion and/or erosion may be caused by the corrosive effect of fluid, sand, and/or reactive constituents such as carbon dioxide in the gas withdrawn from the storage formations and the natural degradation of buried steel casing. External corrosion to buried steel casing may be caused by contact with certain underground soil formation conditions.

DT.2 – Aging asset infrastructure: This risk driver is based on the age of the wells at SoCalGas' storage fields. Although the four SoCalGas storage fields have been in service for various timeframes, the average age of all injection/withdrawal wells is approximately 49 years.

DT.3 – Incorrect/inadequate asset records: This risk driver is based on the potential for inaccurate or incomplete information that could result in the failure to construct, operate, and maintain SoCalGas' wells safely.

---

20 An indication that a risk could occur. It does not reflect actual or threatened conditions.

21 D.18-12-014 at Attachment A, A-11 ("Bow Tie").

DT.4 – Outside forces (natural disasters, landslides): This risk driver includes both natural forces and those from external sources that can affect the integrity of the storage facilities. Examples of natural forces include ground movement, landslides, and subsidence from earthquakes.

DT.5 – Human error: This risk driver is based on the potential for maintenance or inspection functions to be performed incorrectly by employees or contractors. The cause of this could be inadequate procedures, failure to follow procedures, inadequate training or inexperienced personnel.

E. Potential Consequences of Risk Event

Potential Consequences are listed to the right side of the Bow Tie illustration provided above. If one or more of the Drivers/Triggers listed above were to result in an incident, the Potential Consequences, in a reasonable worst-case scenario, could include:

- Serious injuries[22] and/or fatalities;
- Property damage;
- Uncontrolled release in high consequence areas;
- Loss of storage injection and withdrawal capacity
- Loss of stored gas
- Adverse litigation
- Diminished public confidence
- Penalties and fines
- Environmental impacts

---

[22] As defined by Cal/OSHA as "any injury or illness occurring in a place of employment or in connection with any employment which requires inpatient hospitalization for a period in excess of 24 hours for other than medical observation or in which an employee suffers a loss of any member of the body or suffers any serious degree of permanent disfigurement, but does not include any injury or illness or death caused by the commission of a Penal Code violation, except the violation of Section 385 of the Penal Code, or an accident on a public street or highway." http://services.claremont.edu/ehs/wp-content/uploads/sites/16/2017/03/cal-osha-serious-injury-definition.pdf.

These Potential Consequences were used in the scoring of the Storage risk for the development of SoCalGas' 2018 ERR.

IV. RISK QUANTIFICATION

The SA Decision sets minimum requirements for risk and mitigation analysis in RAMP,[23] including enhancements to the Interim Decision 16-08-018.[24] SoCalGas has used the guidelines in the SA Decision as a basis for analyzing and quantifying risks, as shown below. Chapter RAMP-C of this RAMP Report explains the Risk Quantitative Framework which underlies this Chapter, including how the Pre-Mitigation Risk Score, Likelihood of Risk Event (LoRE), and Consequence of Risk Event (CoRE) are calculated.

Table 3: Risk Quantification Scores[25]

Storage Well Integrity Event	Low Alternative	Single Point	High Alternative
Pre-Mitigation Risk Score	339	**348**	363
LoRE		**0.1**	
CoRE	3957	**4062**	4237

A. Risk Scope & Methodology

The SA Decision requires a pre- and post-mitigation risk calculation.[26] The below section provides an overview of the scope and methodologies applied for the purpose of risk quantification.

---

23 D.18-12-014 at Attachment A.

24 *Id.* at 2-3.

25 The term "pre-mitigation analysis," in the language of the SA Decision (Attachment A, Item Nos. 17-19), refers to required pre-activity analysis conducted prior to implementing control or mitigation activity.

26 D.18-12-014 at Attachment A, A-11 ("Calculation of Risk").

Table 5: Risk Quantification Scope

In-Scope for purposes of risk quantification:	The risk of storage incidents caused by storage well structural integrity issues, which results in significant consequences including injuries or fatalities.
Out-of-Scope for purposes of risk quantification:	The risk of storage incidents unrelated to storage well structural integrity issues.

Pursuant to Step 2A of the SA Decision, the utility is instructed to use actual results, available and appropriate data (e.g., PHMSA data).[27] The safety risk assessment primarily considered historical occurrences of unintended releases from underground gas storage facilities of varying severity as described in the "Analysis of Occurrences at Underground Fuel Storage Facilities and Assessment of the Main Mechanisms Leading to Loss of Storage Integrity" paper as cited in the Section IV.B below, "Sources of Input." The incident rates with safety consequences were calculated as the product of national average (the frequency of an incident per field) and the number of fields SoCalGas operates currently. The safety risk was evaluated by using Monte Carlo simulation.

The reliability assessment considered internal and national data. Internal data over the past five years indicates no storage risk incidents which led to loss of service to customers. Additionally, PHMSA does not record loss of service and the US Rock Mechanics Presentation also did not provide analysis involving loss of service.

The financial assessment was estimated based on historical data from the U.S Natural Gas Storage Risk-Based Ranking Methodology and Results[28] and further supported by input from Company subject matter experts (SMEs). The data includes storage field incidents dating back approximately 70 years and their respective estimated financial impacts.

---

[27] *Id.* at Attachment A, A-8 ("Identification of Potential Consequences of Risk Event").

[28] U.S. Natural Gas Storage Risk-Based Ranking Methodology and Results, Argonne National Laboratory, (October 2016), *available at* https://publications.anl.gov/anlpubs/2016/12/132436.pdf.

B. Sources of Input

The SA Decision[29] directs the utility to identify Potential Consequences of a Risk Event using available and appropriate data. The below provides a listing of the inputs utilized as part of this assessment.

- Analysis of Occurrences at Underground Fuel Storage Facilities and Assessment of the Main Mechanisms Leading to Loss of Storage Integrity
  - Conference: 51st US Rock Mechanics/Geomechanics Symposium, at San Francisco, California
  - Authors: Evans, David J. British Geological Survey, UK; Schultz, Richard A. Petroleum and Geosystems Engineering, The University of Texas at Austin, USA
  - Link: https://www.researchgate.net/publication/317873326_Analysis_of_Occurrences_at_Underground_Fuel_Storage_Facilities_and_Assessment_of_the_Main_Mechanisms_Leading_to_Loss_of_Storage_IntegrityLink: Annual Report mileage for Gas Distribution Systems
- Number of Depleted Fields, Underground Natural Gas Storage Capacity
  - Agency: U.S. Energy Information Administration (EIA)
  - Link: https://www.eia.gov/dnav/ng/ng_stor_cap_a_EPG0_SA2_Count_a.htm
- U.S. Natural Gas Storage Risk-Based Ranking Methodology and Results
  - Agency: Argonne National Laboratory (U.S. Department of Energy laboratory)
  - Link: https://publications.anl.gov/anlpubs/2016/12/132436.pdf

V. RISK MITIGATION PLAN

The SA Decision requires a utility to "clearly and transparently explain its rationale for selecting mitigations for each risk and for its selection of its overall portfolio of mitigations."[30] This section describes SoCalGas' Risk Mitigation Plan by each selected control and mitigation for this risk, including the rationale supporting each selected control.

---

[29] D.18-12-014 at Attachment A, A-8 ("Identification of the Frequency of the Risk Event").

[30] *Id.* at Attachment A, A-14 ("Mitigation Strategy Presentation in the RAMP and GRC").

As stated above, SoCalGas' Storage risk is defined as the risk of an uncontrolled release of gas that occurs over an extended period due to a storage well structural integrity issue that requires complex well control operations resulting in gas reliability issues, extensive customer impacts, injuries and/or fatalities. The Risk Mitigation Plan discussed below includes both controls that are expected to continue for the period of SoCalGas' TY 2022 GRC cycle.[31] The controls are those activities that were in place as of 2018, most of which have been developed over many years, to address this risk and include work to comply with laws that were in effect at that time.

A. SCG-8-C1 – Well Construction Requirements and Dual Barrier System

SoCalGas gas storage wells are operated such that injection and withdrawal of gas into and out of the storage reservoir is accomplished only through the tubing, which is the innermost string of piping in the well configuration. The outer production casing acts as a secondary containment barrier. This is a change from historical operations at the storage fields, which previously allowed for injection and withdrawal through the tubing and casing. Retrofit activities to execute conversion of the wells to tubing only flow can include replacement of the wellhead, replacement of valves, replacement of the tubing and packer, installation of an inner casing string or liner, and installation of shallow-set subsurface safety valves.

B. SCG-8-C2 – Well Abandonments

Under certain circumstances, SoCalGas may abandon a well rather than continue to utilize it for gas storage operations. The decision to plug and abandon a well is driven by various factors including, but not limited to, well-specific information, location-specific information, deliverability, operation and maintenance history, and operational needs. To abandon a well, SoCalGas isolates the well from injection and withdrawal operations, removes casing to a certain depth and wellhead equipment, and fills the wellbore with cement.

---

[31] *Id.* at p. 33. A "Control" is defined as a currently established measure that is modifying risk. A "Mitigation" is defined as a measure or activity proposed or in process designed to reduce the impact/consequences and/or likelihood/probability of an event.

C. SCG-8-C3 – Pressure Monitoring and Alarming

SoCalGas is implementing continuous, real-time pressure monitoring at gas storage wells in each storage field. Monitoring devices are installed at each tubing and casing annulus, with certain setpoints established to reflect normal operating conditions. Through automated alerts, exceedance of a setpoint will notify local operations, enabling SoCalGas to investigate a potential abnormal condition or integrity issue. In alignment with DOGGR regulations,[32] the real-time pressure monitoring system will be implemented by January 1, 2020. The equipment functions continuously unless it needs to be deactivated on a temporary basis for maintenance purposes. In those instances, pressure reads are conducted manually.

D. SCG-8-C4 – Wellhead Leak Detection and Repair

Wellhead Leak Detection and repair entails performing a daily audio-visual inspection, as well as a quarterly leak survey with the use of Optical Gas Imaging. Inspections are performed on each active and idle injection/withdrawal wellhead assembly owned and operated by SoCalGas.

SoCalGas also has implemented and follows a CARB approved monitoring plan for its underground storage facilities in compliance with the CARB Oil & Gas Rule, 17 CCR § 95668(h) as of August 6, 2019. This monitoring plan addresses three CARB Oil & Gas Rule regulatory requirements: (1) continuous ambient air monitoring, (2) wellhead daily or continuous leak screening, and (3) well blowout procedures. The CARB Oil & Gas Rule requires daily or continuous leak screening at each injection/withdrawal wellhead assembly and attached pipelines according to one or both of the following methods: (1) daily leak screening with the use of US EPA Reference Method 21 instrument, or the use of Optical Gas Imaging, or (2) continuous leak screening with the use of automated instruments and a monitoring system with an alarm system.[33]

Additionally, pursuant to the CARB Oil & Gas Rule regulations, on or after January 1, 2020, any component with a leak measuring total hydrocarbon concentrations greater than or equal to 1,000 ppmv but not greater than 9,999 ppmv will be successfully repaired or removed from service within 14

---

32 14 CCR § 1726.7(d).

33 17 CCR § 95668(h).

calendar days of initial leak detection. Component leaks with measured total hydrocarbon concentrations greater than or equal to 10,000 ppmv but not greater than 49,999 ppmv will be successfully repaired or removed from service within five (5) calendar days of initial leak detection. Component leaks with measured total hydrocarbon concentrations greater than or equal to 50,000 ppmv will be successfully repaired or removed from service within two (2) calendar days of initial leak detection. Critical components or critical process units will be successfully repaired by the end of the next process shutdown or within 12 months from the date of initial leak detection, whichever is sooner.

E. SCG-8-C5 – Integrity Management for Gas Storage Operations

SoCalGas has integrated its Risk Management for Gas Storage Operations department into SoCalGas' Integrity Management organization, unifying the gas storage integrity management practices with its transmission and distribution integrity management practices. The Integrity Management organization is tasked with such responsibilities as developing and implementing processes and procedures to manage storage well integrity and compliance with new underground storage regulations, advancing the approach to data management, data governance and risk assessment, developing and tracking training of company employees on procedures pertinent to storage integrity management, and supporting execution of drills and exercises to evaluate emergency response plans.

As discussed in Chapter RAMP-G, SoCalGas has been implementing the Company's Safety Management System (SMS), which includes the principles set forth in the Petroleum Institute (API) Recommended Practice 1173 Pipeline Safety Management System. API 1173 is a systematic way to identify hazards and control risks while validating that these risk controls are effective, and has a strong emphasis on process safety and safety culture. SoCalGas also highlights several new regulations that support this implementation and which share elements of API 1173:

- PHMSA IFR Underground Storage regulations, 49 CFR § 192.12, adopts API 1171, Functional Integrity of Natural Gas Storage in Depleted Hydrocarbon Reservoirs and Aquifer Reservoirs into regulation, and is an integral component of creating an SMS for Underground Storage. Specifically, "[s]torage design, construction, operation, and maintenance include activities in risk management, site security, safety, emergency preparedness, and procedural documentation and training to embed human and organizational competence in the management of storage facilities."[34]

- DOGGR Requirements for California Underground Gas Storage Projects, 14 CCR § 1726.3: which includes, among other things, incorporation of human factors into risk management plans.[35]

F. SCG-8-C6 – Integrity Demonstration, Verification, and Monitoring Practices

SoCalGas performs integrity inspections on gas storage wells to verify the pressure containing capability of the well, detect possible leaks, and identify metal loss anomalies in the tubing and casing. Inspections can include pressure testing, noise and temperature surveys, magnetic flux leakage (MFL) inspection, ultrasonic (UT) inspection. Pressure testing and wall thickness inspections (MFL or UT) are currently required to be performed on each gas storage well at a two-year recurring frequency.[36] Temperature and noise surveys are required at least annually at Aliso Canyon and Honor Rancho. Temperature surveys are required semiannually, and noise surveys are required annually, at La Goleta and Playa del Rey.

VI. POST-MITIGATION ANALYSIS

As described in Chapter RAMP-D, SoCalGas has performed a Step 3 analysis where necessary pursuant to the terms of the SA Decision. SoCalGas has not calculated an RSE for activities beyond the requirements of the SA Decision but provides a qualitative description of the risk reduction benefits for each of these activities in the section below.

A. Mitigation Tranches and Groupings

The Step 3 analysis provided in the SA Decision[37] instructs the utility to subdivide the group of assets or the system associated with the risk into Tranches. Risk reduction from controls and

---

[34] API RP 1171, Preamble, *available* at http://www.api.org/~/media/files/publications/whats%20new/1171_e1%20pa.pdf.

[35] 14 CCR § 1726.3.

[36] *Id.* at § 1726.6 (a)(3).

[37] D.18-12-014 at Attachment A, A-11 ("Definition of Risk Events and Tranches").

mitigations and RSEs are determined at the Tranche level. For purposes of the risk analysis, each Tranche is considered to have homogeneous risk profiles (i.e., the same LoRE and CoRE). SoCalGas' rationale for the determination of Tranches is presented below.

Given the vast number of activities SoCalGas performs to mitigate the Storage risk, SoCalGas grouped like activities with like risk profiles into mitigation programs. SoCalGas' Storage risk controls have the same risk profile and are not further tranched. A single tranche is appropriate for the Storage risk event as there is no logical disaggregation of assets or systems related to the controls put forth in the mitigation plan.

B. Post-Mitigation/Control Analysis Results

For purposes of this post-mitigation and post-control analysis, SoCalGas looked at historical safety performance results and the improvements year-over-year to calculate an overall risk reduction benefit of performing these activities.[38] SoCalGas then looked at existing/continuing programs (i.e., controls), and expects to get similar results (i.e., percentage of risk reduction benefit by continuing the activity). SoCalGas also accounted for the risk increase that would occur over time if we stopped performing these activities. The specific risk reduction benefit percentages used for each identified control is included under each program heading below.

1. SCG-8-C1 – Well Construction Requirements and Dual Barrier System

a. Description of Risk Reduction Benefits

Well design and construction to achieve a dual barrier system has changed storage operations in that the injection and withdrawal of gas occurs only through the innermost tubing, with the outer casing acting as a secondary containment barrier. Equipping gas storage wells with tubing and packer and implementing a new configuration to limit operations to tubing only flow introduces a second mechanical barrier that would need to also fail, concurrent with a failure of the primary barrier, in order to result in an uncontrolled gas release at surface. Consequently, such a system has the effect of reducing the likelihood that a well integrity event will occur.

---

38 *Id.* at Attachment A, A-12 ("Determination of Post-Mitigation LoRE," "Determination of Post-Mitigation CoRE," and "Measurement of Post Mitigation Risk Score")

SoCalGas has not performed an RSE Evaluation on SCG-8-C1 because the program elements are mandated by law and/or regulation. SoCalGas is required to comply with all applicable laws/regulations, and thus, SoCalGas has not calculated the risk reduction benefits received for performing this activity.

b. Elements of the Bow Tie Addressed

SCG-8-C1 addresses several Drivers/Triggers and Potential Consequences as outlined above in Section I. Replacement and remediation activities as described in Section V will alleviate complications associated with several risk drivers, including internal/external corrosion (DT.1), aging asset infrastructure (DT.2), and outside forces (DT.4). Additionally, a dual barrier system aims to reduce the Potential Consequences identified in the right side of the bow tie including, but not limited to, serious injuries and/or fatalities (PT.1), property damage (PT.2), well blow-out in high consequence area (PT.3), loss of stored gas (PT.5), and environmental impacts (PT.9).

2. SCG-8-C2 – Well Abandonments

a. Description of Risk Reduction Benefits

Well abandonments may occur for various reasons, including operational issues for which remediation is not a viable option. This control accounts for well plug and abandonments required by state DOGGR regulations 14 CCR §1726.3(d)(1), which requires an operator to have a work plan and schedule to either bring noncomforming wells into compliance or plugging and abandoning the wells in accordance with PRC §3208. This control allows for the well to be fully abandoned, where necessary, and it will also allow for the completion of the abandonment process on wells where partial abandonment has already occurred. Eight full abandonments and three partial abandonments are forecasted for 2020 along with three full abandonments in each of years 2021 and 2022. Abandonment of wells through isolation of the reservoir from the wellbore have the effect of reducing the likelihood that a well integrity event will occur and result in an uncontrolled gas release at surface.

SoCalGas has not performed an RSE Evaluation on SCG-8-C2 because the program elements account for well plug and abandonments required by regulation. SoCalGas is required to comply with all applicable laws/regulations, and thus has not calculated the risk reduction benefits received for performing this activity.

b. **Elements of the Bow Tie Addressed**

SCG-8-C2 addresses several Drivers/Triggers and Potential Consequences as outlined above in Section I. Well abandonment will address the following drivers: internal/ external corrosion (DT.1), aging asset infrastructure (DT.2), outside forces (DT.4), and human error (DT. 5). Additionally, well abandonments aim to reduce the Potential Consequences identified in the right side of the bow tie including serious injuries and/or fatalities (PT.1), property damage (PT.2), well blow-out in high consequence area (PT.3), loss of storage injection and withdrawal capacity (PT.4), loss of stored gas (PT.5), adverse litigation (PT.6), diminished public confidence (PT.7), penalties and fines (PT.8), and environmental impacts (PT.9).

3. **SCG-8-C3 – Pressure Monitoring and Alarming**

a. **Description of Risk Reduction Benefits**

This control allows for real-time pressure monitoring at each tubing and casing annulus of gas storage wells. Pressure readings deviating from what is typically observed during normal operations can be an indication of equipment failure or compromised barriers. Continuous monitoring can allow for prompt notifications and issue assessments. As such, pressure monitoring and alarming reduces the likelihood that an abnormal condition or integrity issue goes unnoticed or grows to the extent that failure occurs and causes an uncontrolled release at the surface.

SoCalGas has not performed an RSE Evaluation on SCG-8-C3 because the program elements are mandated by law and/or regulation. SoCalGas is required to comply with all applicable laws/regulations, and thus has not calculated the risk reduction benefits received for performing this activity.

b. **Elements of the Bow Tie Addressed**

SCG-8-C3 addresses several Drivers/Triggers and Potential Consequences as outlined above in Section I. This control addresses a number of drivers related to safety, including: internal/external corrosion (DT.1), aging asset infrastructure (DT.2), incorrect/inadequate records (DT.3), outside forces (DT.4) and human error (DT.5). Additionally, pressure monitoring and alarming will aim to reduce the Potential Consequences identified in the right side of the Bow Tie including serious injuries and/or fatalities (PT.1), property damage (PT.2), well blow-out in high consequence area (PT.3), and environmental impacts (PT.9).

4. SCG-8-C4 – Wellhead Leak Detection and Repair

a. Description of Risk Reduction Benefits

SoCalGas' monitoring plan addresses continuous ambient air monitoring, wellhead daily or continuous leak screening, and well blowout procedures. The monitoring equipment is used for detection of aboveground piping for leaks and is required per DOGGR (14 CCR § 1726.7), PHMSA (49 CFR § 192.12) and CARB (17 CCR § 95668(h)). In the event of a well blowout, CARB requires Optical Gas Imaging (OGI) video footage of the well blowout to notify concerned parties. The stationary air monitors will analyze concentrations of methane in the ambient conditions. Wellhead leak detection and repair tools will be owned, installed and monitored by Aboveground Storage (AGS).

The leak detection and repair program reduces the likelihood that an abnormal condition or integrity issue goes unnoticed or grows to the extent that a failure occurs and causes an uncontrolled release at surface. OGI detects potential leaks or abnormalities efficiently so that problems can be quickly prioritized and mitigated.

SoCalGas has not performed an RSE Evaluation on SCG-8-C4 because the program elements are mandated by law and/or regulation. SoCalGas is required to comply with all applicable laws/regulations, and thus has not calculated the risk reduction benefits received for performing this activity.

b. Elements of the Bow Tie Addressed

SCG-8-C4 addresses several Drivers/Triggers and Potential Consequences as outlined above in Section I. Wellhead leak detection and repair will address the following drivers: internal/ external corrosion (DT.1), aging asset infrastructure (DT.2), outside forces (DT.4), and human error (DT.5). Additionally, wellhead leak detection and repair aims to reduce the Potential Consequences identified in the right side of the bow tie including serious injuries and/or fatalities (PT.1), property damage (PT.2), well blow-out in high consequence area (PT.3), and environmental impacts (PT.9).

5. SCG-8-C5 – Integrity Management for Gas Storage Operations

a. Description of Risk Reduction Benefits

By integrating the Risk Management department into SoCalGas' Integrity Management organization, SoCalGas reduces the likelihood and the consequences associated with a well integrity event. Unifying the gas storage integrity management practices with its transmission and distribution integrity management practices centralizes specific resources to this control to help enhance processes and procedures are in place to identify, monitor, and respond to integrity issues, supports the accuracy and accessibility of data, and enables risks to be adequately assessed and managed.

This control will allow for increased data analytics on storage activities, the standardization of processes, data integration, and a structure of work prioritization.

SoCalGas has not performed an RSE Evaluation on SCG-8-C5 because the program elements are mandated by law and/or regulation. SoCalGas is required to comply with all applicable laws/regulations, and thus has not calculated the risk reduction benefits received for performing this activity.

b. Elements of the Bow Tie Addressed

SCG-8-C5 addresses several Drivers/Triggers and Potential Consequences as outlined above in Section I. This control addresses the following drivers, including: internal/ external corrosion (DT.1), aging asset infrastructure (DT.2), incorrect/inadequate records (DT.3), outside forces (DT.4) and human error (DT.5). Additionally, Integrity Management for Gas Storage Operations aims to reduce the Potential Consequences identified in the right side of the bow tie including, but not limited to, serious injuries and/or fatalities (PT.1), property damage (PT.2), well blow-out in high consequence area (PT.3), loss of storage injection and withdrawal capacity (PT.4), loss of stored gas (PT.5), adverse litigation (PT.6), diminished public confidence (PT.7), penalties and fines (PT.8), and environmental impacts (PT.9).

6. SCG-8-C6 – Integrity Demonstration, Verification, and Monitoring Practices

a. Description of Risk Reduction Benefits

Implementation of a program to perform integrity inspections on gas storage wells on a recurring basis is designed to reduce the likelihood that an abnormal condition or integrity issue goes unnoticed or grows to the extent that a failure occurs and causes an uncontrolled release at surface. Similar to the other controls presented in this risk chapter, this control is also mandated by DOGGR regulations (14 CCR § 1726.6), with the exception where the Company exceeds minimum requirements (14 CCR § 1726.6(a)(2)) by employing casing wall thickness inspection using magnetic flux <u>and</u> ultrasonic technologies. As discussed in Chapter RAMP-D, the Company calculated RSEs for certain mandated controls where the Company exercised discretion in meeting the mandate, or in cases where the Company exceeded the mandate as it did with this control.

b. Elements of the Bow Tie Addressed

SCG-8-C6 addresses several Drivers/Triggers and Potential Consequences as outlined above in Section I. This control addresses the following safety drivers, including: internal/ external corrosion (DT.1), aging asset infrastructure (DT.2) and outside forces (DT.4). Additionally, this control aims to reduce the Potential Consequences identified in the right side of the Bow Tie including serious injuries and/or fatalities (PT.1), property damage (PT.2), well blow-out in high consequence area (PT.3), loss of storage injection and withdrawal capacity (PT.4), loss of stored gas (PT.5), adverse litigation (PT.6), diminished public confidence (PT.7), penalties and fines (PT.8), and environmental impacts (PT.9).

c. RSE Inputs and Basis

Scope	At least 66 wells per year would undergo a set of assessments, additional wells might undergo re-assessment.
Effectiveness	The tests are not considered infallible; thus 95% effectiveness is assumed.
Risk Reduction	Of storage risk, 11%[39] is assumed attributable to casing. Using these assumptions, this mitigation could improve storage safety, reliability, and financial risk by up to 13%. Note that in order to estimate the RSE, it was necessary to add the cost of prep work to funding earmarked for testing.

39 *See* "Well Integrity – Basics, Prevention, Monitoring, Red Flags & Repair Options," Petroleum Safety Authority Norway (PSA), dated November 21, 2014, *available* at https://www.usea.org/sites/default/files/event-/King_DOE%20Well%20Integrity%20–%20Basics,%20Prevention,%20Monitoring,%20Red%20Flags%20and%20Repair%20Options%2021%20Nov%202014%20v3.pdf.

d. Summary of Results

		Low Alternative	Single Point	High Alternative
Pre-Mitigation	**LoRE**		**0.086**	
	CoRE	3956.67	**4061.67**	4236.67
	Risk Score	339.14	**348.14**	363.14
Post-Mitigation	**LoRE**		**0.097**	
	CoRE	3956.67	**4061.67**	4236.67
	Risk Score	383.03	**392.16**	409.06
	RSE	0.62	**0.64**	0.66

VII. SUMMARY OF RISK MITIGATION PLAN RESULTS

SoCalGas' mitigation plan takes into account compliance with regulatory requirements. SoCalGas has performed RSEs, in compliance with the S-MAP decisions, but ultimate mitigation selection can be influenced and is contingent on other factors including, but not limited to, new compliance requirements, planning, reliability, safety, and other operational and execution considerations.

Table 6 below provides a summary of the Risk Mitigation Plan, including controls and mitigations activities, associated costs, and the RSEs, by Tranche.

SoCalGas does not account for and track costs by activity; rather, SoCalGas accounts for and tracks costs by cost center and capital budget code. The costs shown in Table 6 were estimated using assumptions provided by SMEs and available accounting data.

Table 6: Risk Mitigation Plan Summary[40]

(Direct 2018 $000)[41]

ID	Mitigation/Control	Tranche	2018 Baseline Capital[42]	2018 Baseline O&M	2020-2022 Capital[43]	2022 O&M	Total[44]	RSE[45]
SCG-8-C1	Well Construction Requirements and Dual Barrier System	T1	62,000	0	160,000 – 220,000	0	160,000 – 220,000	-
SCG-8-C2	Well Abandonments	T1	22,000	0	21,000 – 30,000	0	21,000 – 30,000	-

---

40 Recorded costs and forecast ranges were rounded. Additional cost-related information is provided in workpapers. Costs presented in the workpapers may differ from this table due to rounding.

41 The figures provided are direct charges and do not include company loaders, with the exception of vacation and sick. The costs are also in 2018 dollars and have not been escalated to 2019 amounts.

42 Pursuant to D.14-12-025 and D.16-08-018, the Company provides the 2018 "baseline" capital costs associated with Controls. The 2018 capital amounts are for illustrative purposes only. Because capital programs generally span several years, considering only one year of capital may not represent the entire activity.

43 The capital presented is the sum of the years 2020, 2021, and 2022 or a three-year total. Years 2020, 2021 and 2022 are the forecast years for SoCalGas' Test Year 2022 GRC Application.

44 Total = 2020, 2021 and 2022 Capital + 2022 O&M amounts.

45 The RSE ranges are further discussed in Chapter RAMP-C and in Section VI above.

ID	Mitigation/Control	Tranche	2018 Baseline Capital[42]	2018 Baseline O&M	2020-2022 Capital[43]	2022 O&M	Total[44]	RSE[45]
SCG-8-C3	Pressure Monitoring and Alarming	T1	0	490	0	450 – 650	450 – 650	-
SCG-8-C4	Wellhead Leak Detection and Repair	T1	0	3,000	0	2,300 – 3,300	2,300 – 3,300	-
SCG-8-C5	Integrity Management for Gas Storage Operations	T1	2,800	6,300	4,100 – 5,900	5,000 – 7,200	9,100 – 13,100	-
SCG-8-C6	Integrity Demonstration, Verification, and Monitoring Practices	T1	0	3,800	0	7,100 – 10,000	7,100 - 10,000	0.62 – 0.66
		TOTAL COST	**87,000**	**14,000**	**190,000 – 260,000**	**15,000 – 21,000**	**200,000 – 280,000**	

It is important to note that SoCalGas is identifying potential ranges of costs in this Risk Mitigation Plan and is not requesting funding herein. SoCalGas will integrate the results of this proceeding, including requesting approval of the activities and associated funding, in the next GRC.

In addition, as discussed in Section VI above, the table below summarizes the activities for which an RSE is not provided:

Table 7: Summary of RSE Exclusions

ID	Control/Mitigation Name	Reason for No RSE Calculation
SCG-8-C1	Well Construction Requirements and Dual Barrier System	Mandated activity per 14 CCR § 1726.5
SCG-8-C2	Well Abandonments	Mandated activity per 14 CCR § 1726.3(d)(1)
SCG-8-C3	Pressure Monitoring and Alarming	Mandated activity per 14 CCR § 1726.7
SCG-8-C4	Wellhead Leak Detection and Repair	Mandated activity per 14 CCR § 1726.7, 17 CCR § 95668, 49 CFR §192.12
SCG-8-C5	Risk Management for Gas Storage Operations	Mandated activity per 14 CCR §1726.3, 49 CFR §192.12

VIII. ALTERNATIVE ANALYSIS

Pursuant to D.14-12-025 and D.16-08-018, SoCalGas considered alternatives to the mitigations for the Storage Risk. Typically, analysis of alternatives occurs when implementing activities. The alternatives analysis for this Risk Mitigation Plan took into account risk reduction, cost, new and existing requirements and compliance obligations, and constraints, such as budget and resources.

SoCalGas
A Sempra Energy utility

A. SCG-8-A1 – Casing Wall Thickness Inspection Tools

SoCalGas plans to continue to employ both magnetic flux leakage (MFL) and ultrasonic (UT) technologies each time a casing integrity inspection is performed (*see* SCG-8-C6). Current regulations do not require both technologies be employed, and as such SoCalGas considered an inspection plan that just utilizes one or the other instead of both. While potentially offering a cost savings due to elimination of contractor costs, using only one technology was deemed to be inferior to the existing practice of employing both MFL and UT technologies. It has been SoCalGas' experience that each inspection technology has specific strengths and weaknesses and utilizing both in a complimentary way reduces the chances that an anomaly is missed, thus providing a more informed assessment of the casing integrity.

		Low Alternative	Single Point	High Alternative
Pre-Mitigation	LoRE		**0.086**	
	CoRE	3956.67	**4061.67**	4236.67
	Risk Score	339.14	**348.14**	363.14
Post-Mitigation	LoRE		**0.0952**	
	CoRE	3956.67	**4061.67**	4236.67
	Risk Score	376.55	**386.54**	403.20
	RSE	0.58	**0.59**	0.62

B. SCG-8-A2 ‐ Multi-String Metal Loss Inspections

SoCalGas Control SCG-8-C6 – Integrity Demonstration, Verification, and Monitoring Practices described in Section V of this chapter refers to the use of MFL and UT inspection tools to measure the wall thickness of the casing. In order to perform these inspections on the casing, the tubing string must first be removed from the well. Emerging pulsed-eddy current technology (through-tubing inspection) is being developed that could facilitate inspection of the casing by running an inspection tool in the tubing, thus eliminating the need to remove the tubing prior to inspection. The inspection tool, in this scenario, would need to be capable of detecting, and differentiating, metal loss in both the tubing and the casing. The result is a less intrusive inspection and the elimination of the need for a workover rig in order to perform the inspection.

SoCalGas utilized this type of through-tubing inspection on several wells and considered a wider application of its use as part of the integrity demonstration, verification, and monitoring practices. However, the preliminary through-tubing inspection logging results suggests that the pulsed-eddy technology (1) is currently limited in its ability to determine if metal loss is localized or circumferential, (2) does not provide a direct measurement ability to characterize defects for corrosion models, and (3) provides a vertical resolution that can be larger than what might be deemed through-wall defects. Through-tubing inspection technology shows potential for being used for a screening program, however its output data currently remains qualitative. SoCalGas will continue to monitor the progress of this technology and evaluate opportunities to incorporate these inspections into the integrity demonstration, verification, and monitoring practices.

		Low Alternative	Single Point	High Alternative
Pre-Mitigation	**LoRE**		**0.086**	
	CoRE	3956.67	**4061.67**	4236.67
	Risk Score	339.14	**348.14**	363.14
Post-Mitigation	**LoRE**		**0.0961**	
	CoRE	3956.67	**4061.67**	4236.67
	Risk Score	380.11	**390.20**	407.01
	RSE	0.60	**0.62**	0.65

Table 8: Alternative Mitigation Summary

(Direct 2018 $000)[46]

ID	Mitigation	2020-2022 Capital[47]	2022 O&M	Total[48]	RSE[49]
SCG-8-A1	Casing Wall Thickness Inspection Tools	0	5,500 – 8,000	5,500 – 8,000	0.58-0.62
SCG-8-A2	Multi-String Metal Loss Inspections	0	2,100 – 3,100	2,100 – 3,100	0.60-0.65

46 The figures provided are direct charges and do not include company loaders, with the exception of vacation and sick. The costs are also in 2018 dollars and have not been escalated to 2019 amounts.

47 The capital presented is the sum of the years 2020, 2021, and 2022 or a three-year total.

48 Total = 2020, 2021 and 2022 Capital + 2022 O&M amounts.

49 The RSE ranges are further discussed in Chapter RAMP-C and in Section VI above.

APPENDIX A: SUMMARY OF ELEMENTS OF RISK BOW TIE ADDRESSED

ID	Control/Mitigation Name	Drivers/Triggers/Potential Consequences Addressed
SCG-8-C1	Well Construction Requirements and Dual Barrier System	DT.1; DT.2; DT.4 PC.1, PC.2, PC.3, PC.5, PC.9
SCG-8-C2	Well Abandonments	DT.1; DT.2; DT.4; DT.5 PC.1, PC.2, PC.3, PC.4, PC.5, PC.6, PC.7, PC.8, PC.9
SCG-8-C3	Pressure Monitoring and Alarming	DT.1; DT.2; DT.3; DT.4; DT.5 PC.1, PC.2, PC.3, PC.9
SCG-8-C4	Wellhead Leak Detection and Repair	DT.1; DT.2; DT.4; DT.5 PC.1, PC.2, PC.3, PC.9
SCG-8-C5	Integrity Management for Gas Storage Operations	DT.1; DT.2; DT.3; DT.4; DT.5 PC.1, PC.2, PC.3, PC.4, PC.5, PC.6, PC.7, PC.8, PC.9
SCG-8-C6	Integrity Demonstration, Verification, and Monitoring Practices	DT.1; DT.2; DT.4 PC.1, PC.2, PC.3, PC.4, PC.5, PC.6, PC.7, PC.8, PC.9