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PG&E Comments on CEC Gas R&D Workshop

Additional submitted attachment is included below.

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RE: Docket 19-ERDD-01: Pacific Gas and Electric Comments on the May 22, 2019 Natural Gas Sector Climate Resilience Solicitation Workshop

Pacific Gas and Electric Company (PG&E) appreciates this opportunity to comment in response to the May 22, 2019 Workshop hosted by the California Energy Commission (CEC) Energy Research and Development Division to seek input on where to best focus research grants for the purpose of fostering natural gas sector resilience.

As a provider of critical infrastructure services, PG&E faces a variety of risks from a changing climate, including heat waves, more frequent and extreme storms and wildfires, drought, subsidence and rising sea levels. Building greater climate resilience involves understanding the impacts of climate change on our business and being prepared to withstand and rapidly recover from major disruptions to service caused by changing climate conditions and weather events.

PG&E has established an internal Climate Resilience Officer Committee, as well as a staff-level Climate Resilience Working Group, to coordinate work across enterprise risk management; internal culture, integration and planning; and external engagement. Using climate science as a foundation, the Committee is overseeing a multi-year research and action plan to close gaps in our approach to addressing the impacts of climate change.

Key aspects to PG&E's approach include:

- Near-term planning through robust emergency response plans and procedures to address near-term risks, including more extreme storms, heat and wildfires.
- Risk assessment and operational planning through a multi-year, comprehensive risk assessment process to prioritize infrastructure investments for longer-term risks, such as sea level rise. Among other things, PG&E completed a quantitative risk assessment that was submitted to the California Public Utilities Commission (CPUC) in 2017 and

associated foundational work to help the company plan for and mitigate adverse impacts from climate change. These include developing tools for climate resilience screening and data visualization, performing research and metrics development, completing staff training on climate resilience, and working across our lines of business to develop plans for asset prioritization.
- External engagement at the federal, state and local levels on climate change adaptation and resilience. This includes PG&E's participation in the U.S. Department of Energy's Partnership for Energy Sector Climate Resilience as well as the Technical Advisory Committee to the Governor's Office of Planning and Research Integrated Climate Adaptation and Resiliency Program.

With these priorities in mind, PG&E is pleased to provide the following comments to the CEC. Included in Table 1 are our rankings of the suggested research gaps proposed by the CEC. Additionally, we have provided a list of industry-wide research projects supporting similar objectives in Attachment A. Generally, our prioritization reflects:

- The need to more deeply understand the foundational dynamics of weather patterns and the contributing factors associated with extreme weather events, flooding, landslides and other land movement and the impacts to natural gas infrastructure;
- Understanding the risk of wildland fires and the impacts to natural gas infrastructure;
- Developing new tools and advancing existing tools specific to California's geology and evolving probabilistic models of ground movement and their structural impacts to natural gas infrastructure;
- Leveraging industry research to prevent duplication of effort and to further develop areas of focus beyond the current state-of-the-art.

PG&E is a supporter of research that reflects our priorities and produces meaningful and actionable results. With respect to how the investor-owned utilities (IOUs) should be involved in the CEC's research grant solicitation, PG&E has and will continue to provide written support for proposals, participate on technical advisory committees, and provide asset performance data to successful grant awardees. Additionally, PG&E supports applications submitted through utility-based consortia on behalf of its members, like those consortium projects listed in Attachment A. PG&E does not plan to directly apply for CEC research-and-development grants nor directly craft or partner on applications. However, PG&E is available to provide feedback at the proposal writing stage.

Table 1: CEC Proposed Research Gaps Prioritization

CEC Proposed Research Gaps	Ranked Priority			PG&E's Comments
	Low	Medium	High	
Identifying what climate-related **scenarios** are most important for stress-testing the resilience of the natural gas system.			**x**	PG&E believes this is of high priority and should take a probabilistic approach. One example is planning and forecast loads under extremely hot weather conditions. Changing weather means changing surface dynamics related to landslides and other geo-hazards, floods, vegetation types, more frequent and intense wildfires, higher surface temperatures and, potentially, higher temperatures at depths at which underground utilities are installed. Understanding the influences of each of these on our assets and infrastructures is a high priority.
Analysis of existing data to illuminate pipeline-specific stresses.			**x**	Pipeline-specific stresses are critical to risk assessment and integrity management. Better utilization of existing data is very beneficial and economically sound. There is some related work being done by other organizations such as Pipeline Research Council International (PRCI) that can be leveraged to avoid duplication.
Development of stress thresholds beyond which resilience interventions should be initiated.			**x**	PG&E has already completed risk ranking of our pipeline based on its attributes and defined risk models. This guides us on how we should invest in our systems. Much work in this area has already been done in the industry so PG&E recommends coordinating with those related organizations (e.g. PRCI) outside California to ensure alignment. Developing a fragility database will be very beneficial to California's utility industry.
Research to improve our understanding of floods, droughts, and atmospheric rivers. A. Grapple with uncertainty in GCM projections of extreme precipitation-related events that can lead to landslides, mudslides, debris flows, and/or subsidence-related stresses. B. Investigate projected changes in frequency, intensity, and distribution of ARs in California.			**x**	Since California has many micro-climates, regionalization is crucial. For geo-hazards, PG&E has been implementing the US Geological Survey Post-Fire Debris-Flow Model, which has been found to be quite conservative because California has larger debris flow than what the model predicts. Thus, few projects at PRCI regarding rivers and streams and their impacts on pipelines can be leveraged. Taking a California focus with the specific rivers and streams, erosion, soil and rock types in this state would be beneficial.

High-resolution historical reanalysis for major weather variables governing climate-related risks to the natural gas system. (Presently, our understanding of historical climate at fine resolution limits our ability to develop models of future projected climate.)			**x**	This can provide a better baseline understanding of major weather variables and associated impacts to guide future work on some of the other research gaps. Better utilization of historical/existing data is also economically sound.
Analysis of sub-daily historical observed precipitation data to: A. Delineate regionally-specific trends B. Support development of climate projections that illuminate extreme precipitation events of interest to California's natural gas sector.			**x**	Same as for the previous item.
Developing **metrics to assess and track progress** in natural gas system resilience.		**x**		PG&E uses a probabilistic asset risk modeling and management approach to assess and monitor impacts of climate changes on our infrastructures. PRCI and Joint-Industry-Projects have been researching in this area. The new focus should be on characterization of the consequences of climate changes that have not yet been understood.
Conducting potential **case studie**s to pilot test methods.		**x**		PG&E defines this as modeling of various scenarios with input variables including weather, geo-hazards, etc. and their magnitude, occurrence frequency and subsequent impacts on infrastructure. Note, there is a already a CEC project for a flooding specific study completed in 2015 (CEC-500-11-016: Assessment of Bay Area Gas Pipeline Vulnerability to Sea Water Intrusion).
Prioritization of regions for monitoring stresses to pipelines associated with vertical land movement through repeated portable LiDAR surveys.		**x**		Regions of interest for monitoring should be prioritized on perimeters and areas with a high density of infrastructure, with a focus on aerial LiDAR data and correlation of pipeline stress-strain to surface terrain movement. It should be noted that the pace of change has the most severe impacts rather than the magnitude of the change. Since 2014 PG&E has been collecting LiDAR data of our Right-of-Way to better understand ground attributes that can be utilized for prioritization. Efficient pipeline measurement and monitoring with different technologies (e.g. new in-line inspection tools, emerging above-ground non-intrusive large standoff magnetometry, etc.) needs more research efforts – PG&E also recommends coordinating with other industry research organizations such as PRCI.

Evaluation of evolving risks related to compound and cascading events: Development of methodologies to evaluate changing risks of interdependent events that can have devastating impacts in California, such as those leading to intense rainfall in Santa Barbara in January 2018 and California's deadliest debris flow on record.		**x**		Risks related to compound and cascading events typically have tertiary impacts with high consequence. However, currently this is considered as a longer-term item since a much better understanding of the underlying issues needs to be obtained first.
Developing **methods for integrating resilience investments** into enhanced cost-benefit analyses that incorporate deep uncertainty.	**x**			PG&E recommends this item would be better pursued in the longer term, after successfully gaining predicative outcomes from the items above. PG&E routinely evaluates risk and needed investments to mitigate these risks, and will benefit more from better understanding the underlying dynamics that affect the pipeline.
Identification of associated interventions, timing, and costs.	**x**			This does not seem like an item for R&D.

Conclusion

PG&E continues to support the CEC's research efforts and appreciates the opportunity to provide feedback on the research priorities for increasing the resilience of the natural gas sector in California.

Please feel free to contact me if you have any questions or concerns.

Sincerely,

/s/

Fariya Ali

Expert Representative, State Agency Relations

Pacific Gas and Electric

Attachment A: Industry Wide Research Projects

Table 2: CEC and Department of Transportation (DOT) Projects

CEC or DOT Project	Project Description	Project Type
DOT #DTPH56-14-H-00008L/ BMT Fleet: Definition of Geotechnical and Operational Load Effects on Pipeline Anomalies	The development of an engineering tool will consider the effects of operational and geotechnical loads on liquid and gas pipeline systems to define the local nominal strain state. Localized anomalies/defects or the potential for wrinkle/buckle formation will be assessed to support pipeline integrity decision making or repair scheduling. Using the validated BMT soil-structure interaction model, complex loading scenarios including pipeline subsidence and lateral pipeline movements will be considered. The results of the project will support design and in-service maintenance decisions for geotechnical hazards resulting in improvements in pipeline safety	Threat Prevention
DOT #DTPH5615T00020L / GTI: Combined Vibration, Ground Movement, and Pipe Current Detector	To use a suite of sensors to monitor pipelines and determine if there is unauthorized activity within the right of way. The sensors are discrete point types that can be installed in a small excavation. A vibration sensor and a current sense wire are attached directly to the pipe; a motion sensor is placed in the soil close by. The coincidence of events seen by these devices will help discriminate false positives	Threat Prevention
CEC-500-2012-011: Coastal Flooding-Potential Projections: 2000-2100	The change in flooding potential along the California coast over the twenty-first century was estimated from both ocean wave and sea level rise projections produced from global climate model data. Changes in flooding potential were inferred from changes in wave runup (the vertical height reached by wave-driven water levels), which depends on the instantaneous sea level (or still water level), beach slope, and wave height and wave period.	Geohazard threat projection

CEC-500-11-016: Assessment of Bay Area Gas Pipeline Vulnerability to Sea Water Intrusion	Researchers developed an improved, high-resolution hydrodynamical model to simulate storm surge coupled with various increments of sea level rise to estimate the potential impacts to natural gas pipelines in the San Francisco Bay Area and the Sacramento/San Joaquin Delta region. The researchers worked very closely with PG&E to investigate the vulnerability of natural gas infrastructure to inundation associated with sea level rise and extreme storm events as well as possible resilience options and their economic costs.	Geohazard threat impacts
CEC-500-14-001: High Resolution Measurement of Levee Subsidence Related to Natural Gas Infrastructure in the Sacramento-San Joaquin Delta	The researchers measured subsidence in the Delta Island levee system with unprecedented detail in space and time. Researchers studied the most critical areas of the Delta's energy infrastructure, which includes natural gas pipelines and storage as well as electricity transmission lines. Initial surveying occurred at the Rio Vista Gas Field, followed by Pacific Gas & Electric's (PG&E) McDonald Island gas storage, and then systematic scanning of levees associated with gas pipelines. A broader view of the levees in the Delta, including areas with important transmission lines, is needed to determine if levee subsidence is a local or a Delta-wide effect. This work improves on DWR's past monitoring of Delta subsidence and may be incorporated into PG&E's risk management activities and the DSC's Delta Stewardship Investment Plan.	Geohazard measurement
CEC-500-14-003: Visualizing Climate-Related Risks to the Natural Gas System Using Cal-Adapt	The natural gas system is vulnerable to climate-related changes and events such as sea level rise and storm surge, inland flooding, subsidence of the delta and levees, and climate-related fluctuations in natural gas supply and demand. This work ensures that the best peer-reviewed scientific results are visualized in a readily accessible, understandable form to support planning and adaptation efforts. This project provides critical support to communicate scientific advances regarding climate-related risks to the natural gas sector and foster planning to protect infrastructure and vulnerable populations. Use cases include supporting design of a compressor station in Blythe; and eventual intention (expressed by an IOU in an IEPR workshop) of supporting General Rate Cases through use of data on Cal-Adapt. The Technical Advisory Committee includes IOUs, a publicly owned utility, and the California Office of Emergency Services. The Technical Advisory Committee includes	Risk data

	IOUs, a publicly owned utility, and the California Office of Emergency Services.	
CEC-500-14-0: Weather Related Scenarios for the Natural Gas System: California's Fourth Climate Change Assessment	The researchers performed the following main tasks: 1) produced enhanced climate scenarios by adding the simulation of other variables, such as relative humidity and wind velocity; 2) estimated potential changes in cooling-degree-days over the 21st century in key locations in California; 3) developed quasi-probabilistic sea level rise projections; and, 4) developed drought scenarios informed by the paleo-record as well as by global climate model projections.	Climate change projection
CEC-PIR-15-005: Probabilistic Seasonal and Decadal Forecasting for the Natural Gas System	This project develops weather and climate forecast models that provide seasonal predictions for temperature and precipitation of 0-9 months and decadal predictions of 10-20 years for selected meteorological stations in California. The average projected temperature and precipitation from 10 downscaled global climate models will be constructed to estimate the mean changes and spread of possible changes over the next 20 years. Hindcasts of temperature and precipitation, using the same methodology, will be compared with historical observed data to evaluate decadal forecast skill. These projections will form the basis of 10-20-year lead-time predictions of weather and climate fluctuations that will affect California. Preliminary results show that improved predictability is possible for only a few months in advance	Forecast modeling
CEC-PIR-15-004: Investigate Climate Vulnerability of the Natural Gas System and Identify Resilience Options in the San Diego Area	The goal of the project is to develop an understanding of climate-related hazard vulnerability and adaptation options in the San Diego Gas & Electric (SDG&E) territory at a level of detail appropriate for informing energy sector policy and planning. The recipient is partnering with SDG&E to conduct a detailed, robust climate change vulnerability assessment and identify and evaluate appropriate adaptation measures. Possible adaptation measures are determined using literature reviews, interviews with key experts, modeling, and workshop elicitation. Potential direct and indirect impacts and adaptation measures are evaluated at an asset-by-asset level, and through system wide assessment. This provides a suite of practical, actionable climate change adaptation measures optimized to SDG&E's natural gas system and customer needs.	Assessment of impacts

CEC-PIR-17-012: Developing Next-generation Cal-Adapt Features to Support Natural Gas Sector Resilience	With funding and oversight from the Energy Commission, UC Berkeley's Geospatial Innovation Facility (GIF) is developing Cal-Adapt to provide new visualizations of locally relevant climate-related risks to the natural gas system. Cal-Adapt provides natural gas system stakeholders with actionable information through interactive, compelling, and useful visualizations. These tools can identify vulnerable populations and infrastructure locations that are at risk from climate-related factors, thereby helping to secure California's energy future.	Risk data

Table 3: Pipeline Research Council International (PRCI) Projects

PRCI Project	Project Description	Project Scope
PRCI Project #ABD-1: DOT PROJECT: Validation and Documentation of Tensile Strain Limit Design Models for Pipelines	The primary benefits of the project are to develop enabling technology to allow: New pipelines to be designed that would otherwise be uneconomic, Existing pipelines to be maintained, should they be exposed to strain induced hazards such as ground movement. Also, the provision of the guideline document will provide designers, owners and regulators with an unambiguous means of judging the acceptability of a specific pipeline under a given set of conditions. The proposed project extension will provide a greater breadth and validation of the procedures to encompass a wider set of as-built and operating conditions.	Strain Based Design

PRCI Project #ABD-1-2: Review of Compressive Strain Capacity Assessment Methods	Buried pipelines subjected to non-continuous ground movement such as frost heave, thaw settlement, slope instability and seismic movement experience high compressive strains that can cause local buckling (or wrinkling), in which the pipe wall buckles like a thin cylindrical shell in axial compression. In a strain-based design and assessment framework, excessive local buckling deformation that may cause loss of serviceability, or even pressure containment in some cases, is managed by limiting the strain demand below the strain limit. The determination of compressive strain limit is typically performed by full-scale structural testing or nonlinear finite element analysis that takes into account material and geometric non-linearity associated with the inelastic buckling of cylindrical shells. Before performing testing and numerical analysis (or when such options do not exist), empirical equations are used to estimate the strain limit. In this report a number of representative equations were evaluated by comparing strain limit predictions to full-scale test results. Work prior to this study has identified the importance of key variables that have the greatest impact on the local buckling behavior. Examples of these variables include the diameter-to-thickness (D/t) ratio, internal pressure and shape of the stress strain curve. The evaluation focused on how existing equations address these key variables, and the performance with respect to key variables and in different ranges.	Strain Based Design
PRCI Project #SBD-1-3: Guidance on Predicting Pipeline Strains Induced by Slope Movement	This work will provide better understanding of the pipeline response to localized slope failures and thus the operator may focus maintenance efforts or design resources on those cases that pose a threat to pipeline integrity. The analysis tool will be of immediate benefit to operators for a more efficient approach to assessing the effect of ground movement events. Once completed, the results of this numerical model development effort will provide benchmarks that can be used to develop and/or refine guidelines and criteria that are currently being developed under other PRCI strain based design and assessment projects for the evaluation and protection of buried pipeline subjected to geotechnical failures.	Geohazards
PRCI Project #SBD-1-2: Guidance for Conducting Strain-Based Assessment of	Enabling technology for pipeline design in harsh environments (deep water, reeled pipe, unstable slopes, permafrost, seismic and subsidence areas). Benefits include more accurate pipeline design for	Geohazards

Buried Pipelines Subjected to Ground Movement	complex/demanding environments and loading situations, greater safety and reliability and lower cost.	
PRCI Project #SBD-1D: Compressive Strain Capacity	Enabling technology for pipeline design in harsh environments (deep water, reeled pipe, unstable slopes, permafrost, seismic and subsidence areas). Benefits include more accurate pipeline design for complex/demanding environments and loading situations, greater safety and reliability and lower cost.	Geohazards
PRCI Project #SBD-1-6: Enhancing Strain Capacity of Pipelines Subjected to Geohazards	When pipeline segments are found to be subjected to geohazards or have the potential of being subjected to geohazards, causing high longitudinal stresses or strains on the segments, engineering critical or risk assessment may be necessary. One of the key inputs to such assessment is the strain capacity of the pipeline, particularly the strain capacity of the girth welds. If the strain capacity is suspected to be potentially inadequate, the next step may be finding viable options to enhance the strain capacity. The outcome of this project will help pipeline operators make informed decision on appropriate mitigation options which can lead to cost-saving while achieving necessary integrity enhancement.	Geohazards
PRCI Project #SBD-1-5: Guidance on the Excavation and Backfill Procedures in Areas of Geohazards and High Axial Stress and Strains	The work will cover the following areas: (1) assessment of risks associated with working in areas of geohazards, (2) assessment of risks associated with disturbing pipe segments potentially under high axial stresses and strains, (3) determine the need and effectiveness of pressure reduction, (4) excavation procedure and associated risks, and (5) backfill procedure and associated risks.	Geohazards
PRCI Project #SBD-1C: Strain Based Design and Assessment - Integrity Management	The objective of the Tensile Strain Capacity portion of the Strain Based Design Program is to accomplish all the research tasks necessary to fully understand and develop efficient design and analysis methodologies for the tensile strain capacity aspect the program. This component of the program will extend the technology developed in prior PRCI research to the wider range of material and geometric parameters that are needed if this capability is to be fielded for use by our industry. Benefits include enabling technology for pipeline design in harsh environments (deep water, reeled pipe, unstable slopes, permafrost,	

	seismic and subsidence areas). Benefits include more accurate pipeline design for complex/demanding environments and loading situations, greater safety and reliability and lower cost.	
PRCI Project # ENV-4-1A: Modernize the Assessment of Pipeline Water Crossings	The proposed project scope described in detail below are intended to achieve the three stated objectives: The first objective, which is to supplement and strengthen industry consensus standards, will be achieved in two ways. Primarily, the development of screening level and detailed assessment level analytical and risk tools will enable pipeline operators to effectively implement the current draft of API RP 1133 consistently to identify which crossings may potentially be at risk for flooding conditions, and in turn require monitoring and/or mitigation measures. Secondly, field verification to test the applicability of advances in vortex-induced fatigue criteria and vortex-induced vibration (VIV) response models within inland water crossings of various channel widths will also help create consensus in industry and lead to value-added improvements to the on-going (and proposed to be expanded) project to modernize the assessment of exposed pipeline waterway crossings. The second objective, which is to collaboratively develop new technology, will be achieved through the development of improved flood monitoring alert mechanisms. This will be accomplished by leveraging both the National Oceanic and Atmospheric Administration (NOAA) National Water Model (NWM) to create “virtual stream gages” and by using radar-based Quantitative Precipitation Estimation (QPE) data from the National Weather Service. Leveraging this data will enable pipeline operators to receive flood alerts for even the smallest watersheds with water crossings. The project’s software deliverables will assist integrity management programs to effectively diagnose the probability of loss of containment and thus focus time and resources to address potential identified concerns from predicted flood flows.	Geohazards, Water Crossings, Flooding, Climate

	The third objective, which is to promote new knowledge, will be achieved through inclusion of fluvial geomorphological and related engineering principles to identify potential pipeline exposures at riverine crossings. It will also be achieved through field testing and verification of channel scour and bank erosion. When the efforts of meeting these objectives is combined, these advances will help pipeline operators better identify and evaluate pipeline asset integrity threats at water crossings and better comply with existing and future regulations. These advances may also allow pipeline operators to discover which crossings may require operational (e.g., monitoring) or engineering (e.g., mitigations) controls to minimize the probability of future flooding hazards leading to loss of containment and can be used to screen locations for future crossings.	
PRCI Project #ENV-4-1: Modernization of the River-X Software	When pipelines at river crossings become exposed, such as during flooding, there is an urgent need to perform an integrity assessment. The pipe may see high loads due to free spans and may be subjected to vortex-shedding induced oscillations that can lead to fatigue failure. The River-x software is the most popular and widely used tool for performing this type of ECA assessment, however, it has become outdated and requires modernization and upgrades as it is prone to instability. The proposed project will update the software and thus give member companies a tool to perform the necessary integrity assessments in a timely manner, thereby giving information for urgently needed operational decisions.	Geohazard, Water Crossings, Flooding. Climate
PRCI Project #ENV-1: DOT PROJECT: Pipeline Integrity Management for Ground Movement Hazards	A rational and defensible basis for pipeline design and operational decisions in geographic areas subject to potential large-scale ground displacements. Compliance with new regulations requiring the assessment of geohazards along pipeline routes, and the ability to accurately assess and prove the integrity of a pipeline system using a qualitative risk-based framework.	Geohazards

PRCI Project # ENV-1-1: Guidance for Establishing Geohazard Integrity Performance Goals	Geohazards present a significant threat to the integrity of energy pipelines warranting the best preventive design approaches and analytical response methods that can be provided to operators. Current geohazard guidelines are several years old and do not reflect current state-of-the-art approaches since there have been several important developments resulting from field experience and research in the intervening years that have not been included. This deficiency was recognized and confirmed by the attendees of the recent JTM in Sydney who identified this project to address that requirement as a top priority.	Geohazards
PRCI ROW-3J: DOT RITA: Ground Based Radar Monitoring of Slope Stability and Subsidence along Pipeline Right of Ways	The GB-SAR instrument enables the measurement of creeping movements with magnitudes approaching a few millimeters per month on moderate angle to vertical slopes or man-made infrastructure. Whereas conventional instrumentation provides sparse point-wise monitoring, this technique provides continuous areal coverage. The GBSAR is also expected to be complementary to satellite-based InSAR monitoring, providing increased monitoring revisit or immediate monitoring results when dangerous slope instability conditions exist. The results derived from the GBSAR are suitable for input into numerical models to aid in the analysis and design process or the mitigation of hazards.	Geohazards
PRCI Project #ROW-6A: CONTINUING PROJECT: Demonstration of Second-Generation Satellite-based Pipeline Integrity Management - Lateral Ground Movement Detection Capabilities Derived from Synthetic Aperture Radar ("SAR")-based Sensor	The objectives of this Research Project are to evaluate the use of SAR satellites to provide 3-dimensional motion analysis of ground movement along the pipeline right-of-way ("ROW") and assist in identifying points where pipeline stress may be accumulating from ground movement.	Geohazards
PRCI Project #ROW-6-1: Demonstration of Second-Generation Satellite-based Pipeline Integrity Management for Encroachment/Right of Way (RoW) and Ground Movement Monitoring	To quantify the monitoring frequency, report turnaround and resolution improvements of Virtual Satellite Constellation (VSC) over legacy satellites and determine what long-term satellite RoW monitoring provides. In addition, provide guidance on detection/identification algorithms to reduce false calls and follow-up site visits. In Phase Two, the goal will be to quantify improvement of VSC over legacy satellites to evaluate increased value for mapping and monitoring long term ground movements.	Geohazards

	The benefit is to provide the pipeline industry with a cost effective demonstration of the effectiveness of using high frequency satellites for monitoring encroachments for various damage prevention and integrity reviews (class location) and well as for long term geohazard management.	
PRCI Project # ROW-6I: InSAR Detection and Quantification of Pipeline Corridor Movement Induced by Longwall Mining	The objectives of this Research Project are to develop methodologies and algorithms to extract ground movement measurements in areas of rapid and substantial movement caused by longwall mining using MDA GSI pioneered Interferometric approaches and Synthetic Aperture RADAR (SAR) data from the RADARSAT-2 satellite program.	Geohazards
PRCI Project #GHZ-2-03: InSAR Monitoring of Pipeline Geohazards in Vegetated and Very Large Non-Vegetated Areas	Approximately 8% of pipeline incidents are related to geohazards, and these incidents often result in devastating consequences. InSAR is a cost-effective remote sensing technology that can help detect and monitor these geohazards across large geographic areas to reduce risk. The objective of the proposed project is to demonstrate recent advances in InSAR that allow 3vG to offer InSAR monitoring services of geohazards in two new ways: 1. Vegetated areas: based on recent availability of satellite imagery that uses a longer wavelength L-band sensor. 2. Very large non-vegetated areas at very low cost: based on availability of free satellite imagery that cover 24,000 square miles per image. These developments in SAR imaging became accessible starting in late 2014. To take advantage of these new datasets, 3vGeomatics Inc. (3vG) has pioneered new InSAR processing techniques that expanded the operational use of InSAR technology.	Geohazards
PRCI Project #GHZ-2-02: New Multi-Year Project: Case Study: Optimal Approach to Cost Effective, Multi-source, Satellite Surveillance of River Crossings, Slope Movements and Land Use Threats to Buried Pipelines	Regulations require pipeline operators to mitigate geohazard and land use threats to pipeline integrity - particularly on slopes and at and near river and stream crossings. In addition to applicable regulatory requirements, detecting and mitigating geohazard motion and ROW land use encroachment threats are primary elements of pipeline operators' damage prevention strategies and programs. Depth of cover is reduced or changed by such phenomena as subsidence/compaction, erosion (surface water	Geohazards, water crossings

	runoff, river bank slope creep, slumping, mass movements), and removal of topsoil primarily for agricultural or urban development reasons. It is also potentially adversely affected by seasonally dynamic fluvial processes within the natural and engineered channels of rivers and streams: including precipitation accumulation and downslope flow along river banks, within drainage basins, valleys, riverine plains and watercourses.	
PRCI Project #GHZ-2-01: Autonomous System for Monitoring Pipeline Integrity, ROW Geohazards, and Product Leaks at River Crossings	Phase 1 - Development During the first stage Syscor will develop the Autonomous System for Monitoring Pipeline Integrity, ROW Geohazards, and Product Leaks at River Crossings. The PRCI and the other consortium members will provide guidance through the PRCI work group. This phase will last 18 months. At the end of this phase all sensor types would be operational, but the treat detection algorithms would remain basic. Development of the system's intelligence would accelerate in the project's second phase. Phase 2 - Trial Deployment The Consortium partners will start deploying the system shortly after it becomes technically viable. System improvements, development of advanced event recognition algorithms, and integration with SCADA systems will continue for another 18 months. System scalability from the perspective of managing geographically dispersed installations through a single platform would be developed. During this period, as the solution's reliability increases, additional deployments will take place in increasingly difficult to access locations. It has been estimated that each river trial will cost approximately USD$160K. The consortium will target 10 river trials (5 in the USA and 5 in Canada).	Geohazard monitoring
PRCI Project #GHZ-1-01: Use of Aerial LiDAR Data Collection for Geohazard Assessment	Aerial LiDAR data collection is becoming more cost effective. New data analysis techniques provide actionable information in quasi real time. However limited guidance exists today for optimal deployment. The Proposed Research will provide guidance to operators, based on lessons learned by PG&E and Enview, on how to best deploy and operationalize LiDAR while minimizing costs for geohazard assessment such as ground movement and change of depth of cover.	Geohazards

Table 4: Joint Industry Project (JIP)

JIP Project	Project Description	Project Resource
Joint Industry Project (JIP) with Center for Reliable Energy Systems (CRES): Management of Ground Movement Hazards for Pipelines	Ground movements, such as landslides and subsidence/settlement, can pose serious threats to the integrity of pipelines. The consequence of a ground movement event can vary greatly. Certain types of ground movements are slow moving and can be monitored and mitigated before a catastrophic failure. Other forms of ground movements can be difficult to predict. Occasionally catastrophic failures occur. Such incident can lead to significant damage to properties and cause injuries or even death. Traditional pipeline designs primarily focus on pressure containment through limiting the hoop stress to a certain percentage of the specified minimum yield stress (SMYS). Although pipeline design standards, such as ASME B31.4 and B31.8, nominally limit the longitudinal stress to 90% of SMYS, this limit is typically considered only in the design phase (for lines after the applicable standards came in place). Longitudinal stresses on pipelines are typically not monitored or actively managed except in segments which are expected to have high stresses or heightened risk of failures from historical experience. In this sense, the “design limit” on longitudinal stresses is treated very differently from limits on internal pressure. Historically, failures due to longitudinal stresses/strains are relatively rare. Therefore, the historical approach seems reasonable. The project delivered a complete guide for Risk-informed fitness-for-service assessment of pipelines subjected to ground settlement and movement hazards.	Comprehensive guidance document