

Program Steering Committee - 2006/07 Research Roadmap

Outcome S1: Improved methods to assess the performance and condition of existing transportation structures				
Resulting In: Reduced frequency of on-site inspections; reduced exposure of staff to traffic safety hazards; improved reliability of the performance assessment beyond the capabilities of visual inspection; and reduced maintenance costs.				
Strategic Focus Area: System Preservation: produce long-lived facilities; Worker Safety: construct and maintain facilities in the safest possible manner				
Problems & Research				
	Content Description	Problem #1: Improve Worker Safety	Problem #2: Develop means to rapidly assess structural capacity and remaining service life.	
Overview	(Description of the problems that need to be addressed to achieve the "Outcome".)	Visual inspection is the primary means by which structures in general are inspected. Current regulations require the inspector to be within twenty-four (24) inches of the component to be inspected. Underwater foundations are visually inspected by divers. Physical inspection is not efficient in terms of cost or time. Methods that reduce worker exposure to traffic or other hazards are needed.	Visual inspection is the primary means by which structures in general are inspected. This results in a qualitative assessment of the structural capacity or remaining service life of the structure. Physical inspection is not efficient in terms of cost or time and the reliability of the results can be questioned. Non-destructive methods are needed to rapidly assess the structural capacity and remaining service life of the bridge.	
Recent Research	(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)	<ul style="list-style-type: none"> • TRIS website • Literature search by OEE staff • Expert panel Meeting. • NCHRP / TRB website 	<ul style="list-style-type: none"> • NCHRP website • TRIS website • Literature search by OEE staff • CT funded research has extended non-destructive damage detection algorithms to bridge structures. Additional work is needed to evaluate capacity and remaining service life using these results • Expert panel review 	
Future Research	(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)	<ul style="list-style-type: none"> • Compare divers vs side-scan-sonar in bridge inspection • Development of alternative inspection methods to improve worker safety. • Develop "local" NDT techniques / test methods that complement the "global" methods to be identified / implemented as a result of Problem #2. 	<ul style="list-style-type: none"> • Develop standard tests (ASTM) to evaluate materials and components • Evaluate recent monitoring devices and systems. • Develop method/model to evaluate risks for events in conjunction with routine preservation needs. • Develop inspection procedures for MSE Walls and Overhead sign structures • Develop method to assess capacity of P_S tendons in box girder structures • Develop method/model to evaluate risks for events in conjunction with routine preservation needs (risk management) 	
Research Products	(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)	<ul style="list-style-type: none"> • Equipment that reduces worker exposure to hazards 	<ul style="list-style-type: none"> • Inspection protocols • Risk management tools • Standard test methods • Non-destructive damage evaluation tools 	

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Outcome S2: Extend Service Life of all Highway Structures					
Resulting In: reduced maintenance, rehabilitation and replacement costs, and reduced impacts to traffic associated with bridge rehabilitation or repair.					
Strategic Focus Area: System Preservation: the existing transportation system will need to be maintained and rebuilt in future years. Performing highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities is essential.					
Problems & Research					
	Problem #1: Truck Weight and Volume	Problem #2: Extreme Events	Problem #3: Develop better design details	Problem #4: Corrosive Environment	Problem #5: Material Quality
Overview	Increases in truck weight and volume are leading to accelerated degradation of transportation structures, in particular bridge decks.	Extreme events, such as scour, earthquakes, vehicle impacts and blast decrease the life of transportation structures. Better methods are needed to quantify the deterioration that accumulates from each event, as well as rehabilitate the structure after the event.	Design and construction details that have recently been implemented appear to result in more rapid deterioration of bridges than previous details. Work is needed to determine if the detail is the problem or the material.	Corrosion reduces service life. Better methods are needed to reduce damage in bridge structures due to corrosion.	Covered by Group "B"
Recent Research	<ul style="list-style-type: none"> • TRIS website • NCHRP / TRB websites • Literature search by OEE staff • Expert panel Meeting. • On-going work funded at UC-Irvine • HITEC Project to evaluate FRP composite bridge decks • HERMIS 	<ul style="list-style-type: none"> • TRIS website • NCHRP / TRB websites • Literature search by OEE staff • Expert panel Meeting • CT funded research in the area of non-destructive damage detection 	<ul style="list-style-type: none"> • TRIS Website • NCHRP / TRB websites • Literature search by OEE staff • Expert panel Meeting • Research on-going at Georgia Tech on FRP materials and lightweight concrete • HITEC project to evaluate FRP composite decks • On-going work in durability of FRP composite materials at UCSD 	<ul style="list-style-type: none"> • TRIS website • NCHRP / TRB website • Expert panel meeting 	
Future Research	<ul style="list-style-type: none"> • Development of automated process for assessing condition of bridge decks • Development of non-destructive damage evaluation of entire bridge with minimal traffic disruptions. • Develop better bridge deck design/materials [HIGH] • Evaluate impact on deck due to non-standard-width trucks • Determine why old decks last longer than new decks. 	<ul style="list-style-type: none"> • Develop hardware / software for real-time monitoring and damage assessment • Determine the foundation type and depth when plans are unavailable • Develop an early warning system to avoid impacts • Develop risk management strategies • Develop scour retrofit strategies 	<ul style="list-style-type: none"> • Develop feedback loop to enable design to better understand how bridge details perform in the field based on maintenance inspection • Research opening design to facilitate bearing maintenance • Research alternative materials 	<ul style="list-style-type: none"> • Improve concrete deck design • Development of corrosion inhibiting methods / materials • Develop methods to protect steel cable restrainers from corrosion • Investigate salt extraction methods to extend service life 	
Research Products	<ul style="list-style-type: none"> • New materials • Design guidelines • Test equipment • Standard tests • Standard detail sheets 	<ul style="list-style-type: none"> • Risk management strategies • Design guidelines • Products / Equipment 	<ul style="list-style-type: none"> • Product / Material • Standard detail sheets • Memo to Designers 	<ul style="list-style-type: none"> • Product / Material • Standard detail sheets • Memo to Designers 	

Outcome S3: Reduce the impact of structure construction and maintenance activities on the traveling public				
Resulting In: reduced impacts to the traveling public, reduced worker exposure to traffic safety hazards, and reduced construction costs while meeting design performance requirements				
Strategic Focus Area: System Preservation: perform highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities. Worker Safety: construct and maintain facilities in the safest possible manner. Accelerated Project Delivery: efficient and effective delivery of transportation projects and services. Improvements to the project development process to accelerate project delivery. Operational Improvements: increase the efficiency and safety of the transportation system				
Problems & Research				
	Content Description	Problem #1: Reduce the length of time necessary to construct a bridge.	Problem #2: Reduce the time required to maintain a bridge	
Overview	(Description of the problems that need to be addressed to achieve the "Outcome".)	Construction has too large an impact on the traveling public. Bridge construction projects delay the traveling public. The process required to bring a structure on-line must be reduced.	The risk to maintenance crews working on the transportation system is high. Exposure of crews to traffic hazards must be reduced.	
Recent Research	(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)	<ul style="list-style-type: none"> • TRIS website • Literature search by OEE staff • NCHRP Project 12-72 • Research completed at UNR and Univ WV • Expert panel Meeting. • FHWA Scan Trip on accelerated construction methods and techniques 	<ul style="list-style-type: none"> • TRIS website • NCHRP Website • Literature search by OEE staff • HITEC website • Expert panel Meeting 	
Future Research	(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)	<ul style="list-style-type: none"> • Determine situations most suitable for total bridge movement systems • Develop a specification for the total movement of a bridge • Identify situations best suited for a total bridge movement • Pilot construction of total bridge movement systems • Pilot prefabricated bridge construction projects • Develop a suit of prefabricated bridges designed to current seismic design criteria. • Expand design specifications to allow greater use of precast elements in a bridge. • Investigate the benefits of precast segmental construction • Investigate the use of stay-in-place (SIP) formwork as a means to reduce the time necessary to construct a bridge. 	<ul style="list-style-type: none"> • Determine situations most suitable for total bridge movement systems • Pilot construction of total bridge movement systems • Pilot prefabricated bridge construction projects • Develop a suit of prefabricated, seismically-resistant bridges • Reduce delays due to environmental approval for common activities such as painting and widening. • Determine pre-defined mitigation steps for environmental approval • Identification and testing of advanced materials to reduce maintenance time • Determine if initial high costs to design & construct a structure result in lower overall maintenance and repair costs during the life of the structure. 	
Research Products	(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)	<ul style="list-style-type: none"> • Products • Revisions to Segmental Bridge Design Specifications • Standard Detail Sheets 	<ul style="list-style-type: none"> • Products • Information to modify environmental policy 	

Outcome S4: Optimized and validated new and/or existing materials, systems and components for bridges and highway structures				
Resulting In: Reduced life cycle costs, reduced maintenance costs, extended service life through improved durability, improved bridge serviceability, and reduced project delivery time through standardization and modularization.				
Strategic Focus Area: System Preservation: Produce long-lived facilities. Accelerated Project Delivery: Improvements to the project development process to accelerate project delivery.				
Problems & Research				
	Problem #1: The properties of High Performance Materials need to be well understood and documented to implement into practice	Problem #2: Alternatives to masonry block are needed for soundwalls on bridges and for improved acoustic absorption properties	Problem #3: Precast bridge components need to be made more cost effective with improved constructability for greater utilization	Problem #4: Need to consider how new materials can be used to improve long term bridge deck performance
Overview	High performance materials including concrete, and rebar have been developed but properties need to be understood to implement into practice for improved durability, reduced construction cost and improved performance	The most common soundwall type used in California is masonry block. Alternatives need to be developed for use on bridges to reduce need to reconstruct bridge overhangs due to heavy mass and to take advantage of materials with better acoustic absorption properties.	Precast members show promise to improve project delivery and to reduce traffic impacts, but initial construction costs of cast-in-place construction is often lower than precast structure types	Deck cracking and durability is one of the most pervasive problems being addressed by the Department, exposing staff to traffic hazards to inspect, and affecting traffic to address.
Recent Research	<ul style="list-style-type: none"> Confer with a Material Science expert from academia TRIS NCHRP/FHWA/TRB LRFD liaison CT funded research HITEC research UCSD composites contract for durability Lawrence Livermore project for composites Numerous high performance material projects 	<ul style="list-style-type: none"> TRIS NCHRP FHWA TRB New Products Coordinator New products submitted to Caltrans 	<ul style="list-style-type: none"> TRIS NCHRP FHWA TRB LRFD liaison CT funded research NCHRP contract w/ UCSD and Sac State on precast bent caps UCSD precast girders w/ CIP integral bent caps New girder shapes through other DOTs and NCHRP 	<ul style="list-style-type: none"> Confer with a Material Science expert from academia TRIS NCHRP FHWA TRB LRFD liaison CT funded research Fiber reinforced concrete
Future Research	<ul style="list-style-type: none"> Determine durability of high performance concrete Ductility of high performance rebar Development of ultimate and serviceability couplers for high performance rebar Properties of self-consolidating concrete Development of construction specifications for high performance materials Confined concrete strain capacity of fiber reinforced concrete Curvature capacity of columns with high performance concrete and rebar Develop methods to protect A490 bolts from corrosion Development of improved materials for MSE wall reinforcing corrosion Develop design specifications and other guidance material for DOT use Develop guidance material for use of composites to strengthen and repair existing structures Survey materials used for other applications for civil application. Develop fatigue models for high performance materials Develop construction specifications and techniques for use of new materials in the field Determine properties of steel Buckle Restraint Bracing for bridge substructures Develop improved methods to inspect welds Improve weld properties and reliability Develop weld code for OBG's Develop method specs as well as performance specs. Evaluate use of composites and steel tubing for bridge column applications Characterize properties of geomaterials geosynthetics and ground improvement techniques Develop LRFD compliant specifications including limit state criteria Perform life cycle cost/benefit studies Corrosion resistance of epoxy coated and stainless steel rebar in concrete Corrosion resistance options for ASTM A490 bolts Criteria for evaluating use of new material including consideration of life cycle costs versus initial costs 	<ul style="list-style-type: none"> Best practices survey of other DOT's Development of improved methods to verify claims of improved acoustic properties Development of structural details and testing of new materials to ensure it meets Department performance requirements for wind, seismic and other loads Improve ASTM tests to assess acoustic properties 	<ul style="list-style-type: none"> Perform best practices survey of other DOT's on the use of precast elements Evaluate long term performance of precast deck panels Assess the seismic performance of precast girders on inverted-T bent caps Hold workshop with stakeholders to determine how precast members can be made more cost effective Develop new precast girder shapes using high performance concrete and/or high performance rebar Assess the ability of new precast components and systems to meet Caltrans Goals/Focus Areas/Outcomes, and test to validate their performance Perform parametric studies to optimize precast components and systems using new materials Standardize precast components and systems with tables, nomographs, charts, standard details and other tools for effective design practices Coordinate the development of precast component to ensure compatibility and together as a system will meet the overall bridge performance requirements Develop methods to streamline bridge design of precast bridge elements and systems. Perform best practices survey. 	<ul style="list-style-type: none"> Perform best practices survey Determine the feasibility of using high performance concrete to address deck cracking Determine whether high performance materials can be used to reduce cracking of precast decks Develop fatigue models for high performance materials Develop improved understanding of traffic loads Develop alternatives to eliminate 3" extension of prestressing strand for precast deck panels Determine how high performance materials be used to cost effectively repair, rehabilitate or strengthen existing bridges Methods needed to assess life cycle costs versus initial costs. May require change in CT bidding process.

Structure & Geotechnical Program Steering Committee – STAP 2006/07 Research Roadmap

Research Products	<ul style="list-style-type: none"> • Updated LRFD and SDC manual on material properties • Information to be used for following phases on optimization of the materials • Standardized test methods for testing new materials 	<ul style="list-style-type: none"> • Results of best practices survey • New XS sheets for new wall types • Updated MTD with revised loads and properties • New testing methods for evaluation of new products 	<ul style="list-style-type: none"> • Results of best practices survey • New XS sheets • Updated LRFD BDS • Updated SDC • Updated MTD 	<ul style="list-style-type: none"> • Results of best practices survey • New XS sheets • Updated LRFD BDS • Updated SDC • Updated MTD
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Outcome S5_1: <u>Improved Soil-Foundation-Structure-Interaction Analysis Tools, Techniques, and Methods</u>				
Resulting in: Reduced construction costs due to design conservatism associated with SFSI uncertainty, improved ability to assess the impact of liquefaction/lateral spreading hazards on existing structures to determine whether they meet performance requirements, improved ability to model ground motion interaction with bridge foundations to assess seismic performance, and improved safety and serviceability through better understanding of performance.				
Strategic Focus Area: System Preservation: Produce long-lived facilities Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters				
Problems & Research				
	Content Description	Problem #1: <u>Soil Liquefaction and Lateral Spreading</u>	Problem #2: <u>Uncertainties related to Soil Foundation Interaction</u>	Problem #3: <u>Field Verification of developed Analytical Design Methods</u>
Overview	(Description of the problems that need to be addressed to achieve the "Outcome".)	Field observations of liquefaction and lateral spreading are well documented as a major hazard to structural stability and safety during the seismic events.	- There is lack of understanding of soil/foundation interaction that lead to more conservative design assumptions that increase the cost. - Lack of rational modeling for soil/foundation interaction lead to uncertainties related to structural performance during the seismic event.	Most of the existing design tools were developed without taking into account the complexity of seismic loading. Existing design tools were developed for small diameter piles subjected to mainly axial loading .
Recent Research	(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)	_ On going research with PEERS.	- Large-scale testing at UCLA. - Large scale testing for bridge system at UNR, NEES project. - SWM analytical tools at UNR	- Large scale Testing at UCLA - Treasure Island testing - SWM analytical study, UNR
Future Research	(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)	- Develop experimental testing program to identify soil parameters playing major role in causing this phenomena. - Develop rational analytical design tool to take into account this phenomena.	- Large scale system testing to obtain quality data then correlate the field data with the analytical tools.	- Utilize Field instrumentation to verify existing design tools and develop new rational ones.
Research Products	(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)	- Design Guidelines and procedures to take into account the effect of liquefaction and lateral spreading on bridge foundations. - Design recommendations on how to mitigate the effect of this phenomena during the seismic event.	- Design guidelines for modeling bridge/foundation. - Design guidelines for modeling bridge abutment.	- Rational design tools for analyzing bridge foundations during the seismic event.

Outcome S5_2: Improved Soil-Foundation-Structure-Interaction Analysis Tools, Techniques, and Methods
Resulting in: Reduced construction costs due to design conservatism associated with SFSI uncertainty, improved ability to assess the impact of liquefaction/lateral spreading hazards on existing structures to determine whether they meet performance requirements, improved ability to model ground motion interaction with bridge foundations to assess seismic performance, and improved safety and serviceability through better understanding of performance.

Strategic Focus Area: System Preservation: Produce long-lived facilities Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters

Problems & Research

	Content Description	Problem #4: <u>Improve Structure/Foundation Connections</u>	Problem #5: <u>Improve Soil Investigation/Characterization</u>	Problem #6: <u>Develop Technologies for Ground Improvement</u>
Overview	(Description of the problems that need to be addressed to achieve the "Outcome".)	- Capacity of bridge/foundation connection are crucial to the performance of the bridges during the seismic events. - There is lack of rational modeling for connection during the analysis state.	Soil parameters used in analytical tools play an important role in predicting the performance of the bridges during the seismic events.	Ground improvement often considered as a solution to mitigate liquefiable soil.
Recent Research	(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)	Drill and bond research at CSUS. Couplers and mechanical splices testing verification.		
Future Research	(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)	- Verify pile structure connections through large scale testing.	- Utilize the available new technologies to establish a more representative soil parameters.	- Investigate typical techniques and their effectiveness. - Develop new reliable techniques
Research Products	(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)	- Design recommendations for approved splicing and types of connections.	- New soil investigation techniques utilizing new technologies.	- Recommendations on the effective methods, materials, and tools for soil liquefaction mitigation.

Outcome S5_3: Improved Soil-Foundation-Structure-Interaction Analysis Tools, Techniques, and Methods
Resulting in: Reduced construction costs due to design conservatism associated with SFSI uncertainty, improved ability to assess the impact of liquefaction/lateral spreading hazards on existing structures to determine whether they meet performance requirements, improved ability to model ground motion interaction with bridge foundations to assess seismic performance, and improved safety and serviceability through better understanding of performance.

Strategic Focus Area: System Preservation: Produce long-lived facilities Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters

Problems & Research

	Content Description	Problem #7: <u>Seismic Performance of Retaining Walls/Sound Walls</u>	Problem #8: <u>High Foundation Cost</u>	Problem #9: <u>Quantifying Bridge Abutments Effect of the Overall Performance of Bridges during the Seismic Event.</u>
Overview	(Description of the problems that need to be addressed to achieve the “Outcome”.)	Design procedures for retaining walls and sound walls were not validated through research yet.	- Foundation cost is considered high to account for many uncertainties. - Design policy requires that foundations to be designed to stay elastic that drive the cost up.	- Bridge abutments are effective in resisting seismic loading especially in short bridges. - There is agreement about a lack of rational modeling techniques for abutment and soil interaction.
Recent Research	(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)		- Improve foundation capacity using grouting, UNR.	- On going research for abutment stiffness and soil parameters in CSULB. - Effect of abutment skew on the overall performance of short bridges , UNR, and CSULB. - Data collected from instrumented bridges.
Future Research	(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)	- Develop interactive research program to take into account types of walls used in California. Interaction with other state DOTs and FHWA will provide a good starting point to develop this research program	- Introduce non-linearity to foundation design. - Verify the concept of foundation rocking in order to reduce seismic demand.	- Integration of data from instrumented bridges and lab testing will pave the way to develop rational design tools to model bridge abutments.
Research Products	(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)	-Design guidelines for modeling, and analyzing retaining wall and or sound walls.	-Adapting policies that may lead to reduce the cost of building bridge foundations.	- Design guidelines to rationally model bridge abutment interaction with soil during the seismic event.

<p>Outcome S6: <u>Seismic Analysis and Design Tools, Techniques, and Methods</u> Resulting in: Reduced construction costs associated with design conservatism due to analytical uncertainty, improved ability to assess the impact of seismic hazards to ensure highway structures meet performance requirements, and improved safety and serviceability through better understanding of seismic performance.</p>				
<p>Strategic Focus Area: System Preservation: Produce long-lived facilities. Operational Improvements: Increase the efficiency and safety of the transportation system. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters</p>				
<p>Problems & Research</p>				
	Content Description	Problem #1: <u>Verification of Design Tools through System Testing</u>	Problem #2: <u>Lack of Design Tools to account for adapting new devices / concepts.</u>	Problem #3: <u>Verification of Design Tools using Data collected from Instrumented Structures.</u>
Overview	(Description of the problems that need to be addressed to achieve the "Outcome".)	- Caltrans completed high priority program testing bridge components to determine their capacities. Now Caltrans with the existing large shake table testing should verify bridge system subjected to a more realistic seismic loading	Lately Industry introduced new devices and Caltrans validate their use in California bridges. - There is lack of simplified analytical tools to model and analyze the new devices.	- Caltrans has significant inventory of instrumented bridges. - Caltrans owns large inventory of testing data obtained through aggressive seismic research program. - Seismic design tools are based on design assumptions and engineering judgments.
Recent Research	(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)	- Caltrans 2-D Frame testing at UNR. - NEES bridge/soil system testing at UNR.	- Validation testing for bridge bearing systems at UCSD. - effect of heat on the capacity of viscous dampers study was conducted at UCB.	
Future Research	(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)	- Develop system testing with reasonable scale to obtain quality data that simulate the actual seismic event. - Correlate the obtained system testing with data collected from instrumented bridges.	- Interaction between researchers , industry engineer and Caltrans engineer to develop rational simplified design tools for the new devices.	- Correlate testing data with data obtained from instrumented bridges and bridge design tools predications in order to validate/improve design tools.
Research Products	(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)	- Refinement of design tools. - Develop new design tools for irregular bridges based on instrumentation and testing.	- Design guidelines and tools to model new devices during the seismic design of bridges.	- Refinement of seismic design tools.

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Outcome S7_1: <u>Improved Understanding of Seismic Hazards</u> Resulting in: Reduced construction costs associated with design conservatism due to uncertainty, improved ability to assess seismic performance, and improved safety through better understanding of seismic performance.				
Strategic Focus Area: System Preservation: Produce long-lived facilities. Operational Improvements: Increase the efficiency and safety of the transportation system. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters				
Problems & Research				
	Content Description	Problem #1: <u>Causes/Risks of Tsunami on Structures</u>	Problem #2: <u>Design Bridges near/crossing faults.</u>	Problem #3: <u>Designing Bridges for more realistic seismic Loading</u>
Overview	(Description of the problems that need to be addressed to achieve the "Outcome".)	- Faults under oceans water may contribute to Tsunami phenomena that may cause significant devastation	- Almost 50% of California bridges are built either near or crossing faults. - Large ground displacement can be significantly devastated for bridges near or crossing faults.	Performance of the bridges during seismic events is impacted by the existing faults and bridges proximity to the faults. - Soil types contribute to the performance of bridges during the seismic event.
Recent Research	(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)	-Tsunami research center at Oregon State university .	- Design Guidelines for bridges near faults at UNR. - Design guidelines for bridges crossing faults at UCB. - Effect of vertical acceleration on bridge performance during the seismic event at UCD.	Multi- support excitation at UCB
Future Research	(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)	<ul style="list-style-type: none"> - Develop research program to investigate the potential of Tsunami in California - Develop warning system and possible retrofit for bridges that may be affected by tsunami. - Develop research work for improving bridge performance during Tsunami. 	- Integrate the on going studies to develop design guidelines for bridges near or crossing faults.	- Investigation into deterministic verses probabilistic seismic loading determination - Multi-support excitation research for long bridges.
Research Products	(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)	<ul style="list-style-type: none"> - Warning system for tsunami. - Retrofit guidelines for bridges that may be affected by tsunami. - Design guidelines for bridges built in potential tsunami zones. 	- Design guidelines for Performance of bridges Near and or crossing faults.	More realistic policy identifying seismic loading to be used by design engineers.

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Outcome S7_2: Improved Understanding of Seismic Hazards (2)				
Strategic Focus Area:				
Problems & Research				
	Content Description	Problem #4: <i>Strategic Planning for Risk Related to Seismic Events.</i>	Problem #5	Problem #6
Overview	(Description of the problems that need to be addressed to achieve the "Outcome".)	Better understanding of all possible seismic risks will pave the way to better strategic planning for minimizing the social/economical impact of the seismic events.	.	
Recent Research	(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)	- Social/economic impact of North Ridge Earthquake 1994 on LA area. Study completed at UCI		
Future Research	(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)	- Develop research study for social/economic impact of major seismic events. - Develop management tools to minimize the risk.		
Research Products	(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)	- Management tools to minimize the social/economical impact of a major seismic event.		

Outcome S8_1: Improved performance of bridges and highway structures to earthquakes and other man-made and natural extreme events, and improved ability to quickly restore facilities to full functionality.				
Resulting In: Reduced post-EQ traffic impacts associated with inspection or repair, reduced repair costs, and reduced exposure of staff to hazards associated with damaged structures and traffic hazards using Devices, Materials, and Systems requiring minimal Maintenance, Inspection or Testing during the Design Life of the Bridge; and Cost-effective reductions in risk due to the multitude of infrequent extreme event hazards, improved safety of traveling public, and the identification and prioritization of the use of scarce resources.				
Strategic Focus Area: Worker Safety: Construct and maintain facilities in the safest possible manner. System Preservation: Perform [post-EQ/Extreme Event] highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities. Operational Improvements: Increase the efficiency and safety of the transportation system. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters.				
Problems & Research				
	Problem #1: Reduce Structural Damage	Problem #2: Seismic Response Modification Devices	Problem #3: Assess Post-Event Performance	Problem #4: Facility Restoration
Overview	Alternatives to column plastic hinging and other structure damaging response need to be developed to resist the loads and absorb the energy from extreme events	SRMD's can be used to protect bridge components, but their long term performance can not be verified except through lab testing and their design life is significantly less than bridge lifespan. Removing SRMD's is expensive and often very disruptive to traffic	Improvements are needed to quickly and effectively assess bridge performance capacity following an extreme event	Methods, tools and techniques must be developed to quickly and effectively inspect and repair or replace damaged structural components to restore facility functionality.
Recent Research	<ul style="list-style-type: none"> Confer with a Material Science expert from academia TRIS NCHRP FHWA TRB LRFD liaison CT funded research PEER and UNR research on prestressed columns UCSD segmental bridge testing Univ. of Michigan study of plastic hinging capacity of columns with fiber reinforced concrete 	<ul style="list-style-type: none"> TRIS NCHRP FHWA TRB LRFD liaison CT funded research UCSD testing of seismic devices SUNY-Buffalo design and construction specifications synthesis project for Caltrans UCSD seismic device/health monitoring 	<ul style="list-style-type: none"> TRIS NCHRP FHWA TRB LRFD liaison CT funded research UCSD post-earthquake damage catalog MCEER's REDARS project UC-Berkeley contract to assess post-earthquake live load capacity of SDC designed column 	<ul style="list-style-type: none"> TRIS NCHRP FHWA TRB LRFD liaison CT funded research UNR contract to use FRP composites as a "band-aid" to provide temporary repairs of damaged columns Numerous structural health monitoring projects
Future Research	<ul style="list-style-type: none"> Assess new materials to reduce structural damage requiring post-event repair Develop new types of structural components or systems that resist damage Need improved methods to remove and replace SRMD's Develop improved analytical modeling capabilities to more reliably predict post-event performance Develop improved performance based specifications Guidelines are needed to assess multi-hazard risks to make cost-effective decisions and prioritize efforts Assess probability of hazards and the effects if the extreme event in question occurs Need effective strategies to reduce damage due to high vehicle impacts to structures Best practices study to develop cookbook extreme event mitigation measures which can be implemented during planning phases with no or minimal analysis Perform parametric studies to determine effectiveness of potential mitigation measures against multiple hazards Develop improved understanding of seismic hazards including near fault effects, fault rupture, ground movement. Develop mitigation measures for structures crossing faults with large displacement potential Determine the seismic response of masonry block soundwall on bridges Determine effects of repairs to shear walls using FRP composites 	<ul style="list-style-type: none"> Need improved ability to assess performance of SRMD's in service. Need improved methods to remove and replace SRMD's Need improved performance from standard bearings to avoid need for post-event repair or replacement Need improved details to easily inspect, remove and replace SRMD's, particularly bearings Enhance the reliable design life of SRMD's 	<ul style="list-style-type: none"> Conduct best practices survey Need methods and tools to monitor the bridge performance remotely Once methods and tools created, need to install a system to send out an alert if the bridge is damaged If multiple structures are threatened, need a system to help prioritize the use of available resources responding to the event Need improved tools, techniques and methods beyond visual inspection to assess post-event damage Need methods, tools and techniques to determine the post-event traffic carrying capacity 	<ul style="list-style-type: none"> Best practices survey on bridge repair methods Develop new types of structural components or systems that can be quickly and efficiently repaired or removed and replaced with minimal traffic impacts. Need guidance material with recommendations on how to manage a damaged bridge Develop new techniques to temporarily repair a structure and restore functionality until final repairs can be made
Research Products	<ul style="list-style-type: none"> Results of best practices survey New XS sheets Updated LRFD BDS Updated SDC Updated MTD New modeling techniques or proposed modifications to software 	<ul style="list-style-type: none"> New XS sheets Updated LRFD BDS Updated SDC Updated MTD New modeling techniques or proposed modifications to software 	<ul style="list-style-type: none"> Results of best practices survey New tools, methods and systems to monitor structures Tools, techniques, hardware and software to assess structure Guidance material and manuals on assessing structure 	<ul style="list-style-type: none"> Results of best practices survey New or updated structural systems Guidance material including SDC, LRFD BDS, MTD Recommendations leading to new or revised ASTM standards

Outcome S8_2: Improved performance of bridges and highway structures to earthquakes and other man-made and natural extreme events, and improved ability to quickly restore facilities to full functionality.				
Resulting In: Reduced post-EQ traffic impacts associated with inspection or repair, reduced repair costs, and reduced exposure of staff to hazards associated with damaged structures and traffic hazards using Devices, Materials, and Systems requiring minimal Maintenance, Inspection or Testing during the Design Life of the Bridge; and Cost-effective reductions in risk due to the multitude of infrequent extreme event hazards, improved safety of traveling public, and the identification and prioritization of the use of scarce resources.				
Strategic Focus Area: Worker Safety: Construct and maintain facilities in the safest possible manner. System Preservation: Perform [post-EQ/Extreme Event] highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities. Operational Improvements: Increase the efficiency and safety of the transportation system. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters.				
Problems & Research				
	Problem #5: Blast and other Manmade Extreme Event Loads	Problem #6: Scour		
Overview	Effective strategies must be developed to improve the performance of bridges to multiple manmade threats	The effects of Scour are some of the most common extreme events that threaten bridges. Effective means are needed to better identify bridges vulnerable to scour, mitigate the effects, monitor vulnerable bridges.		
Recent Research	<ul style="list-style-type: none"> • TRIS • NCHRP • FHWA • TRB • LRFD liaison • CT funded research • TSWG • Army Corps of Engineers • UCSD box girder projects • WSDOT prestressed girder pooled fund • Army Corps/FHWA tower blast project 	<ul style="list-style-type: none"> • TRIS • NCHRP • FHWA • TRB • LRFD liaison • CT funded research 		
Future Research	<ul style="list-style-type: none"> • Best practices survey of blast and other manmade hazard mitigation methods • Determine response of cellular box girder bridges to blast effects • Determine response of cellular/hollow bridge towers to blast effects • Assess most critical location of critical bridges 	<ul style="list-style-type: none"> • Best practices survey of scour mitigation methods • Need improved deterministic/probabilistic methods to assess scour risk. • Need improved methods and techniques to mitigate for scour hazards • Need a California specific scour model to better predict structure performance. • Develop improved, cost-effective scour monitoring and warning tools and techniques • Improved tools are needed to predict, measure, monitor and mitigate scour 		
Research Products	<ul style="list-style-type: none"> • Updated LRFD Bridge Design Specifications • New MTD 	<ul style="list-style-type: none"> • Results of best practices survey • Improved analytical and modeling methods • New monitoring tools • Updated LRFD BDS • Updated SDC • Updated MTD 		

Outcome S9: Nationally Accepted Specifications Advanced for Implementation in California				
Resulting In: Reduced life cycle costs, reduced maintenance costs, extended service life through improved durability, improved bridge serviceability under extreme events, and reduced project delivery time through specification standardization for California-type transportation structures.				
Strategic Focus Area: System Preservation: Produce long-lived facilities. Accelerated Project Delivery: Improvements to the project development process to accelerate project delivery. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters				
Problems & Research				
	Content Description	Problem #1: Traffic loads are not well defined for California	Problem #2: Improved LRFD specifications are needed for California	Problem #3: Improved LRFR specifications are needed for California
Overview	(Description of the problems that need to be addressed to achieve the “Outcome”.)	Traffic loads need to be better understood and defined to better predict long term bridge performance	California’s most predominant structure type is the prestressed box girder. This is not as common nationally and thus the LRFD code must be supplemented for California.	Permit loads and structure types used in California are not as common nationally. The LRFR code needs to be supplemented for Structure Maintenance to implement in Caltrans.
Recent Research	(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)	<ul style="list-style-type: none"> • TRIS website • LRFD liaison • NCHRP • FHWA • TRB • State collected data • Ontario WIM traffic data for Canada 	<ul style="list-style-type: none"> • TRIS website • NCHRP • FHWA • TRB • CT funded research • LRFD liaison • UC-Davis study of live load distribution on box girder superstructures • Caltrans Prestress Loss project • I405/55 analytical study 	<ul style="list-style-type: none"> • TRIS website • NCHRP • FHWA • TRB • CT funded research • LRFD liaison • UC-Davis study of live load distribution on box girder superstructures
Future Research	(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)	<ul style="list-style-type: none"> • Format Weigh-in-Motion (WIM) data for design use • Verify or modify the new P-15 Permit Load • With WIM data, determine fatigue effects and mitigation measures • Develop updated skew factors for skewed exterior girders • Develop relationship between updated traffic loads and deck cracking • Determine the distribution of live load to bent caps • Assess the interaction between live load and seismic loads and when to consider 	<ul style="list-style-type: none"> • Develop updated post-tensioned friction factors • Develop updated lateral prestress load design and detail guidance material • Long term lump sum prestress losses • Effect of duct diameter on shear capacity of post-tensioned concrete girders • 	<ul style="list-style-type: none"> • Determine distribution of permit vehicles on decks and girders. Widths vary from standard width to two times standard design width • Determine skew effects on permit load distribution • Compare effects of HL93 vs. new Permit vs. Previous Permit vehicle
Research Products	(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)	<ul style="list-style-type: none"> • New definition for permit vehicle • Revised LRFD Load Case and Specs • Revised SDC on EQ/LL interaction • Revised MTD on skew factor 	<ul style="list-style-type: none"> • Revised LRFD BDS on friction factors, prestress losses and shear • Updated MTD on prestress losses and curved girder lateral details 	<ul style="list-style-type: none"> • Revised LRFR specifications • Updated Structure Maintenance guidance material

<p>Outcome G1_1: <u>Improve the methods for collecting, storing and disseminating Geotechnical data.</u> Resulting in: A clear definition of what compromises geotechnical data. Identification and standardization of critical data needed for geotechnical operations. Determination of what additional geotechnical data the program can be collecting to better serve the public. Development of a data standard for more effectively sharing data both within and outside the Department. Evaluation and adoption of selected national and international best practices for collection, storage and dissemination of geotechnical data. Developing techniques that can be used to improve our data management practices. Developing criteria and guidelines for sharing data outside of Caltrans.</p>				
<p>Strategic Focus Area: System Preservation: Produce standardized easily retrievable geotechnical data. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters. Accelerated Project Delivery: More efficiently collect, use, archive, and share geotechnical data.</p>				
<p>Problems & Research</p>				
	<p>Content Description</p>	<p>Problem #1: <u>Development of data archiving methods</u></p>	<p>Problem #2: <u>Decreasing redundancies in data handling and storage</u></p>	<p>Problem #3: <u>Utilization of geologic mapping to connect borehole data.</u></p>
<p>Overview</p>	<p>(Description of the problems that need to be addressed to achieve the “Outcome”.)</p>	<p>Data archiving methods</p> <ul style="list-style-type: none"> • What compromises geotechnical data? • What is the critical data needed for geotechnical operations and which of this data should be standardized? • Can we develop a data standard for more effectively sharing data within the Department? • What national and international best practices exist for collection, storage and dissemination of geotechnical data that could be adopted by the program? 	<p>Decreasing redundancies in data handling and storage</p> <ul style="list-style-type: none"> • Is there additional data the program can be collecting that would better serve the public? • What techniques can we use to improve our data management practices? • How do we implement data standards? 	<p>Utilization of geologic mapping to connect borehole data.</p> <ul style="list-style-type: none"> • What national and international best practices exist for collection, storage and dissemination of geotechnical data that could be adopted by the program?
<p>Recent Research</p>	<p>(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhr.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhr.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhr.gov/structure/gtr/century</p>
<p>Future Research</p>	<p>(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)</p>			
<p>Research Products</p>	<p>(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)</p>	<p>Caltrans geotechnical data archive that is compliant with existing national and international standards.</p>	<p>Continuous improvement of data handling practices.</p>	<p>Comprehensive evaluation of available tools to enhance visualization of geologic and geotechnical data. Maximize the usefulness of geologic and geotechnical data.</p>

<p>Outcome G1_2: <u>Improve the methods for collecting, storing and disseminating Geotechnical data.</u> Resulting in: A clear definition of what compromises geotechnical data. Identification and standardization of critical data needed for geotechnical operations. Determination of what additional geotechnical data the program can be collecting to better serve the public. Development of a data standard for more effectively sharing data both within and outside the Department. Evaluation and adoption of selected national and international best practices for collection, storage and dissemination of geotechnical data. Developing techniques that can be used to improve our data management practices. Developing criteria and guidelines for sharing data outside of Caltrans.</p>				
<p>Strategic Focus Area: System Preservation: Produce standardized easily retrievable geotechnical data. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters. Accelerated Project Delivery: More efficiently collect, use, archive, and share geotechnical data.</p>				
<p>Problems & Research</p>				
	<p>Content Description</p>	<p>Problem #4: <u>How can we leverage geotechnical data collected and archived by outside agencies (e.g. Ca geographic survey)?</u></p>	<p>Problem #5: <u>How can we best identify, evaluate, and incorporate new geotechnical data collection tools?</u></p>	
<p>Overview</p>	<p>(Description of the problems that need to be addressed to achieve the “Outcome”.)</p>	<p>How can we leverage geotechnical data collected and archived by outside agencies (e.g. Ca geographic survey)?</p> <ul style="list-style-type: none"> • Should we share data standards outside of Caltrans? • What are the requirements for sharing data? • What are the security issues with data sharing? 	<p>How can we best identify, evaluate, and incorporate new geotechnical data collection tools?</p> <ul style="list-style-type: none"> • What national and international best practices exist for collection, storage and dissemination of geotechnical data that could be adopted by the program? 	
<p>Recent Research</p>	<p>(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhr.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhr.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhr.gov/structure/gtr/century</p>
<p>Future Research</p>	<p>(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)</p>			
<p>Research Products</p>	<p>(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)</p>	<p>Caltrans geotechnical data archive that is compliant with existing national and international standards. Ability to easily access and use geotechnical data archives maintained by others.</p>	<p>Continuous improvement in geotechnical data collection abilities.</p>	

<p>Outcome G2_1: Improve the reliability and consistency of Geotechnical recommendations and designs through the development of standardized best practices. Resulting in: Best practices for preparing a log for test boring and material testing. Guidelines for determining what and how much field and laboratory testing is appropriate. Development of standard geotechnical designs. QC/QA of geotechnical products (e.g. foundation report, GDR, ,etc.). Guidelines to address geotechnical impacts on project constructability. Documentation of knowledge/solutions from prior challenges for future use.</p>				
<p>Strategic Focus Area: System Preservation: Produce reliable and consistent geotechnical recommendations and designs. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters. Accelerated Project Delivery: More efficiently produce geotechnical recommendations and designs.</p>				
<p>Problems & Research</p>				
	<p>Content Description</p>	<p>Problem #1: <u>What are costs/benefits of increasing or decreasing geotechnical investigations for producing a final highway/structure design?</u></p>	<p>Problem #2: <u>What are the best practices for preparing a log for test boring and material testing?</u></p>	<p>Problem #3: <u>What earth materials should be tested? What is the appropriate level of both field and laboratory testing needed for producing geotechnical recommendations and designs?</u></p>
<p>Overview</p>	<p>(Description of the problems that need to be addressed to achieve the “Outcome”.)</p>	<p>What are costs/benefits of increasing or decreasing geotechnical investigations for producing a final highway/structure design?</p> <ul style="list-style-type: none"> • What is the optimal level of geotechnical field investigation required to produce geotechnical recommendations and designs? 	<p>What are the best practices for preparing a log for test boring and material testing?</p> <ul style="list-style-type: none"> • What are the best practices for preparing a log for test boring and material testing? • How do we most effectively convey geotechnical data to both stakeholders and clients? 	<p>What earth materials should be tested? What is the appropriate level of field and laboratory testing needed for producing geotechnical recommendations and designs?</p> <ul style="list-style-type: none"> • What is the optimal level of field and laboratory testing required to produce geotechnical recommendations and designs?
<p>Recent Research</p>	<p>(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrc.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrc.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrc.gov/structure/gtr/century</p>
<p>Future Research</p>	<p>(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)</p>			
<p>Research Products</p>	<p>(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)</p>	<p>A rational criteria for determining the appropriate level of geotechnical investigation for each highway project.</p>	<p>An improved method for conveying geologic and geotechnical data to stakeholders and clients.</p>	<p>Guidelines and methodologies for developing a geotechnical testing program for individual highway projects.</p>

<p>Outcome G2_2: Improve the reliability and consistency of Geotechnical recommendations and designs through the development of standardized best practices. Resulting in: Best practices for preparing a log for test boring and material testing. Guidelines for determining what and how much field and laboratory testing is appropriate. Development of standard geotechnical designs. QC/QA of geotechnical products (e.g. foundation report, GDR, ,etc.). Guidelines to address geotechnical impacts on project constructability. Documentation of knowledge/solutions from prior challenges for future use.</p>				
<p>Strategic Focus Area: System Preservation: Produce reliable and consistent geotechnical recommendations and designs. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters. Accelerated Project Delivery: More efficiently produce geotechnical recommendations and designs.</p>				
<p>Problems & Research</p>				
	<p>Content Description</p>	<p>Problem #4: <u><i>What are the best practices for QC/QA of Geotechnical products (e.g. foundation report, GDR, FR, etc.)</i></u></p>	<p>Problem #5: <u><i>Is a standard geotechnical design process, including guidelines for constructability, beneficial?</i></u></p>	
<p>Overview</p>	<p>(Description of the problems that need to be addressed to achieve the “Outcome”.)</p>	<p>What are the best practices for QC/QA of Geotechnical products (e.g. foundation report, GDR, FR, etc.)</p>	<p>Is a standard geotechnical design process, including guidelines for constructability, beneficial?</p> <ul style="list-style-type: none"> • Should we have a boilerplate design for standard geotechnical problems? • Should there be a standard design process across Caltrans? • Should we have guidelines for constructability guidance issues? 	
<p>Recent Research</p>	<p>(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrc.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrc.gov/structure/gtr/century</p>	
<p>Future Research</p>	<p>(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)</p>			
<p>Research Products</p>	<p>(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)</p>	<p>Development of QC/QA procedures for Geotechnical Services.</p>	<p>Guidelines for producing geotechnical recommendations and designs. Standard geotechnical designs for specific situations.</p>	

<p>Outcome G3: <u>Develop a comprehensive risk management strategy for Geotechnical hazards:</u> Resulting in: Define, identify, and locate existing geologic hazards. Define acceptable levels of risk from known geologic hazards. Develop a systematic approach for prioritizing geologic hazards for mitigation.</p>				
<p>Strategic Focus Area: System Preservation: Enhance system reliability. Transportation Security: Prevent, prepare for, respond to, and recover from both natural and man-made disasters. Accelerated Project Delivery: Identify, prioritize, and systematically correct known geologic hazards.</p>				
<p>Problems & Research</p>				
	<p>Content Description</p>	<p>Problem #1: <u>What are the geologic and geotechnical hazards that affect the state's transportation infrastructure?</u></p>	<p>Problem #2: <u>What are the locations of geologic and geotechnical hazards?</u></p>	<p>Problem #3: <u>What level of risk is acceptable from geologic and geotechnical hazards?</u></p>
<p>Overview</p>	<p>(Description of the problems that need to be addressed to achieve the "Outcome".)</p>	<p>What are the geologic and geotechnical hazards that affect the state's transportation infrastructure?</p> <ul style="list-style-type: none"> • Characterization of ground motion. • Characterization of ground failure (fault rupture, landslide, rockfall, lateral spreading). 	<p>What are the locations of geologic and geotechnical hazards?</p> <ul style="list-style-type: none"> • Which corridors are most susceptible to geologic and geotechnical hazards? • How can we best identify individual geologic and geotechnical hazards? 	<p>What level of risk is acceptable from geologic and geotechnical hazards?</p> <ul style="list-style-type: none"> • Improved characterization techniques for structural fragility • Impact on traffic. • Assessment of network reliability. • How do we assign risks to seismic hazards? • How do we assign risks to non-seismic geologic and geotechnical hazards?
<p>Recent Research</p>	<p>(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)</p>	<p>See "A Quarter Century of Geotechnical Research", disseminated by FHWA Research, Development, and Technology http://www.tfhrcc.gov/structure/gtr/century</p>	<p>See "A Quarter Century of Geotechnical Research", disseminated by FHWA Research, Development, and Technology http://www.tfhrcc.gov/structure/gtr/century</p>	<p>See "A Quarter Century of Geotechnical Research", disseminated by FHWA Research, Development, and Technology http://www.tfhrcc.gov/structure/gtr/century</p>
<p>Future Research</p>	<p>(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)</p>			
<p>Research Products</p>	<p>(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)</p>	<p>Consistent definition and comprehensive list of all geologic and geotechnical hazards affecting the state's transportation infrastructure.</p>	<p>Development of a rational criteria for corridor-level and individual geologic and geotechnical hazards.</p>	<p>Development of a documented risk assignment system for geologic and geotechnical hazards. Tools to aid in prioritizing mitigation strategies for corridor-level and individual geologic and geotechnical hazards.</p>

<p>Outcome G4: <u>Develop more cost-effective foundations:</u> Resulting in: improved constructability of foundations. Define benefits of doing more extensive geotechnical investigations upfront versus the cost of foundations, including differing site conditions claims. Improved concrete mix design for CIDH pile foundations. Optimized mix of steel and concrete in foundation elements. Improved CIDH pile acceptance criteria. Quantifying the reliability of rapid testing methods vs. traditional static testing for evaluating capacity of pile foundations. Improved usage of alternate foundation design technologies.</p>				
<p>Strategic Focus Area: System Preservation: Enhance system reliability. Accelerated Project Delivery: Overall more cost-effective foundation designs.</p>				
<p>Problems & Research</p>				
	<p>Content Description</p>	<p>Problem #1: <u>What are the constructability issues we are having with foundations?</u></p>	<p>Problem #2: <u>What is the cost/benefit ratio between geotechnical investigations and foundation construction costs?</u></p>	<p>Problem #3: <u>What is the optimum design for CIDH pile foundations?</u></p>
<p>Overview</p>	<p>(Description of the problems that need to be addressed to achieve the “Outcome”.)</p>	<p>What are the constructability issues we are having with foundations?</p> <ul style="list-style-type: none"> • What can we do differently to achieve a better outcome with foundations? • Should we care if voids are present? • Why are voids occurring? • Should we change our acceptance criteria? 	<p>What is the cost/benefit ratio between geotechnical investigations and foundation construction costs?</p> <ul style="list-style-type: none"> • What is the cost/benefit of re-doing foundation piles vs upfront mitigation? • How do we define cost-effectiveness? • Is there a benefit from doing more geotechnical investigations upfront to reduce the cost of site changes? • What is the trade off between a foundation design less sensitive to site conditions and amount of geotechnical investigations required and overall foundation costs? 	<p>What is the optimum design for CIDH pile foundations?</p> <ul style="list-style-type: none"> • What is the ideal concrete mix for CIDH pile foundations? • What can we change in the mix of steel and concrete? • Do we have too much steel in our CIDH piles? • Are there improved alternate foundation design technologies?
<p>Recent Research</p>	<p>(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrc.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrc.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrc.gov/structure/gtr/century</p>
<p>Future Research</p>	<p>(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)</p>			
<p>Research Products</p>	<p>(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)</p>	<p>Improved constructability for foundation systems. More clearly defined constructability performance issues by foundation type.</p>	<p>Criteria to develop a rational approach to quantifying the appropriate level of geotechnical involvement in project development and design.</p>	<p>Optimized foundation designs for CIDH piles. Enhanced constructability and performance of CIH pile foundations.</p>

<p>Outcome G5: <u>Reduce the impact on the environment from foundation construction:</u> Resulting in: Reduced impact on aquatic environments from foundation construction. Reduce noise and vibration caused by foundation construction in urban areas. Development and implementation of best practices for disposal of drilling waste during design and construction. On site evaluation of hazards of drilling spoils. Development and implementation of methods for re-using and recycling construction wastes.</p>				
<p>Strategic Focus Area: System Preservation: Enhance system reliability. Accelerated Project Delivery: Overall more cost-effective foundation designs.</p>				
<p>Problems & Research</p>				
	<p>Content Description</p>	<p>Problem #1: What additional techniques can be used to reduce impacts to sensitive aquatic from pile driving?</p>	<p>Problem #2: What new/emerging technologies and/or best practices are available for reducing noise and vibration in urban areas from foundation construction?</p>	<p>Problem #3: What are the best practices for minimizing the environmental impact of foundation construction materials?</p>
<p>Overview</p>	<p>(Description of the problems that need to be addressed to achieve the “Outcome”.)</p>	<p>What techniques can be used to reduce impacts to sensitive aquatic environments from foundation construction (esp. pile driving)?</p> <ul style="list-style-type: none"> • What are the impacts on the marine environment from pile driving? 	<p>What new/emerging technologies and/or best practices are available for reducing noise and vibration in urban areas from foundation construction?</p> <ul style="list-style-type: none"> • How can foundation construction noise and vibration in urban areas be mitigated? 	<p>What are the best practices for minimizing the environmental impact of foundation construction materials?</p> <ul style="list-style-type: none"> • Best practices for disposal of drilling waste during design and construction • On site evaluation of hazards of drilling spoils • Methods for re-using and recycling construction wastes
<p>Recent Research</p>	<p>(Recent research focused on the problem. DRI can assist in providing this information, including Caltrans-sponsored research and other relevant research.)</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrcc.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrcc.gov/structure/gtr/century</p>	<p>See “A Quarter Century of Geotechnical Research”, disseminated by FHWA Research, Development, and Technology http://www.tfhrcc.gov/structure/gtr/century</p>
<p>Future Research</p>	<p>(Additional research needed to overcome the problem. What research questions need to be answered? TAP/PSC and DRI work together to determine.)</p>			
<p>Research Products</p>	<p>(Brief description of deployable product(s) that are desired from the future research. Products will usually be technology, processes, or information for policy formulation.)</p>	<p>Improved methods for mitigating environmental impacts of foundation construction in sensitive environments.</p>	<p>Improved methods for mitigating environmental impacts of foundation construction in sensitive environments.</p>	<p>Improved methods for mitigating environmental impacts of foundation construction in sensitive environments.</p>