Blue Sky CONSULTING GROUP

IMPLEMENTING EARTHQUAKE EARLY WARNING IN CALIFORNIA

A BUSINESS PLAN FOR THE CALIFORNIA EARTHQUAKE EARLY WARNING SYSTEM

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Prepared by

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California Governor's Office of Emergency Services

Cal OES GOVERNOR'S OFFICE OF EMERGENCY SERVICES

Contents

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1 EXECUTIVE SUMMARY

As the daily seismic activity in California reminds us, a catastrophic earthquake with devastating consequences is a looming danger for Californians. But, much of the risk can be mitigated. In addition to strengthening buildings and encouraging Californians to prepare for earthquakes, the technology now exists to provide a warning a few seconds to a minute or more in advance of an earthquake. This technology, known as earthquake early warning (EEW), is currently being developed for deployment in California by the California Governor's Office of Emergency Services (Cal OES) in cooperation with the United States Geological Survey (USGS), the University of California Berkeley, the California Institute of Technology (Caltech), and the California Geological Survey (CGS).[1]

EEW in California is built off the existing seismic sensor network administered by the California Integrated Seismic Network (CISN). The CISN is composed of six organizations that operate seismic sensors to monitor earthquakes, some of which provide real-time data that can be used to provide advance warnings of impending earthquakes. The six organizations include the California Geological Survey, Caltech Seismological Laboratory, Berkeley Seismological Laboratory, USGS Menlo Park, USGS Pasadena, and the California Governor's Office of Emergency Services.

CISN is comprised of three data centers that produce earthquake notifications and Shake Maps based on shaking parameters from stations in the combined seismographic networks, supplemented with predicted ground motions in areas where limited data are available, and are distributed electronically within minutes of the occurrence of earthquakes larger than magnitude 3.5. Many of these elements can be utilized to also create warnings for public safety protection.

While much work has been done up to this point, challenges still remain before EEW can reach full implementation to provide accurate and reliable warnings to all Californians. Additional capital investments are needed in order to fully develop the system: continued research and development is required to refine the computer algorithm that translates seismic and GPS data into a reliable warning of an impending earthquake; a system for delivering alerts to cell phones is still being refined; an extensive public outreach and education campaign will be needed to inform Californians about how to react in the event of an early warning; and a financing plan will need to be implemented in order to provide an ongoing, stable funding source for EEW in California. Equally important, the various organizations involved in running the system will need to strengthen their partnership to align with state laws, such as SB 135 that mandated Cal OES to implement earthquake early warning, and more clearly specify roles and responsibilities in order to ensure effective governance of the system going forward.

[1] The developing California Earthquake Early Warning System (CEEWS) is connected to a larger seismic network intended to provide alerts to the entire west coast of the United States, which is being developed by USGS in partnership with the University of Washington and the University of Oregon. This product is known as ShakeAlert.

1.1 What is the "Business Plan"?

This business plan outlines the steps toward fully realizing an EEW system in California as prescribed in Senate Bill No. 438 by Senator Hill (Chapter 803 Statutes of 2016) entitled "Earthquake safety: statewide earthquake early warning program and system." In order to advance the state's EEW system beyond the current "test bed" or "beta" version, Cal OES sought to develop a business plan aimed at ensuring that a fully capable EEW system is brought on-line in California as soon as possible through a public-private partnership. This business plan contains a budget for one-time and ongoing costs for the system, a financing plan, a timeline and project plan, and a risk assessment for the overall project. The goal of this document is to guide the further development of EEW in California in order to ensure that Californians realize the benefits of the system as soon as possible while ensuring the long-term viability of the system through implementation of a stable ongoing financing mechanism.

1.2 Budget

Much remains to be done to complete the development of a fully functional EEW system in California and to adequately educate the public on its purpose and use. An additional estimated investment of approximately $16.4 million in one-time and capital costs is required to complete the system; this figure assumes that the $15.75 million proposed by the Governor in his 2018-19 budget is approved.[2] In addition, approximately $16.4 million will be needed annually to support ongoing operations and maintenance (O&M) of the EEW system.

These budget figures are based in part on a preliminary telemetry plan.[3] The telemetry plan has only recently been developed, and it may well change based on further analysis and refinement.

1.3 Financing Plan

Although substantial investments in the EEW system have already been made by both the state and federal governments, to finish the capital investment needed and finance the ongoing costs for EEW in California, additional funding must be identified.

Multiple options to finance both one-time and ongoing costs were considered, from a surcharge on income tax returns to charges imposed on utilities and regulated transportation providers to continued reliance on the state General Fund. The figure below identifies several of the options considered and presents the pros and cons of each.

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[2] The total remaining capital costs to complete the system total $37.6 million. The Federal budget for fiscal year 2018 includes additional funds for one-time costs, of which $5.5 million is estimated to apply to California based on historical spending patterns. The Governor has proposed an additional state investment of $15.75 million. If the legislature approves this amount of funding, the remaining unfunded capital costs total $16.4 million.

[3] Telemetry is the name for the process of transmitting data from the seismic and GPS stations back to the central processing facility. The preliminary telemetry plan was initially developed by USGS and was modified by the Blue Sky Consulting Group working with Cal OES. This modified telemetry plan reflects just costs for telemetry needs in California and makes more use of the existing state microwave network relative to the original USGS plan.

FIGURE 1: POTENTIAL FINANCING SOURCES

Criteria	Pros	Cons
Electric Utility Users Charge	Provides a dedicated, stable revenue source. Can be added to existing bills with little administration cost.	Could incur (minor) additional administration costs if other users (e.g., gas customers) are also charged. Potential opposition from utilities.
Natural Gas Users Charge	Provides a dedicated, stable revenue source. Can be added to existing bills with little administration cost.	Could incur (minor) additional administration costs if other users (e.g., electricity customers) are charged. Potential opposition from utilities.
Transportation Providers Charge	Provides a dedicated, stable revenue source. Can be charged to regulated transportation providers (and likely passed on to riders of regional transit systems, Caltrain and High Speed Rail) with little administration cost.	Could incur (minor) additional administration costs if other users (e.g., electricity customers) are charged. Potential opposition from transportation providers.
Cell Phone Connection Charge	Clear nexus between payers and beneficiaries. Can be added to existing bills with little administration cost. Provides a dedicated, stable revenue source.	Potential opposition from cell carriers.
Income Tax Surcharge	Provides a dedicated, stable revenue source. Administration costs would be relatively low if charge added to existing tax returns.	Limited nexus between payers and beneficiaries.
Charge on EEW technology and service providers	Establishes a nexus between benefits and (certain) beneficiaries of the system. Avoids the need to increase taxes/charges paid directly by individual Californians.	Revenues could fluctuate based on number and type of technology and service providers.
Foundation and federal grants	Avoids the need to increase taxes/charges imposed on Californians.	Does not provide a stable, dedicated revenue source.
Charge on industries that benefit from EEW	Avoids the need to increase taxes/charges imposed on Californians.	Would require multiple, new and costly revenue collection mechanisms.
State General Fund	Establishes a nexus with users and beneficiaries to the extent entire state benefits from EEW. No new revenue collection costs.	Would require annual appropriations and so may not provide a stable, dedicated revenue source.

1.3.1 Financing One-time and Capital Costs

In addition to paying for ongoing operations and maintenance of the system, additional capital and one-time investments are needed in order to make the system fully operational. In his 2018-19 budget, Governor Brown proposed an additional $15.75 million investment in EEW. To the extent the Legislature approves this additional investment, $16.4 million in one-time costs remain. The remaining investment could be financed on a "pay as you go" basis, assuming a dedicated revenue stream is implemented.[4]

1.4 EEW Timeline, Risks and Benefits

Advancing the state's EEW system from the current "beta" version to one that is fully operational will require thoughtful planning and decisive actions on the part of EEW program administrators and the partners responsible for building out and operating the system. California's management of the system is governed by state law, which charges Cal OES with responsibility for the program. However, the context is particularly important given the currently decentralized nature of EEW management in California, in which both state and federal agencies as well university partners within and outside of California have some responsibility for managing the system. In other words, because the state does not control all aspects of the system, its ability to directly manage and swiftly implement the EEW system is constrained.

Cal OES is the state agency with overall responsibility for EEW in the California. The state has provided funding for the system, both through annual support of $1.5 million for the California Integrated Seismic Network (CISN) as well as through a recent $10 million general fund appropriation. And, in his 2018-19 budget, Governor Brown proposed an additional $15.75 million state contribution to the system. The Legislature has demonstrated its commitment to EEW through legislation passed in 2013 (SB 135) and 2016 (SB 438), which sought to accelerate the development and implementation of the system by mandating a system be implemented and funding secured and establishing governance through the California EEW Program (CEEWP) and Advisory Board.[5] These activities reflect the state's commitment to developing and implementing an EEW system in California and recognition that additional state financial support and leadership are fundamental elements of a successful system.

While Cal OES is the lead state agency with responsibility for EEW in California, most of the seismic stations and key components of the telemetry network are controlled by the CISN partners, (including USGS and the university partners) which manage the technical functionality of the system, including the flow of seismic data from the stations and the algorithm which develops the earthquake alert warning itself.

During the development of the EEW system, Cal OES, the USGS, and other CISN partners have sought to work in partnership, jointly developing, for example, the California Earthquake Early Warning Implementation Framework. This framework provides a foundation for further developing a coherent and effective management structure for this decentralized system. However, additional delineation of

[4] Specifically, capital costs could be paid for out of ongoing revenues as a result of the fact that ongoing costs would be lower in the early years of the program. Capital and one-time costs total $37.6 million. To the extent the Governor's proposal is implemented and federally allocated funds are utilized, remaining unfunded capital costs would total $16.4 million.

[5] CEEWP consists of four functional areas within Cal OES: system operations, education and training, research and development, and finance. The Advisory Board advises the Cal OES Director on all matters related to the implementation and long-term operation of the CEEWP.

roles and responsibilities is still in process. For example, current discussions include development of a clearly defined mechanism for determining who will decide when and how to launch the system to the public, what the initial rollout would consist of, who would inform the public or respond to questions about how to access the signal, and many other important details about how and when the system will be launched. While both Cal OES and the USGS have vested interests in these issues, in order to ensure that the system is made available to the public as soon as possible, a decision-making process to resolve any concerns or protocols should be developed.

Ultimately, whatever decision making process is developed will need to provide the state -- in return for its sustained, substantial investment in EEW as envisioned by this business plan -- with the necessary decision-making authority and accountability mechanisms to ensure that its priorities are reflected in the implementation and management of the EEW system. These needs, however, must also be balanced by recognition of the fact that the USGS has a significant operational stake and has made substantial investments into the system.

1.4.1 Limited Public Rollout

In addition to the adoption of an EEW financing source, the contours of the limited public rollout comprise perhaps the most critical elements of the EEW business plan. While partners appear to agree that some sort of public rollout of the system is appropriate by the end of 2018, work continues with respect to what, specifically, that rollout should consist of. Although the rollout scheduled for the end of 2018 is called a limited public rollout, the technology needed to provide individual Californians with a warning on their smart phones is still being refined. Therefore, any rollout in 2018 likely will only be available for institutional users. There are sound arguments for proceeding deliberately, making the EEW signal available to a select group of users and carefully monitoring their use of the signal in order to improve the subsequent rollout to a broader group. Although these arguments have merit, they are outweighed by the public protection benefits of providing access to the signal to the largest possible group of institutional users (e.g., schools, fire stations, hospitals, transportation providers, manufacturers, and other private sector entities) at the time of the initial public rollout in December 2018. Such a broad public rollout in 2018 is consistent with the goals expressed by Cal OES leadership to launch the system as soon as practically possible.

This strategy has several advantages. First, and most importantly, it makes the benefits of EEW available to at least a segment of the public as soon as practically possible. A major earthquake could strike at any time, and Californians should not be denied the benefits of the system for any longer than absolutely necessary. Second, the rollout offers a unique opportunity to gain the attention of potential users. There will likely be news stories, public statements, and interviews surrounding the rollout launch, all of which will provide an important opportunity to inform potential users about the benefits of the system. Furthermore, to the extent the system was launched but users who expressed interest were denied access, public frustration could set back the progress of the program. Finally, while there may well be sound reasons to restrict access based on concerns about system performance, it makes far more sense to allow individual users to make a determination for themselves about the relative costs of false or missed alerts. Users with very high costs for false alerts could choose not to utilize the system until performance improves. However, users with a low cost of false alerts could take advantage of the system's benefits more quickly.

For all of these reasons, a limited public rollout with the following characteristics is recommended:

1. Roll out designated segments of the system no later than December 31, 2018. Accompany the rollout with as many public statements, media interviews, and other publicity as can be generated.

2. Allow any institutional user who wishes it to access the signal as long as that user agrees to the terms of an end user licensing agreement (EULA).[6]

3. Terms of the EULA would specify that (a) the user had been informed of the limitations of the system, and (b) the user would not use the signal to directly inform the public of an impending earthquake, but would instead use the signal only to alert properly trained workers or control machinery.[7]

Rolling out the EEW system according to these terms will require a substantial effort on the part of Cal OES and EEW partnering institutions during the coming months. Resources will need to be devoted to ensuring that the system has the technical capability to make the signal available to a broader group of users. And, staffing resources will need to be devoted to informing potential users about the capabilities and limitations of the system as well as how to access and utilize the signal. Nevertheless, further delay in implementing the system would serve to deny Californians of the benefits of this important service.

1.5 Conclusion

Californians are on the cusp of realizing the benefits of EEW. However, several important steps remain before this goal can be achieved. Technological improvements are still needed, and additional investments in building the necessary infrastructure are still required. An estimated additional investment of approximately $16.4 million in one-time and capital costs is required. In order to achieve the goal of EEW in California, a dedicated financing mechanism capable of supporting the system's estimated $16.4 million annual O & M costs must be identified.[8] Finally, consensus among the USGS and Cal OES on roles and responsibilities as well as the terms of the limited public roll out must be achieved.

[6] Note that individual users could also be granted access to the signal as long as those users received sufficient information about the limitations of the system and training in how to respond to an alert.

[7] Once the technology exists to inform individual users via their smart phones and a public outreach and education campaign has been conducted, these terms should be modified to allow users to inform the public directly.

[8] Additional information about the basis for this estimate is provided in Section 3: Budget and in the Appendices.

The following are the key recommendations of this business plan:

1. Cal OES and the USGS should finalize a formal memorandum of understanding that clearly delineates the roles and responsibilities of each entity with respect to implementing EEW in California.

2. The limited public rollout of the system scheduled for December 2018 should proceed with access granted to the widest possible group of institutional users.

3. Cal OES should work with the USGS to refine the preliminary telemetry plan; to the extent feasible and cost-effective, existing state infrastructure should be utilized in place of new investments in order to minimize costs.

4. The Legislature should approve a stable, ongoing source of funding for the program effective January 1, 2019.

California is on the verge of a scientific advancement that would change earthquake mitigation as we know it. Although several important steps remain, California is poised to join Mexico, Japan, Turkey, Romania, China, Italy, and Taiwan in receiving a warning in advance of a major earthquake. Research shows that the relatively modest costs of this system will be more than outweighed by the benefits in terms of avoided injuries and reductions in damage to equipment and machinery resulting from earthquakes.

2 INTRODUCTION

Earthquakes are a looming danger for Californians, but much of the risk can be mitigated. The Uniform California Earthquake Rupture Forecast released in 2015 estimated that there is a 93 percent probability of a 7.0 or larger earthquake occurring in California by 2045.[9] Building retrofits and improved construction standards for new buildings can reduce the risk of damage in a quake, and actions individuals take at home and at work, such as storing critical supplies of water and medication, can help Californians to be more prepared following a major earthquake. But there is more that Californians can do to prepare for a major earthquake.

The technology now exists for Californians to receive a warning in advance of an earthquake's shaking. This technology cannot give hours of warning like a hurricane alert, but it can provide a few seconds (or more) of warning before many types of earthquakes. Such a warning can provide just enough time for people to "drop, cover, and hold on" to prepare for an earthquake, and it can allow enough time through automation to slow a speeding train, interrupt power or gas sources decreasing threat of fire or open elevator doors at the next available floor. These actions and many others can significantly reduce the consequences of a major earthquake.

Many Californians learned about the existence of EEW systems following the series of major earthquakes which rocked Mexico in the fall of 2017. During those earthquakes, Mexico's EEW system sounded an alert which, in addition to alerting residents of Mexico City about the current seismic activity, also alerted Californians to the idea that some advanced warning about an earthquake was possible.[10] Initial steps and authority to establish an EEW program were outlined in SB 135 by Senator Padilla (Chapter 342 Statutes of 2013). This business plan outlines the steps toward fully realizing an EEW system in California as prescribed in Senate Bill No. 438 by Senator Hill (Chapter 803 Statutes of 2016) entitled "Earthquake safety: statewide earthquake early warning program and system."

2.1 Background and Context

2.1.1 How Does Earthquake Early Warning Work?

An earthquake emits different types of ground shaking waves. Sensors first detect the fastest moving seismic energy wave called the P-wave (Primary) and transmit the data to a central processing center before the damaging, slower moving S-wave (Secondary) arrives. Central processing centers combine data from multiple sensors and make a determination as to the location and magnitude of the earthquake. Because ground motion waves travel more slowly than the signals transmitted to the central processing computers, the EEW system can provide several seconds or more of warning of the impending ground shaking, with farther away earthquakes receiving the most advance warning.

[9] Field, E.H., and 2014 Working Group on California Earthquake Probabilities, 2015, UCERF3: A new earthquake forecast for California's complex fault system: U.S. Geological Survey 2015–3009, https://dx.doi.org/10.3133/fs20153009.

[10] In addition to Mexico, Japan also has an established earthquake early warning system.

2.1.2 What is the Current Status of Earthquake Early Warning in California?

Much progress has already been made in developing an EEW system. The California Governor's Office of Emergency Services (Cal OES) is the state agency charged with overseeing EEW in California. Cal OES has been working with the United States Geological Survey (USGS), the California Geological Survey (CGS), the University of California, Berkeley, and the California Institute of Technology (Caltech) to develop the EEW system in California according to a jointly developed implementation framework.[11] The California Earthquake Early Warning System Steering Committee, consisting of these organizations and coordinated by Cal OES, collaboratively developed and produced the implementation framework document in response to Senate Bill 135 (signed into law in 2013 as Government Code 8587.8) that mandated implementation of an earthquake early warning system in California. The implementation framework provides guidance for the development of the system including outlines of the governance structure, minimum technical requirements for a fully functional system, and roles and responsibilities moving forward.[12]

Working together, the partnering organizations have built a network of more than 500 seismic stations throughout the state that contain sensitive instruments capable of sensing ground shaking and transmitting the data to a central processing center (the remaining stations have been financed and are currently being installed).[13] Researchers at the USGS and its university partners have been working to develop the algorithm which translates signals from these stations into a warning of an impending earthquake. A "beta" version of the EEW system, known as ShakeAlert, is currently up and running in California. This system provides warnings to individuals and organizations that have entered into agreements with the USGS to act as "beta," or "pilot," users of the system.[14]

In order to facilitate the progression of the California Earthquake Early Warning System (CEEWS) from a "test bed" or "beta" environment to widespread use, California passed Senate Bill 438, which was signed into law in 2016 as Government Code Sections 8587.11 and 8587.12. SB 438 directed Cal OES to develop CEEWS through a public-private partnership, to establish the California EEW Program (CEEWP), and establish a governance structure and Advisory Board to support the development of CEEWS.[15] Cal OES established CEEWP to manage contracts, develop a strategic business plan to identify funding

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[11] The system is intended to provide alerts to the entire west coast of the United States, and it is being developed in partnership with the University of Washington and the University of Oregon, in addition to the California based partners listed above.

[12] "California Earthquake Early Warning System Project Implementation Framework," (For Official Use Only), Contributors: Cal OES, FEMA, State of California Seismic Safety Commission, CGS, USGS, Caltech Seismological Laboratory, Seismic Warning Systems, UC Berkeley Seismological Laboratory, May 2016.

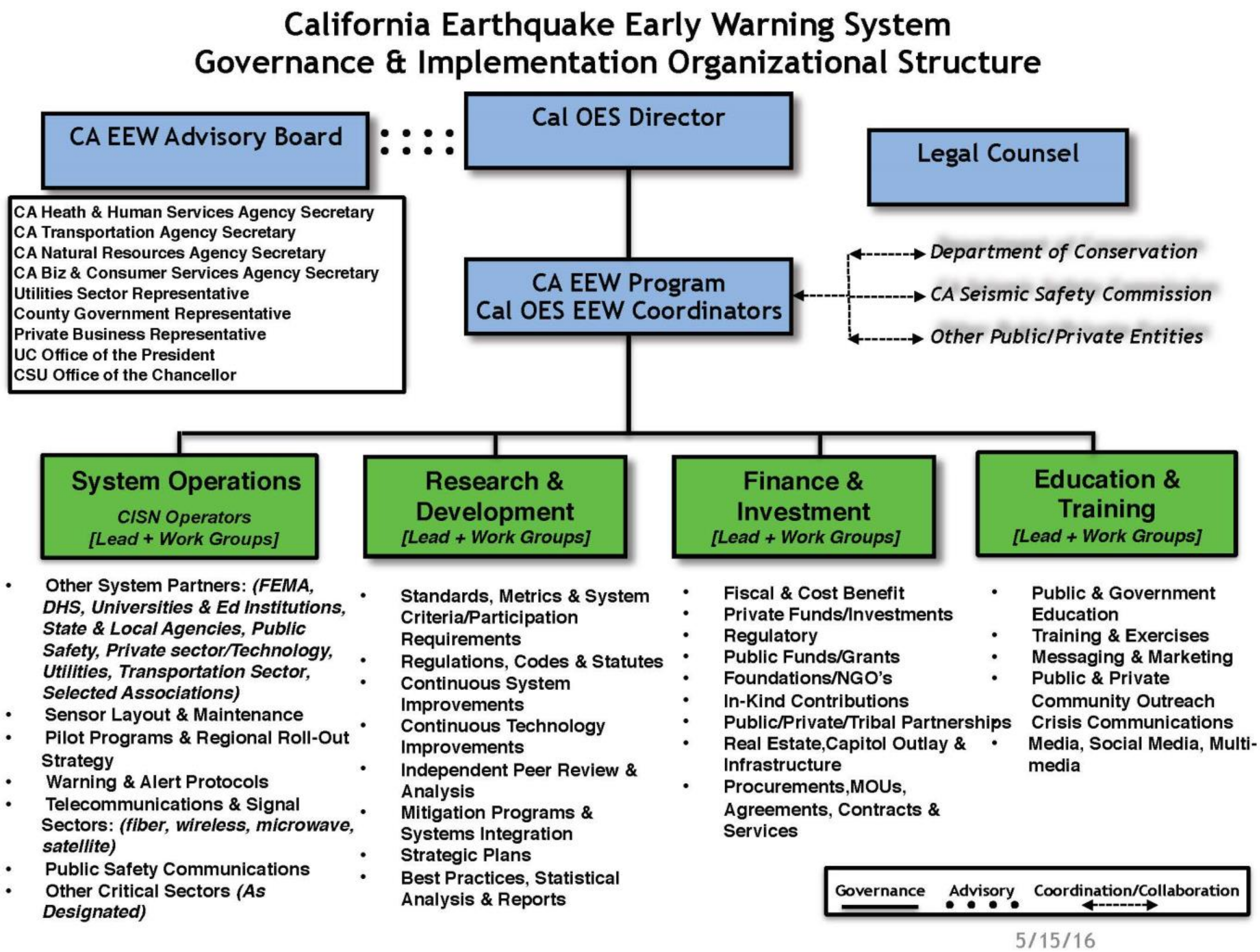
[13] Financing for remaining stations is contingent on the Legislature's approval of the Governor's proposal for an additional $15.75 million for EEW.

[14] Beta users receive the signal and provide feedback about its performance but do not take specific actions within their organizations in response to notification of impending ground shaking. A more limited group of pilot users have entered into agreements with the USGS that allow them to utilize the signal within their organizations.

[15] The CEEWS is comprised of seismic sensors, data processing centers, and end-user distribution mechanisms to warn recipients prior to shaking once an earthquake begins. The CEEWP includes the Advisory Board and four Cal OES functional areas: system operations, education and training, research and development, and finance.

streams, support system build-out, and secure staff to meet the needs of communications, outreach, training and education, project management, and research and development. Cal OES manages the Governance and Implementation Structure, which includes the California EEW Advisory Board, legal support, and California EEW Program as shown in Figure 2. The Advisory Board consists of state agency secretaries, a county representative, a business representative, and a utilities representative, and will advise the Cal OES Director on all matters related to the implementation and long-term operation of the CEEWP.

FIGURE 2: CEEWS GOVERNANCE STRUCTURE



Cal OES's efforts to facilitate the development of CEEWS include administering four contracts worth $6.4 million in state funds for the installation of 183 seismic sensors statewide as well as $1.5 million annually in service agreements with USGS, CGS, UC Berkeley, and Caltech for operations, maintenance, and services of the existing seismic network used for monitoring earthquakes called the California Integrated Seismic Network (CISN). CISN was established in 2000 by these core institutions with a

Memorandum of Agreement.[16] The governance structure consists of a Steering Committee that oversees CISN projects and an external Advisory Committee that represents the interests of structural engineers, seismologists, emergency managers, industry, government, and utilities. A Program Management Group (PMG) consisting of representatives from the core organizations manages the day to day activities, a Standards Committee meets regularly to coordinate technical design and implementation issues, and a Strong Motion Working Group handles topics pertaining to strong-motion data.[17]

Cal OES is also developing a site scouting protocol for sensor stations and completed site scouting surveys focusing on state land, and is working closely with system partners to navigate the state and federal environmental reviews and land use agreements in order to facilitate the installation of additional stations as quickly as possible. Cal OES is also collaborating with the University of California Office of the President, California State University Chancellor's Office, California Department of Parks and Recreation, California Department of Forestry and Fire Protection, and California Department of Transportation (Caltrans) to facilitate the installation of more than 50 new stations on state properties providing cost savings and secure station locations.

Although much of the system has already been completed, several important steps remain before the system is capable of providing accurate and reliable warnings to all Californians. Approximately 500 additional seismic stations still need to be constructed and integrated into network (although funding has been identified for these additional stations, including through the 2018-19 Governor's Budget proposal), telemetry (the mechanism for transmitting the signals back to a central processing site) still needs to be developed or upgraded in many areas, and the algorithm that produces the signal is still being refined by the scientists responsible for developing it. Equally important, a funding mechanism still needs to be identified to pay for the remaining system investments and ongoing operations and maintenance costs.

2.2 What is the "Business Plan"?

In order to advance the state's EEW system, Cal OES sought to develop a business plan to identify the tasks that need to be accomplished in order to bring EEW "on-line." Specifically, the business plan contains the following elements:

1. *Budget.* One-time costs for capital equipment, such as new and upgraded seismic stations as well as ongoing costs for operations and maintenance of the system are presented below.

2. *Future Funding Source Identification*. In order to complete and operate the system, additional resources (as identified in the budget) are required. This business plan identifies specific funding sources.

[16] Specifically, the core institutions are the California Geological Survey, Caltech Seismological Laboratory, UC Berkeley Seismological Laboratory, USGS Menlo Park, USGS Pasadena, and the California Governor's Office of Emergency Services.
[17] See the CISN website for further information: https://www.cisn.org/index.html

3. *Timeline and project plan*. In order to make the EEW system fully operational, several important tasks must be performed and milestones achieved. This business plan identifies these key tasks and milestones and indicates which organizations are responsible for each.

4. *Risk assessment*. As with any large project of this nature, several risks to completion exist. The key risks, as well as suggested mitigation strategies, are identified and presented below.

3 EARTHQUAKE EARLY WARNING BUDGET

The California Early Warning System builds on an existing seismic network used for monitoring earthquakes called the California Integrated Seismic Network (CISN).[18] Where station density allows, the system currently produces a ShakeMap within minutes of an earthquake to provide situational awareness for emergency personnel. CISN is funded by the state through CGS and Cal OES, by the federal government through the USGS, and by financial or in-kind contributions from the participating organizations.[19]

The level of performance required for CISN to provide situational awareness is different than the level of performance necessary for earthquake early warning. Additional capital investment in recent years began the process of developing early warning capability for the entire west coast, including $10.2 million in annual federal funding through USGS, a $6.5 million grant from the Gordon and Betty Moore Foundation, and a one-time $5.6 million contribution from the Federal Emergency Management Agency.[20] In 2012, partners began testing an alert product, referred to as ShakeAlert, by sending real-time notifications to a small group of “beta” users. In 2017, California contributed an additional $10 million toward developing California’s Earthquake Early Warning System, $6.4 million of which has been invested in additional seismic stations. Additional investments are needed, however, to transform the current beta system into one capable of warning 40 million Californians about impending strong shaking.

The California Earthquake Early Warning System (CEEWS) builds on the infrastructure of CISN to deliver an alert of an earthquake seconds prior to ground shaking. The network partners that operate CISN (Cal OES, CGS, USGS, UC Berkeley Seismological Laboratory, and Caltech Seismological Laboratory) will also operate CEEWS.

[18] See www.cisn.org for more information.

[19] The core organizations that operate CISN include USGS Menlo Park, USGS Pasadena, Caltech Seismological Laboratory, UC Berkeley Seismological Laboratory, and California Geological Survey. A few additional universities and organizations with independent regional networks also contribute to California earthquake monitoring including University of Nevada, Reno, the California Department of Water Resources, and Pacific Gas & Electric.

[20] See www.shakealert.org for more information.

3.1 Additional Funding Needed for Early Warning Capability

In order to advance earthquake early warning from the current “beta mode” to a production mode, funding is still needed to install seismic stations, upgrade GPS stations, and improve the telemetry network used to transmit data, as shown in Figure 3.

FIGURE 3: UNFUNDED SYSTEM COMPONENTS

283 seismic stations
294 GPS stations
33 primary and secondary telemetry sites

3.1.1 Seismic and GPS Stations

Seismic and GPS stations are the building blocks of the early warning network. Seismic sensors detect ground velocity and acceleration whereas real-time GPS instruments detect ground displacement necessary for accurately reporting very large earthquakes. Computers at regional central processing centers use this information to rapidly characterize the magnitude and intensity of an earthquake and issue a warning of expected ground-shaking based on the recipient’s location. USGS and university partners have determined that a fully functioning early warning system in California requires 1,115 seismic stations, 283 of which are expected to be funded by the Governor’s proposal of $15.75 million for EEW. Additional funds are also needed to upgrade 294 of 570 GPS stations expected to contribute to the early warning system to enable real-time data transmittal.

3.1.2 Telemetry

Telemetry is the name for the process of transmitting data from the seismic and GPS stations back to the central processing facility. An early warning alert system depends on a reliable telemetry network, including a diversity of modes (such as microwave, cell, Internet, and fiber cable) and redundancy (meaning parallel pathways of more than one mode). Diversity and redundancy reduce the potential for network failure or signal delay during an earthquake.

Currently, the telemetry network relies extensively on cell modems and the Internet, making it vulnerable to failure in the event of an earthquake. Further, many geographic areas have insufficient redundancy, which can result in a delayed alert of up to 12 seconds in some areas if one mode is out of service during an earthquake. Both of these challenges could potentially be reduced by relying on the secure state public safety microwave system which covers many geographic areas that may not have sufficient cell phone coverage. This system already exists broadly throughout the state and has the potential to provide coverage without the added time and expense needed to build new infrastructure.

USGS, the university partners, and Cal OES have developed a telemetry plan that, when implemented, will guard against missed and delayed alerts. This plan relies to the extent possible on the existing state microwave network. In areas where neither the state network nor the USGS network reach, additional microwave towers need to be installed. The plan anticipates the need for only one additional primary microwave tower. Most (approximately 32) of the additional microwave sites will be secondary sites, meaning they have a shorter range of connection, more vulnerabilities, and are cheaper to build.[21] The telemetry plan has only recently been developed, and it may well change based on further analysis and refinement. As a result, there is still some uncertainty about the extent of capital costs for this component of the system. (See Appendix D: Capital and Ongoing Costs for Backbone Telemetry for further description of the telemetry plan.)

3.1.3 Method for Estimating Unfunded Capital Costs

Estimates were developed for unfunded capital costs in consultation with Cal OES, CGS, USGS, UC Berkeley, and Caltech. These network partners have extensive experience installing stations and telemetry networks in California. A model was developed to estimate capital costs for each type of seismic station (such as strong motion only or with broadband, outdoor or indoor) based on current pricing, contracts, and partner input. For each station type, the estimated station cost was multiplied by the number of unfunded stations, and the results summed for a total estimated cost of installing the additional seismic stations.[22] (See Appendix A: Capital Costs of Seismic Stations for a more detailed discussion of methods used.)

The methodology to estimate capital costs for upgrading GPS stations similarly accommodated variation in station characteristics and utilized current pricing, contracts, and partner input. Supplies and equipment for connecting a single station to the rest of the telemetry network, or "last mile" telemetry, were included in the capital budget for both GPS and seismic stations. (See Appendix C: Capital and Ongoing Costs of GPS Stations for a more detailed discussion of methods used.)[23]

3.2 Outreach and Education Costs for California Earthquake Early Warning

In addition to capital costs, initial and ongoing costs for a major public awareness campaign were included in the budget based on interviews with experienced managers of public information campaigns in government agencies and public relations firms. Strategists recommended that the public campaign for EEW include a more expensive initial campaign to introduce early warning to the public in

[21] See Appendix D: Capital and Ongoing Costs for Backbone Telemetry for a discussion of additional capital and one-time telemetry costs included in the budget estimate.

[22] An alternative method of basing cost estimates on the amount spent in Japan and Mexico to build and maintain earthquake early warning systems was considered. This alternative was not used to estimate costs in California because factors that determines spending in Japan and Mexico differ markedly from California, such as labor costs, geology, and land use constraints.

[23] “Last mile” telemetry describes the last connection between a station and the rest of the telemetry network that leads to the central processing sites. “Backbone” telemetry describes data transmittal along a network of nodes with the exception of the last “mile,” or whatever the distance may be, between a network node and an individual station.

addition to a smaller, annual campaign for purposes of maintaining awareness with the public (the costs for which were included in the estimate of ongoing costs discussed below).

The initial public awareness campaign will introduce the early warning system to the public, teach appropriate responses depending on circumstances (e.g., in a house, wheel chair, or car, etc.) and reach people with access and functional needs (AFN), such as those who have physical, developmental or intellectual disabilities, chronic conditions or injuries, limited English proficiency, low incomes, transportation challenges, and homelessness, as well as older adults and children. Further, the campaign will educate Californians on the limitations of the system to manage expectations and maintain confidence in the system in the event of delayed, missed, or false alerts. By educating the public, the campaign can also catalyze demand for organizations to invest in applications of the alert.

3.2.1 Method for Estimating Unfunded One-Time Costs

The cost estimate for this education and outreach campaign was developed based on comparable costs for other statewide public campaigns in California (e.g., H1N1 Flu Prevention, Save Our Water, and Flex Alert). Like the campaign for early warning, these other campaigns encouraged Californians, including those with access and functional needs (AFN), to change behaviors and respond in specific ways to an alert. The budget estimate provides for creative development and media buys for a similar statewide public campaign, such as television, radio, billboards, and social media. The recommended budget assumes outreach strategies used by experienced campaign managers in other public campaigns that leverage partnerships and earned media to generate additional media coverage will also be used for EEW. (See Appendix F: One-Time and Ongoing Outreach and Education Costs for a more detailed discussion of methods used to estimate costs.)

3.2.2 Existing Resources for Outreach and Education

Existing financial and in-kind resources support California's one-time public campaign. The ShakeAlert Joint Committee for Communication, Education, and Outreach (JCCEO) is working with many organizations to develop consistent national guidance and resources for the various earthquake regions nation-wide. JCCEO members and affiliates include Cal OES, CGS, USGS, Caltech, and UC Berkeley as well as others from Oregon, Washington, and British Columbia.[24] JCCEO members in California work closely with organizations piloting ShakeAlert and with those working to develop a pilot application of the signal. The guidance and resources from JCCEO include effective public messaging for earthquake early warning based on social science research, sector-specific guidance for employee training, and sector-specific lessons learned from pilot case studies. The JCCEO is supported by USGS, Cal OES, other state departments of emergency services, and university partners from California, Oregon, and

[24] Specifically, partners from regions outside of California include University of Oregon, Oregon Department of Geology and Mineral Industries, Oregon Office of Emergency Management, Washington Emergency Management Division, Washington Department, Emergency Management British Columbia, and Ocean Networks Canada.

Washington.[25] Although the division of responsibilities among the USGS and Cal OES has not been finally established, it is likely that Cal OES will be tasked with developing and implementing a public awareness campaign in California (based on the research and findings of the JCCEO). The statewide public awareness campaign is expected to cost approximately $9 million, $7 million of which is unfunded. Cal OES previously allocated $2 million in state funds to the CEEWS public awareness campaign in FY2016-17.[26]

3.3 Budget for Unfunded Capital and One-Time Costs for California EEW

Unfunded EEW capital and one-time costs include additional seismic stations, upgrades to GPS stations, improvements to the telemetry network, and a major public awareness campaign totaling $37.6 million. The budget does not include costs associated with receiving or utilizing the signal, such as cell phone upgrades, Public Address (PA) system upgrades, or automated valve closures, among others. The Governor's 2018-19 Budget proposes applying $15.75 million in general fund support to complete the build-out of the seismic stations.[27] In addition, the Federal budget for fiscal year 2018 provides an estimated $5.5 million which could be used to make necessary improvements to backbone telemetry and GPS stations.[28] Taking into account these potential funds as well as a set-aside for contingencies, $16.4 million in capital and one-time costs remain unfunded, as shown in Table 1.

[25] USGS financially supports 1 FTE that serves as the Chair of the JCCEO, .5 FTE in Washington, .5 FTE in Oregon, .5 FTE in Northern California (a UC Berkeley employee), and .5 FTE in Southern California (a Caltech employee).

[26] In the same year, Cal OES allocated state funds to the following outreach efforts: $40,000 for outreach to science teachers, $45,000 for communications equipment for the Cal OES Public Information Office to be used for California EEW outreach, and $38,000 for CSU Fullerton to identify gaps in research on outreach.

[27] This budget assumes the proposed general fund support would apply to capital costs.

[28] The Federal budget passed recently on March 23, 2018 and the USGS has 180 days to develop a spending plan for these additional one-time funds. Based on historical spending patterns, an estimated 55 percent of these EEW funds will apply toward EEW costs in California.

TABLE 1: ESTIMATE OF UNFUNDED CAPITAL AND ONE-TIME COSTS FOR CALIFORNIA EEW

CEEWS and CEEWP Components	Capital/One-Time Costs *(Millions)*
Seismic stations	$16.1
GPS stations	$3.8
Backbone telemetry	$5.9
Outreach and education	$6.9
Subtotal	*$32.6*
Contingencies	$4.9
Subtotal	*$37.6*
Potential State General Fund	($15.75)
FY2018 Federal Fund	($5.5)
TOTAL	***$16.4***

3.3.1 Contingencies

As with any large infrastructure project, costs for the EEW in California may be higher (or lower) than the numbers shown in Table 1. Unforeseen problems with identifying sites for seismic stations, construction, or equipment installation could all require additional resources to resolve. The budget for backbone telemetry is relatively less certain than the other components because telemetry planning is in a preliminary stage. As a result, the estimated contingency for backbone telemetry is relatively larger than that estimated for seismic stations (i.e., 10 percent for seismic and GPS stations and 50 percent for backbone telemetry).[29] The cost estimate for backbone telemetry is based on the telemetry plan developed by experts from the USGS and universities as part of a Telemetry Working Group organized by USGS.[30] This plan was modified based on consultation with Cal OES in order to make maximum use of the state microwave network.

3.4 Ongoing Costs for California EEW

In addition to one-time investments, California Earthquake Early Warning will require ongoing funding to successfully alert Californians of expected ground-shaking. Estimates for operating and maintaining the complete system with 1,115 seismic stations and 570 GPS stations include costs for personnel, permit renewal fees, and replacement of equipment.[31] Central sites that process the data from seismic and GPS stations will have ongoing costs for personnel and equipment replacement. In addition, the

[29] No contingency was added for the outreach and education cost estimate.

[30] The Telemetry Working Group organized by USGS consisted of staff members from the USGS, Caltech, Berkeley Seismological Laboratory, the Pacific Northwest Seismological Laboratory (University of Washington), the University of Oregon, and the Nevada Seismological Laboratory (University of Nevada).

[31] The 1,115 seismic stations that will contribute to early warning will be operated by CGS, USGS, UC Berkeley, and Caltech. The 570 GPS stations are mainly operated by USGS Pasadena (SCSN) and UNAVCO, a non-profit consortium of universities dedicated to geoscience research.

telemetry network involves ongoing costs for maintenance of microwave sites and data transmittal on partner or commercial networks.

Other ongoing programmatic costs include outreach and education, research and development, and program management. The ongoing outreach and education program includes Cal OES personnel for developing and managing California's outreach strategy (e.g., develop and deploy California-specific messaging, develop sector-specific business cases, manage the ad campaign, etc.). The program will also provide technical user support, which may take the form of a regional hands-on team, Help Desk, or online support as needed. The regional hands-on team, comprised of Cal OES personnel, may be necessary in the early years of rolling out the alert system to provide technical assistance that facilitates organizational participation in developing automated responses to the alert or training staff in how to react in the event of a warning. With increased participation, some of these resources may be diverted to telephone and internet support for a broader reach. In addition, a successful outreach program requires annual investment in a public campaign for research and media buys.

The budget for California's early warning program also includes research and development funding for Cal OES to develop improved ways to deliver the signal to users. For example, Cal OES staff have been researching the potential for users to receive the alert through an alternative mode ("datacasting") that may prove to be technologically simpler, more reliable, and more secure for some users than the current mode of distribution through the Internet. Specifically, Cal OES is currently developing a system that can receive the EEW signal and transmit it via excess television broadcasting bandwidth to a device available to consumers or businesses, thereby avoiding the use of the public Internet. This system, referred to as "datacasting," resembles a system currently used in Mexico, which employs a device called the "grillo" or "cricket," that sounds an alert to warn of an earthquake. The datacasting unit currently being developed would also have the capability to trigger other mechanical devices, such as elevators or automatic doors in firehouses.

The budget provides for Cal OES personnel to continue developing signal delivery by datacasting to hasten user adoption as well as exploring other challenges and opportunities that arise with signal delivery as the system matures. Cal OES is well positioned to capitalize on the concurrent development of FirstNet. FirstNet will be a single nationwide, interoperable LTE network dedicated to public safety communications giving first responders an unobstructed pathway for warnings. Finally, the budget covers Cal OES personnel to manage Earthquake Early Warning in California.

3.4.1 Method for Estimating California EEW Ongoing Costs

The method for estimating unfunded ongoing costs for seismic stations and central processing operations involves estimating the total costs of early warning in California and subtracting existing funds expected to continue. Data inputs were provided by the partners (CGS, USGS, UCB, and Caltech) based on experience operating the California Integrated Seismic Network (CISN) and ShakeAlert. Anticipated changes necessary to adapt a network that currently provides situational awareness but not earthquake early warning were included where possible. These adjustments include diversified and redundant real-time telemetry, additional personnel for maintaining stations and data quality, and regularly upgrading and replacing equipment. (See Appendix B: Ongoing Costs for Seismic Stations and Central Site Operations for a more detailed discussion of methods used.)

Estimates for ongoing outreach and education were based on interviews with Cal OES personnel, JCCEO members, state government agencies in California and Florida, and public relations firms in California as well as ongoing funding for analogous public campaigns (e.g., Save Our Water, Slow for the Cone Zone, and severe weather warning in Florida). Estimated costs for Cal OES personnel for outreach, research and development, and program management were based on Cal OES current salaries and benefits. (See Appendix F: One-Time and Ongoing Outreach and Education Costs for a more detailed discussion of ongoing costs.)

3.5 Budget for California EEW Unfunded Ongoing Costs

The estimate of unfunded ongoing costs presented in Table 2 includes annual costs for seismic stations, central processing operations, backbone telemetry, and other program costs (in current dollars). The estimate presented reflects incremental costs net of ongoing funding provided by the federal and state governments. Existing funds applicable to the California EEW system that are expected to continue include approximately 80 percent of the $8 million in federal CISN funds, 75 percent of $1.5 million in state CISN funds, and 68 percent of $12.9 million in federal EEW funds.[32] Accounting for existing funds and contingencies, unfunded ongoing costs total $16.4 million annually.[33]

[32] Blue Sky Consulting Group estimates the remaining 32 percent of the federal EEW funds will go toward the Pacific seismic region in Oregon and Washington based on historical spending patterns and conversations with USGS. The Federal budget passed on March 23, 2018 increased USGS annual funding from $10.2 million to $12.9 million. USGS has 180 days to develop a spending plan. Based on information provided by USGS and the historical allocation of non-central site funds, the Blue Sky Consulting Group anticipates USGS will allocate $1 million of the marginal increase toward additional programming costs and 55 percent of the remaining marginal difference to California. In total, 68 percent of the $12.9 million is expected to apply to the costs included in the business plan for California and central site operations.

[33] Debt service, if needed to fund one-time costs, would raise the estimated ongoing funding amount.

TABLE 2: ESTIMATE OF UNFUNDED ONGOING CALIFORNIA EEW COSTS

CEEWS and CEEWP Components	Ongoing Costs *(Millions)*
Seismic stations, central sites, last mile telemetry	$20.1
GPS stations	$4.5
Backbone telemetry	$2.9
Cal OES Outreach and education	$3.5
Cal OES Research and development	$.3
Cal OES Program management	$.4
Subtotal	*$31.7*
Contingencies	$3.2
Subtotal	*$34.9*
Existing GPS funding	($2.2)
Existing funding for seismic stations & central sites	($16.3)
TOTAL	***$16.4***

3.5.1 Contingencies and Inflation

Note that any ongoing revenue source implemented to fund EEW will require an escalator to cover both increases due to inflation as well as any unfunded amounts to the extent existing federal and state funding sources do not increase over time to keep pace with inflation. In addition, actual costs could be higher (or lower) than estimated for many of the same reasons discussed in the section above on capital costs. Though network partners have extensive experience operating CISN for situational awareness, there is some uncertainty surrounding anticipated costs, particularly with regard to maintaining data quality and IT security. A 10 percent contingency was applied to ongoing costs for seismic and GPS stations and a 25 percent contingency was applied to the ongoing costs for backbone telemetry.[34]

In addition to uncertainty surrounding some cost estimates, programmatic decisions with respect to the desired level of system resiliency and accuracy or the extent of public awareness and education initiatives can influence costs. For example, judgements that informed the budget estimate regarding trade-offs between cost savings and telemetry components or IT security could change over time with experience operating the early warning system. Or, experience with educating Californians about EEW may generate different strategies than those imagined for this cost estimate.

4 FINANCING PLAN

While technology provides the foundation for earthquake early warning in California, developing a mechanism to pay for the system is equally important.

[34] No contingency was added for the outreach and education cost estimate.

In order to develop a financing plan – including the identification of a funding source for both one-time and ongoing costs – a series of criteria or characteristics that a financing source for California Earthquake Early Warning should have were developed:

1. *Capable of generating approximately $16.4 million per year.* An ongoing, stable revenue source must be identified to finance ongoing operations and maintenance costs (as well as debt service on any portion of the capital costs that is financed).

2. *Grows over time as program costs increase.* Costs for the system will likely increase in the future as a result of inflation, changes in technology, and aging of existing equipment.

3. *Establishes a nexus between costs and beneficiaries of the system.* While access to the signal should not be restricted to just those who can pay, the costs for the system should nevertheless be borne by those who benefit (i.e., a nexus, or connection, is established between beneficiaries and payers).

4. *Is inexpensive and efficient to collect.* Administration costs for a new revenue source can consume a significant fraction of the revenues collected. "Piggybacking" on an existing collection mechanism rather than creating a new revenue collection infrastructure can help to keep costs low.

5. *Provides a dedicated, stable source of funding.* Any source that is subject to fluctuations year to year, whether due to changing economic conditions or changing legislative priorities, could jeopardize the ability of the system to produce warnings when needed.

4.1 Possible Financing Sources

The figure below identifies several of the options that could be considered to fund CEEWP.

FIGURE 4: POTENTIAL FINANCING SOURCES

Criteria	Pros	Cons
Electric Utility Users Charge	Provides a dedicated, stable revenue source. Can be added to existing bills with little administration cost.	Could incur (minor) additional administration costs if other users (e.g., gas customers) are also charged. Potential opposition from utilities.
Natural Gas Users Charge	Provides a dedicated, stable revenue source. Can be added to existing bills with little administration cost.	Could incur (minor) additional administration costs if other users (e.g., electricity customers) are charged. Potential opposition from utilities.
Transportation Providers Charge	Provides a dedicated, stable revenue source. Can be charged to regulated transportation providers (and likely passed on to riders of regional transit systems, Caltrain and High Speed Rail) with little administration cost.	Could incur (minor) additional administration costs if other users (e.g., electricity customers) are charged. Potential opposition from transportation providers.
Cell Phone Connection Charge	Clear nexus between payers and beneficiaries. Can be added to existing bills with little administration cost. Provides a dedicated, stable revenue source.	Potential opposition from cell carriers.
Income Tax Surcharge	Provides a dedicated, stable revenue source. Administration costs would be relatively low if charge added to existing tax returns.	Limited nexus between payers and beneficiaries.
Charge on EEW technology and service providers	Establishes a nexus between benefits and (certain) beneficiaries of the system. Avoids the need to increase taxes/charges paid directly by individual Californians.	Revenues could fluctuate based on number and type of technology and service providers.
Foundation and federal grants	Avoids the need to increase taxes/charges imposed on Californians.	Does not provide a stable, dedicated revenue source.
Charge on industries that benefit from EEW	Avoids the need to increase taxes/charges imposed on Californians.	Would require multiple, new and costly revenue collection mechanisms.
State General Fund	Establishes a nexus with users and beneficiaries to the extent entire state benefits from EEW. No new revenue collection costs.	Would require annual appropriations and so may not provide a stable, dedicated revenue source.

4.2 Financing One-Time and Capital Costs

As described in the previous section on program costs, approximately $37.6 million in one-time costs remains to fully implement earthquake early warning in California. In his 2018-19 Budget, Governor

Brown proposed to provide an additional $15.75 million for EEW. To the extent that the Governor's proposal is implemented, the remaining approximately $16.4 million in EEW one-time costs could be financed on a pay-as-you-go basis as long as a dedicated ongoing revenue stream for EEW is implemented. To the extent the Governor's proposal is not included in the final budget, alternatives to pay-as-you-go financing – likely a revenue bond – would need to be considered.

4.2.1 Using an Ongoing EEW Revenue Source for One-Time Costs

During the early years of EEW implementation, several factors will result in lower than budgeted O&M costs. As a result, the additional revenues during this initial period could be dedicated to paying for one-time costs until they are needed to pay for O&M.

First, because the technology for cell phone deployment of EEW will likely not be fully available for several years, the need for a consumer outreach and education campaign will not be as great during the early years.[35] In addition, because only a portion of the needed seismic stations have been installed or upgraded to date, and much of the needed telemetry has not been designed let alone implemented, ongoing O&M costs for station maintenance and telemetry will be lower than the full budget estimate presented above during the first several years of program operations. Therefore, the savings associated with these ongoing costs could be applied to one-time costs. As the ongoing costs increase during the first several years of program operations, capital or one-time expenditures can be decreased.

The following is an illustration of how an ongoing dedicated EEW financing stream could be used to finance one-time capital costs.

[35] Discussions among Cal OES, USGS, FEMA, and telecommunication firms have advanced the notion that sending the ShakeAlert through the existing Wireless Emergency Alerts could be technically feasible as early as fall of 2018.

TABLE 3: UTILIZING SURPLUS O&M FUNDS FOR ONE-TIME COSTS
(in millions)

Cost Category	Annual Budget	2019 Percent Not Needed	2019 Funds Available	2020 Percent Not Needed	2020 Funds Available	2021 Percent Not Needed	2021 Funds Available	2022 Percent Not Needed	2022 Funds Available
Seismic stations	$3.8	35%	$1.3	10%	$.4	0%	$.	0%	$0
GPS stations	$2.3	85%	$1.9	50%	$1.1	25%	$.6	0%	$0
Backbone telemetry	$2.9	85%	$2.5	50%	$1.4	40%	$1.2	25%	$.7
Outreach and education	$3.5	58%	$2.	0%	$.	0%	$0	0%	$0
Research & Development	$.3	0%	$0	0%	$0	0%	$0	0%	$0
Program management	$.4	0%	$0	0%	$0	0%	$0	0%	$0
Contingency for O&M	$3.2	50%	$1.6	25%	$.8	25%	$.8	0%	$.
Annual Total	*$16.4*		*$9.4*		*$3.8*		*$2.5*		*$.7*
Cumulative Total Available			***$9.4***		***$13.1***		***$15.7***		***$16.4***

As shown in Table 3 above, approximately $16.4 million is potentially available to pay for one-time EEW costs using a stable dedicated EEW funding source. The table makes informed assumptions about the amount of funding needed each year and the remaining funding available for one-time costs. For example, if 65 percent of the seismic stations are built by 2019, then 35 percent of the annual funding for seismic stations O&M, or $1.3 million, is available for capital and one-time costs. The unused portion of the annually generated revenue in each of the first four years sums to approximately $16.4 million by 2022. These unused funds can be spent to further build the system as they become available.

4.2.2 Using a Revenue Bond to Finance EEW Capital Costs

Paying for system improvements as-and-when funds are available (pay-as-you-go) has the advantage of avoiding interest expenses, but – to the extent the Governor's proposal is not adopted – could require waiting many years before the system can be completed.

The alternatives to this sort of pay-as-you-go financing include additional state general funds, federal funds, grants, or borrowing. Relying on added state general funds or additional federal funds to pay these costs comes with substantial uncertainty. Although the amounts needed are relatively small compared with the size of the state and federal budgets, funding for EEW has been somewhat unpredictable in the past. State funding for EEW has primarily come in the form of a one-time appropriation of $10 million; while it is possible that additional appropriations of a similar order of magnitude will be forthcoming, there is no guarantee that this will be the case. Therefore, relying on this funding mechanism – particularly if the current Governor's proposal is rejected – could mean waiting years to complete the system (to the extent that funds are forthcoming at some point). Meanwhile, federal funding for EEW has been more consistent (with annual appropriations of about $10 million for the past several years), but it is also subject to uncertainty. For example, the Trump Administration recently proposed removing EEW funding from the federal budget entirely (although funding was ultimately restored by the Congress). Therefore, relying on federal funding to pay for the capital costs is equally uncertain and could result in indefinite delays in implementing the system.

The other option for use of pay-as-you-go is to raise more from a dedicated funding source than is needed to pay for the ongoing O&M costs, and use the surplus to pay for one-time capital costs. The primary disadvantage of this method is that it requires imposing a new tax at a somewhat higher rate than is necessary to pay for ongoing expenses. And, while the tax rate could ultimately be reduced once the one-time costs have been paid for, this extra higher tax rate has the potential to generate additional political opposition and could ultimately jeopardize the success of the additional revenue source in the Legislature.

Another option is to use a revenue bond, which is a mechanism for borrowing funds to pay for one-time costs using an ongoing revenue stream as a repayment vehicle. With a revenue bond, funds from an ongoing revenue source are pledged to pay the debt service on a bond. Proceeds from the bond can then be used to pay upfront costs and repaid over time. Because the debt service is paid for with a dedicated revenue source (rather than the general fund) revenue bonds can be approved by the Legislature without the need for a voter approval of a ballot measure (as required with general obligation bonds). Revenue bonds can be issued for varying lengths of time, as long as the pledged revenue source is available for the entire period of the debt service repayment.

In the case of EEW, a portion of capital costs could be paid on a pay-as-you-go basis, with the remaining amount paid for with a revenue bond. This would allow the system to get up and running more quickly than would an approach that relied exclusively on pay-as-you-go financing, but would also be less expensive in terms of debt service costs relative to an approach that relied exclusively on borrowing.

In order to finance one-time costs with a revenue bond, the Legislature would need to explicitly authorize the use of the proceeds from any dedicated EEW financing source for debt service. With this authorization, the State Treasurer could issue a bond and make the proceeds available to Cal OES for purposes of financing EEW costs.

The authority to issue a revenue bond could be included in the authorizing legislation for a dedicated EEW financing sources, but would only be utilized to the extent other revenue sources were not sufficient to cover the one-time costs.

4.3 Financing Plan Recommendation: Summary

The following is a summary of the recommended financing plan:

1. Enact stable, ongoing funding sources for EEW, effective January 1, 2019 (specific charge to be determined based on amount needed to generate $16.4 million annually).
2. Include in authorizing legislation authority for Cal OES to adjust amount of whatever charge is adopted (within a specified range) based on changes in program costs.

3. Include in authorizing legislation authority to issue revenue bonds (if needed) to be guaranteed by the revenue source(s) adopted.

4. Authorize Cal OES to determine amount of any needed revenue bond financing (up to a specified cap) based on program costs.

5 TIMELINE AND TASKS

Determining the status of earthquake early warning in California is a bit like the old parable about the blind men describing an elephant: it depends on where you "look." In many respects, earthquake early warning is well developed. Extensive sensor networks exist in many parts of the state, an algorithm has been developed which can generate warnings of impending earthquakes, and both web and smart phone-based applications have been developed to communicate warnings to users located throughout the state. In spite of this important progress, more remains to be done. Approximately half of the needed seismic stations have yet to be built (although many of these additional stations are currently in the process of being constructed and funding has been identified for the remaining stations through the 2018-19 Governor's Budget proposal), a robust and reliable telemetry system is yet to be developed, the computer algorithm for determining whether an earthquake is likely to occur is still being refined to avoid false and missed alerts, GPS data have yet to be incorporated into the algorithm, and the technology needed to efficiently notify millions of end users through their smart phones is still being developed by handset manufacturers and telecommunications providers.

These two divergent perspectives are an important element of the context surrounding deployment of earthquake early warning in California, with some individuals and the organizations they represent advocating for a rapid deployment of the system in spite of its current limitations, while others propose a more deliberate pace that will allow for many of the system's perceived shortcomings to be addressed prior to launch. (The subsequent section of this report, "Risk Assessment" beginning on page 41, presents a more detailed discussion of the arguments for each side in this "debate.")

5.1 Roles and Responsibilities

This context is particularly important given the decentralized nature of earthquake early warning management in California, in which both state and federal agencies, as well university partners within and outside of California, have some responsibility for the system.

Cal OES is the state agency with overall responsibility for earthquake early warning in California. However, most of the seismic stations and key components of the telemetry network are controlled by the USGS and the university partners, which manage the technical functionality of the system, including the flow of seismic data from the stations and the algorithm that develops the earthquake alert warning itself. Although the state has provided funding for the system, both through support for the CISN as well as through a recent $10 million state general fund appropriation, most of the stations as well as the computing hardware and key components of the telemetry network are owned or controlled by the USGS and the university partners. Ultimately, the USGS controls significant parts of the system, managing the flow of seismic data from the stations and controlling the algorithm which develops the earthquake alert warning itself. In addition, the USGS, in conjunction with the university partners, has historically had primary responsibility for developing the public outreach and education messaging for the system and conducting outreach to potential beta testers and pilot users.

During the past several years, however, the state's interest in further and more rapid development of the system has increased. This interest has been manifested through the creation of this business plan, a State General Fund contribution of $10 million in 2016-17, a second contribution of $15.75 million proposed as part of the 2018-19 Governor's Budget, and development of a more reliable mechanism for distributing the earthquake early warning message to individuals and institutions through unused television broadcast spectrum (known as datacasting), among other activities.

Although the jointly developed Implementation Framework provides an outline for the management of the EEW program, there is no formal agreement between the various parties to the system (i.e., Cal OES, the USGS, and the university partners). As a result, management of the entire project has at times been somewhat uncoordinated. For example, there is no clear consensus as to which entity, the USGS or Cal OES, has responsibility for communicating with the public around earthquake early warning (including developing and paying for a public outreach and education campaign).

Perhaps even more importantly, there is no mechanism for determining who will decide when and how to launch the system to the public, what that initial rollout would consist of, who would inform the public or respond to questions about how to access the signal, and many other important details about how and when the system will be launched. Both the USGS and Cal OES appear to have a strong interest in these issues, but not, apparently, a decision-making process to resolve them.

Ultimately, if the State of California is going to make a sustained, substantial investment in EEW as envisioned by this business plan, it will want to ensure that with that investment comes with the necessary decision-making authority and accountability mechanisms to ensure that its investment is consistent with the priorities of the Legislature and administration. In addition to the recommendations with respect to development of a financing plan, this report recommends that the Cal OES and the USGS negotiate a memorandum of understanding (MOU) that clearly delineates the roles and responsibilities of each entity with respect to earthquake early warning. Such a negotiated agreement should be in place prior to approval by Cal OES to expend future funds from a dedicated EEW funding source.

One logical division of labor would be for the USGS to take responsibility for the scientific aspects of the system: collecting and processing seismic data, developing the alert algorithm, and determining whether it is scientifically appropriate to issue an alert based on the available data. Cal OES, in turn, would have responsibility for distributing the signal, assisting users in obtaining access to the signal, and communicating with and educating the public about earthquake early warning. Many other arrangements are also possible, and there are also myriad details which would need to be resolved regardless of the broad contours agreed to. However, the important, fundamental element is the need for immediate negotiations with respect to the division of labor that result in a clear, written MOU codifying whatever is agreed to.

5.1.1 Other Roles and Responsibilities

For California to fully realize the benefits of earthquake early warning, entities other than the Cal OES, USGS, and the university partners must play a role. Other public sector entities as well as private sector firms are responsible for developing applications of the signal in order to make use of the alert. For example, cell phone companies are investing resources to update cell phone technology to rapidly deliver the alert to all cell phone devices. Likewise, Bay Area Rapid Transit (BART) has been investing resources into developing an automated mechanism to slow trains in response to an alert and school districts are expected to finance augmentations to PA systems in order to use the signal to alert students and teachers in classrooms to drop, cover, and hold on.

Not all organizations have in-house expertise necessary to make use of the signal. Some private companies referred to as “third party vendors” are currently developing technical assistance services to aid users, such as automating school PA systems in response to an alert or helping a company with sensitive machinery develop a custom automated response to the alert. USGS has supported the development of these services by granting early access to the signal in the form of Cooperative Research and Development agreements with third party vendors so that technical assistance will be available in the private sector as the system is rolled out.

Local departments of emergency management will also play important roles in implementing earthquake early warning in California. These offices will support and augment the statewide public awareness campaign and help local residents understand how to respond to an alert.

5.1.2 Limited Public Rollout

In addition to the adoption of an EEW financing source and the clear delineation of responsibilities among the USGS and Cal OES, the contours of the limited public rollout comprise perhaps the most critical element of the EEW business plan. While all parties appear to agree that some sort of more public rollout of the system is appropriate by the end of 2018, there does not appear to be a consensus with respect to what, specifically, that rollout should consist of. Ultimately, the contours of the rollout will be determined by the state of system readiness – including the availability of staffing resources to assist in providing access to the public and providing technical support – at the time of the rollout. However, because the rollout represents such an important opportunity to both provide the public with the benefits of and generate increased awareness for the system, it is important to make careful preparations that will result in the widest possible deployment of the system at the time of rollout.

Although the name given to the rollout scheduled for the end of 2018 is the limited *public* rollout, full deployment of the system to the general public is still likely several years away. The technology needed to provide individual Californians with a warning on their smart phones is still being refined and, even more importantly, a public outreach and education campaign has not yet been fully developed let alone launched. Therefore, any rollout in 2018 will likely only be available for institutional users such as schools, fire stations, hospitals, transportation providers, manufacturers, and other private sector entities.

The question that confronts EEW managers, then, is how broadly to make available the system's signal to institutional users at the time of the rollout in December 2018. One approach would be to only make the EEW signal available to a select group of users and carefully monitor their use of the signal in order to improve the subsequent rollout to a broader group. The alternative, however, would be to provide the signal to the largest possible group of institutional users at the time of the rollout in December, thereby maximizing the public protection benefits of the system.

This latter strategy has several advantages. First, and most importantly, it makes the benefits of EEW available to the public as soon as practically possible. A major earthquake could strike at any time, and Californians should not be denied the benefits of the system for any longer than absolutely necessary. Second, the rollout offers a unique opportunity to gain the attention of potential users. There will likely be news stories, public statements, and interviews surrounding the rollout launch, all of which will provide an important opportunity to inform the public. Furthermore, this approach eliminates the possibility of public frustration due to selective lack of access. Considerations of the costs of false or missed alerts would be left in the hands of individual users rather than made on their behalf. Restricting use by pursuing a more limited public rollout in order to protect potential system users does not take into consideration the factors that individual users would incorporate into their decision making. Users with very high costs for false alerts, for example, could choose not to utilize the system until performance meets certain standards. However, users with a low cost of false alerts could take advantage of the system's benefits more quickly. For example, school children receiving a false alert could simply treat the alert like an earthquake preparedness drill. Or, if firehouse doors opened needlessly, they could simply and easily be reclosed. So too with elevator riders who might experience a temporary delay in the event that a false alert caused the elevator doors to open unnecessarily. For each of these classes of users and others, the costs of a false alert are quite low. Rather than making a judgement on behalf of users that the costs of false or missed alerts are too high, allowing these users to decide for themselves – after being properly informed of the risks – would allow for a much wider and more rapid deployment of the system, with the accompanying benefits it can offer.

For all of these reasons, a limited public roll out with the following characteristics is recommended:

1. Roll out the system no later than December 31, 2018. Accompany the rollout with as many public statements, media interviews, and other publicity as can be generated.

2. Allow any institutional user who wishes it to access the signal as long as that user agrees to the terms of an end user licensing agreement (EULA).[36]

3. Terms of the EULA would specify that (a) the user had been informed of the limitations of the system, (b) the user would not use the signal to inform the public of an impending earthquake but would instead use the signal only to alert properly trained workers or control machinery.[37]

4. Prepare for the public roll out by developing capacity to inform and assist users that will participate, including a help desk, phone bank, web site or other resources that can inform users about how to access the signal as well as its capabilities and limitations.

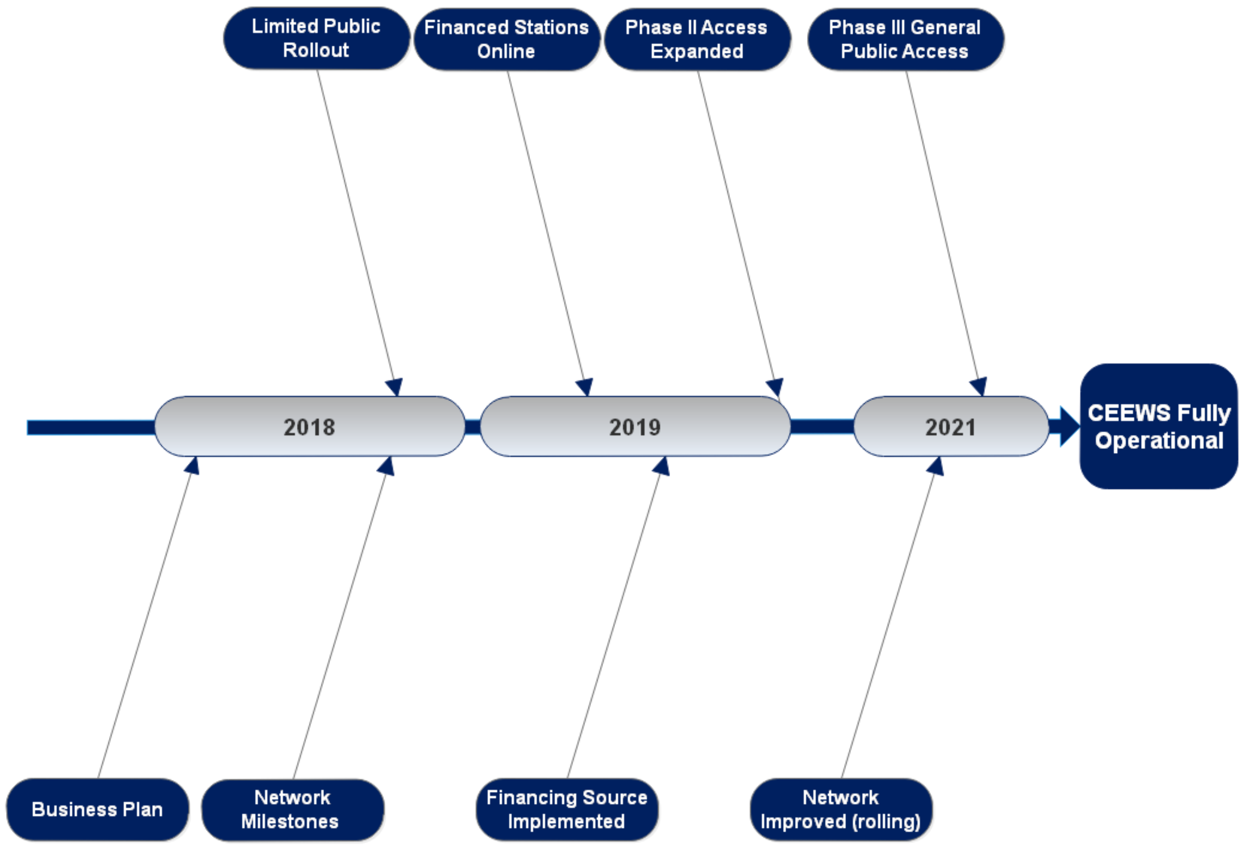
5.2 Timeline

Figure 5 on page 35 and Figure 6 on page 39 present a timeline of program milestones and a detailed list of program tasks and responsibilities, respectively. These two displays incorporate the important recommendations from this business plan and describe the key program milestones that will need to be met in order to successfully deploy the earthquake early warning system. Figure 5 organizes major milestones along the path to achieving the ultimate objective of full system deployment in a timeline. The tasks necessary to achieve each of the milestones in Figure 5 are more specifically identified in Figure 6 along with the entity or entities responsible for completing each task. Though the milestones are presented in the general order in which they need to be accomplished for progression toward the general public rollout, many of the tasks can and should be carried out simultaneously.

[36] Note that individual users could also be granted access to the signal as long as those users received sufficient information about the limitations of the system and training in how to respond to an alert.

[37] Once the technology exists to inform individual users via their smart phones and a public outreach and education campaign has been conducted, these terms should be modified to allow users to inform the public directly.

FIGURE 5: TIMELINE



Milestone 1: Business plan

The first milestone in both Figure 5 and Figure 6 is to submit this business plan to the Legislature; this plan contains important recommendations for financing the system and for a successful limited public rollout that puts the California earthquake early warning system on course to achieve full public rollout as quickly as possible.

Milestone 2: Limited public rollout

A successful limited public rollout of the EEW system will involve making the signal available to the broadest possible group of institutional users while simultaneously ensuring that those users are well informed about the capabilities and limitations of the system. In order to achieve a successful limited public rollout, Cal OES and USGS will need to agree to a delineation of roles and responsibilities as well as the terms of the rollout, which include characteristics of the target users (e.g., users from certain sectors or geographic areas or all interested organizations) and the requirements imposed upon the users to receive the signal (e.g., end user licensing agreement or a more involved application process).

During the period leading up to the limited public rollout, Cal OES must develop the capacity to provide technical assistance for users that will participate. To do so, Cal OES needs to estimate the expected number of participating users, which depends upon the terms of the limited public rollout. Technical assistance may involve a regional team of Cal OES staff to provide hands-on technical assistance to large organizations to facilitate participation and/or a Help Desk to provide less in depth technical assistance to a larger number of users.

Cal OES must also develop and implement a community, education, and outreach (CEO) plan specific to California. In order to maintain consistency with the regional effort for earthquake early warning on the entire west coast, the California-specific CEO plan will need to extend seamlessly from an agreed upon CEO plan for the entire West Coast developed in cooperation with USGS and other members of the Joint Committee for Communication, Education, and Outreach (JCCEO). The California-specific plan for the limited public rollout needs to target potential users in California and explain to others who may not be granted access to the system the reasons for exclusion. In addition, the outreach plan must effectively educate potential users on the limitations of the system so each can decide if the current level of risk for delayed, missed, or false alerts is worth the benefits of accessing the signal prior to system completion. Effective communication of the system limitations, messaging in response to a delayed, missed, or false alert, and expectations for system improvement over time will help to maintain confidence in the system until it reaches its full potential. Cal OES and USGS must work collaboratively to leverage existing skills and resources to craft the necessary information to package and disseminate according to Cal OES' California-specific CEO strategy.

An end user license agreement (EULA) needs to be developed that will, among other things, be designed to prevent users from disseminating the signal to an uninformed public in a manner that denigrates the quality of the alert.

The success of the limited public rollout could be further enhanced by development of improved mechanisms for users to access the EEW signal (i.e. datacasting, discussed previously). Therefore, Cal OES should continue to invest in the development of this system and seek to have it operational at the time of the limited public roll out.

Finally, to successfully begin rolling out the system in a limited way, USGS will need to complete some outstanding technical tasks (such as refining the algorithm and meeting federal computer security requirements) and administrative tasks (such as refining standard operating procedures and developing performance metrics). In addition, network partners will need to continue installing and upgrading as many seismic stations as possible during 2018. Figure 6 outlines these tasks and designates the entities responsible for accomplishing each task.

Milestone 3: Network development milestones

The third milestone describes important steps for further developing the network that need not be completed for successful limited public rollout to occur but should be completed in roughly the same time frame. USGS and Cal OES need to agree to the terms for expanding access to the signal more broadly to users not included in the limited public rollout. In addition, USGS needs to develop performance metrics that communicate to end users the expected performance characteristics of the system and report on system performance as the system matures (based on findings from the PEER study that interviewed organizations in California's major economic sectors).[38] Other tasks that need to be completed in 2018 include finalizing the telemetry plan as well as a plan to incorporate GPS data into the network. Each of these tasks is important to the development of the network and can help inform the Legislature about the progress that is being made toward fully deploying the system.

A report from USGS on measurable improvements to system performance that coincides with investment in the system will facilitate the legislative process.

<u>CEQA Compliance and Land Use Permitting</u>

The timeline assumes that compliance with the California Environmental Quality Act (CEQA) and procurement of land use permits do not delay installation of stations that still need to be constructed. The CEQA process currently used by Cal OES (Notice of Exemption) involves a 35-day public comment period during which the NOE could be contested.[39] In addition, land use or lease agreements must be negotiated for use of public or private lands, the time involved of which varies by location and can involve pursuit of alternative locations. Should the CEQA process or permitting process delay station installation, the timeline for completing CEEWS could be delayed.

Milestone 4: Already-financed stations fully online

Assuming CEQA compliance and land use permitting do not encounter delays, network partners can complete installation of already-financed stations in 2019. Partners will also integrate the data from these stations into the process that generates the alert.

Milestone 5: Phase II access expanded beyond initial limited public rollout

An interim expansion of access to the signal between the limited public rollout and full rollout to the general public will ensure access keeps pace with technical capability and outreach capacity. The specifics of phase II access will depend upon the scope of the limited public rollout. To the extent most or all interested institutions are granted access at the time of the limited public rollout, phase II could focus on expanding access to the general public when located within an organization (such as a sports arena, airport, or shopping mall). The broad contours of the interim phase II rollout should initially be discussed by Cal OES and USGS during 2018 for milestone 3 (Network development milestones:

[38] Johnson, Laurie A., Sharyl Rabinovici, Grace S. Kang, and Stephen A. Mahin, "California's Earthquake Early Warning System Benefit Study," Prepared for California Governor's Office of Emergency Services and California Seismic Safety Commission, Pacific Earthquake Engineering Research Center, July 2016.

[39] CEQA Notice of Exemptions (NOE) requirements under Class 3, CEQA Guidelines Section 15303 (New Construction), Class 4 Section 15304 (Minor Alterations to Land), and Class 6 Section 15306 (Information Collection) require Cal OES to file a Notice of Exemption that allows 35 days for public comment during which the NOE could be contested.

commitment to terms of expanded access after limited public rollout) and the specifics of these terms agreed upon by Cal OES and USGS in 2019.

Leading up to the second phase of expanding access, Cal OES and USGS need to evaluate the limited public rollout and apply lessons learned to outreach and education. Cal OES in collaboration with USGS will need to expand the strategy for public engagement, further develop educational materials for the expansion, and implement the strategy. To expand user participation, Cal OES will also need identify, examine, and seek solutions for any state or federal regulations that could impede applications of the signal, such as automatically opening elevator doors. In preparation for expanded access, USGS will need to enhance security of the network and accommodate increased traffic.

Milestone 6: CEEWS financing source implemented

Completion of the system and successful delivery and use of the signal requires a dedicated source of ongoing funding. The Legislature may need to pass legislation to create the new charge.

Milestone 7: CEEWS network improved (rolling)

Throughout the timeline, the network partners will improve the network by continuing to identify sites for installing seismic stations and telemetry towers, construct stations, implement the telemetry plan, upgrade GPS stations, test and certify the algorithm’s use of GPS data, and fully integrate the seismic stations, GPS stations, and backbone telemetry components into the system for elevated system performance.

Milestone 8: Phase III access expanded to general public

The third and final phase of expanded access will deliver the signal to the general public via cell phones and other media. A specific level of system performance necessary for full access has not been defined, but continuous quality improvement to the system will be necessary to deliver a signal that is as accurate and reliable as possible. To notify the public by cell phone, the cell phone companies will need to finalize and implement technological adjustments that enable delivery of the alert to all relevant users in real time. System operators will need to refine the parameters for issuing an alert to the public such as the severity of expected ground-shaking that warrants an alert. Finally, Cal OES will need to implement an intensive public outreach and education campaign to educate the public on how to interpret the alert, how to respond to the alert in various circumstances, and the potential for and meaning of missed, delayed, and false alerts.

FIGURE 6: TASKS AND RESPONSIBILITIES

CEEWP Tasks and Responsible Parties

Tasks / Responsible Parties	California Office of Emergency Services	United States Geologic Survey	California Institute of Technology	University of California, Berkeley	California Geological Survey	Blue Sky Consulting Group	State Legislature	Tax Collection Agency
Business plan submitted to Legislature (2018)								
Program budget estimate for one-time and ongoing costs finalized	●					●		
Financing plan developed	●					●		
Timeline and recommendations for roles and responsibilities completed	●					●		
Risk assessment completed	●					●		
Draft Business Plan presented to Advisory Board	●					●		
Business Plan submitted to Legislature	●					●		
Limited public rollout (2018)								
Roles and responsibilities agreed to and codified in a memorandum of understanding	●	●						
Terms of roll out agreed upon	●	●						
Expected number of users estimated	●							
West coast plan for communication, education, and outreach agreed upon	●	●						
Preliminary communication, education, and outreach plan developed for California	●							
Outstanding technical tasks completed (e.g. algorithm, federal security computer requirements)		●						
Outstanding administrative tasks completed (e.g. standard operating procedures, performance metrics)		●						
Production of datacasting end unit facilitated	●							
Materials that will accompany alert software/datacasting unit developed (e.g. terms of agreement, CEEWS limitations, DCHO)	●	●						
Website with detailed educational materials launched (e.g. sector-specific examples of application)	●							
Public messaging about the limited nature of the system implemented	●							
Response to false, missed, or delayed alerts prepared	●	●						
Continued installation and upgrade of seismic stations		●	●	●	●			
Regional support team hired	●							
Targeted outreach to initial group of users	●	●						
Signal made accessible to limited public rollout users	●	●						

CEEWP Tasks and Responsible Parties								
Tasks / Responsible Parties	California Office of Emergency Services	United States Geologic Survey	California Institute of Technology	University of California, Berkeley	California Geological Survey	Blue Sky Consulting Group	State Legislature	Tax Collection Agency
Network development milestones (2018)								
Agreement on terms of expanded access after limited public rollout	●	●						
Metrics of systems performance developed and regularly reported		●						
Telemetry plan finalized	●	●						
Plan for incorporating GPS into network finalized		●						
CEQA permitting streamlined	●							
Already financed stations fully online (2019)								
Seismic Station sites identified and permits obtained		●	●	●				
Seismic Stations constructed and equipment installed		●	●	●	●			
Seismic Stations integrated into the network		●	●	●	●			
Phase II access expanded beyond initial limited public rollout (2019)								
Terms of expanded access agreed upon	●	●						
Limited roll-out evaluated and lessons learned applied to outreach strategy and educational materials	●	●						
Public engagement strategy refined and expanded	●	●						
Educational materials further developed and refined	●	●						
Public engagement strategy implemented	●							
State and federal regulations that restrict applications of the signal examined and solutions identified	●	●						
Servers that provide data streams and alerts to users moved behind USGS firewalls		●						
CEEWP financing source implemented (2019)								
Legislative process/discussions for system financing initiated	●						●	
Accountability process for appropriation of state funding developed (e.g. commitments to milestones made)	●	●					●	
Requirements for revenue collection developed	●						●	●
Financing strategy implemented	●						●	●

CEEWP Tasks and Responsible Parties

Tasks / Responsible Parties	California Office of Emergency Services	United States Geologic Survey	California Institute of Technology	University of California, Berkeley	California Geological Survey	Blue Sky Consulting Group	State Legislature	Tax Collection Agency
CEEWS network improved (rolling)								
Seismic station sites and telemetry node sites identified and permits obtained		●	●	●				
Contractors hired, supplies purchased, stations constructed, equipment installed		●	●	●				
Telemetry made more robust through diversification and redundancy	●	●	●	●	●			
GPS stations upgraded and algorithms tested, certified, and applied		●						
Seismic and GPS Stations and telemetry nodes integrated into the network		●	●	●	●			
Phase III access expanded to general public (2021)								
Continuous system quality improvement implemented	●	●						
Development of technology for cell based public notification facilitated		●						
Common Alert Protocal refined (e.g. messaging, geography covered, threshold criteria)	●	●						
Public campaign implemented	●							
General public receives alert message via cell phones and other media	●	●						

6 RISK ASSESSMENT

An important part of successful project planning is anticipation of and development of responses to potential project risks. With respect to EEW, there are two important categories of risk. The first relates to the timing of system deployment and the second to cost.

6.1 Risks Associated with the Timing of System Deployment

While an important overall goal of EEW program managers and of this business plan is to ensure that EEW is implemented as quickly as possible, this goal must be considered in the context of the risks of (too) rapid deployment. Specifically, if the system is rolled out too quickly – before the technology is reliable and accurate enough to perform effectively or prior to adequate preparations with respect to community outreach and education – there is a risk that the public will either (a) be reluctant to use the system due to its stated limitations or (b) lose faith in its capacities as a result of false or missed alerts, with the same ultimate result. That is, if the public is not adequately informed about the limitations of the system or if the system fails to perform properly, individuals and organizations may not use the system or may cease to use it in response to perceived system failures. For example, if the public does not adequately understand that the system can only provide a warning measured in seconds (rather than minutes or hours), and only for earthquakes that originate at some distance from the warning recipient, there is the danger that users may perceive the system as of little value. This risk is exacerbated to the extent the public is not educated about how to respond upon receiving a warning. Specifically, because there is so little time to respond, the public will need to be informed that they will in all likelihood not have time to evacuate the building they are in, gather any belongings, or otherwise do much more than drop, cover, and hold on. In addition, an ill-informed public might well respond in inappropriate ways, causing more harm than good (e.g., panicking and causing injuries while attempting to evacuate a building or public area).

A similar risk is associated with institutional users. If these users are not adequately informed about the risks of false alerts, for example, users of the system may take inappropriate actions, such as stopping medical procedures when it is dangerous to do so or halting production lines in spite of the high costs of doing so. In either case, negative consequences of false alerts could reduce faith in – and ultimately use of – the EEW system.

Consequently, substantial risks to inappropriately early deployment of the system exist. Not only is sufficient time needed to refine the technology and the warning algorithm, but adequate time is needed to fully understand and quantify the systems capabilities on such metrics as the likelihood of false alerts, among other metrics.

Conversely, there are risks associated with delaying implementation too long. The most important of these risks is the potential for a large earthquake occurring prior to full deployment of the system (but after such time as deployment was technically feasible). In such a circumstance, system operators would confront the possibility that injury, property damage, and loss of life could have been avoided had the system been deployed sooner. In addition, members of the public and policy makers alike might well question the competence of system managers, and potentially even move to limit or reduce funding on the grounds that prior investments were not generating sufficient benefits. A related if less significant risk is that continued delays in deploying the system erodes support for funding, thereby jeopardizing the prospects for full deployment at some future date.

Ultimately, resolving these risks will involve making a judgement about their relative likelihood and significance. A logical middle ground (and the strategy recommended by this business plan) would consist of deploying the system initially to well informed institutional users and allowing these users to make their own judgement about the relative costs of responding to a false alert or failing to be notified in the event of a missed alert. Users could be informed at the time of system adoption (e.g., through the use of a well-documented end user licensing agreement, requirement to view a short video or review written materials, or another mechanism). Deploying to such a group of "early adopters" would allow at least some benefits of the system to be realized almost immediately, while simultaneously allowing additional time to refine the system's capabilities and develop a viable education and outreach campaign to inform the public more broadly.

6.1.1 Other Risks Associated with System Deployment

In addition to the broad category of risk discussed above, there are a set of similar, related risks associated with system deployment.

On the one hand, there is the risk that the system will be deployed, but few users will take advantage of its capabilities. Those involved in promoting the current beta testing and pilot user programs to institutional users across the state have reported that, while many emergency managers are interested in the system, these individuals have nevertheless experienced difficulties in getting their organizations to make the needed investments in both physical hardware and staff training necessary to successfully and effectively deploy EEW within their organizations.

While it is likely the case that at least some users will hold out prior to adopting the system until its capabilities are perfected, system adoption could well be enhanced by more rapidly deploying the system, particularly in conjunction with the limited public rollout currently scheduled for December 2018. That is, if the publicity surrounding the limited public rollout can be effectively leveraged to sign up additional users, these users may well have a catalyzing effect on other, similarly situated users. For example, if one school district adopts EEW, it is likely that this will encourage other school districts do to the same, either as a result of word of mouth among school administrators, pressure from parents seeking increased safety for their children, or both. A similar result is likely with respect to a host of categories of commercial users: if one institution adopts the system, pressure on similar institutions might be applied by customers, employees, risk managers, or others.

Another reported risk of premature deployment of the EEW system relates to the possibility that users might misuse the EEW signal, either by inappropriately rebroadcasting it (e.g., with a phone application) or by using it to notify the public (e.g., in an airport, stadium, shopping mall, or other public place) prior to the launch of a successful outreach and education campaign. If users were to design and deploy a phone application (or other mechanism for notifying the public) that misinformed the public, performed poorly (thereby reducing confidence in the system), or notified the public prior to the launch of the full public rollout and accompanying outreach and education campaign, there is the risk that users would lose faith in the system or respond inappropriately, thereby causing injury or other harm. A similar risk relates to the possibility that institutional users would use the signal from the initial public rollout to inform the public (e.g., customers in a store) without the benefit of the outreach and education campaign. While the extent of these potential risks is unknown, they can easily be minimized through a carefully written end user licensing agreement that prevents any activity deemed inappropriate or premature.

Beyond these risks of premature deployment, there is another category of risk associated with system deployment: unanticipated user demand. While there is some reason to believe that users may be slow to adopt the system, there also exists the possibility that, in response to publicity surrounding the initial public rollout, demand for the system exceeds capacity to respond. Specifically, many users will likely need technical assistance in determining how to access the signal and how to integrate it with existing machinery, equipment, or institutional processes. Without adequate preparation to assist these users, existing staff resources within Cal OES (or the USGS, to the extent there is a public facing role for the organization) could easily be overwhelmed. In addition, there is the possibility that the public or specific categories of institutional users not eligible to access the signal (e.g., due to geographical limitations on the signal's reliability in their area) might be concerned about their lack of access.

In order to prepare for such a risk, adequate staff capacity will need to be developed and web and telephone based mechanisms for communicating with users will need to be put in place prior or in conjunction with system deployment.

6.2 Risks Associated with System Cost and Technology

In addition to risks associated with deploying the system too soon or not soon enough, a second category of risk relates to the costs of the system. While every effort has been made to estimate both one-time and ongoing costs, there is nevertheless a substantial amount of uncertainty surrounding these cost estimates. To the extent these estimates turn out to be too low, there is the risk that additional funding may not be available, thereby hampering the ability of the system to perform properly. A similar risk relates to "sticker shock." To the extent that the costs for the system are higher than policy makers or the public are willing to pay, the result could be a further delay in deploying the system. In this case "the perfect could become the enemy of the good" in the sense that budgeting for a well-funded, highly robust, and accurate system could have the unintended effect of resulting in a more poorly funded and less robust system to the extent that additional funding cannot be obtained due to a too large initial price tag.

Related to the risk of system cost is the risk of slow or inadequate development of needed EEW technologies, most importantly the refinement of the alert algorithm and technology needed to alert individuals on their cell phones. While an alert algorithm is currently in use for purposes of notifying beta and pilot users, additional refinements to this algorithm are ongoing. Ultimately, EEW managers believe that the technology will be adequate to the task, but the risk nevertheless remains that additional refinements will be needed, which could delay full deployment of the system. Similarly, the technology to notify individuals on their cell phones is still being developed. It is expected that this technology will be ready within a few years. However, the risk that this system is delayed nevertheless remains.

6.3 Managing Risks

To effectively address the risks identified in this plan as well as others that may arise, Cal OES program managers will need to work effectively with the USGS partners both initially to ensure that a suitable MOU is agreed to as well as on an ongoing basis to resolve problems as they arise.

FIGURE 7: RISKS AND MITIGATION STRATEGIES

Risk	Mitigation Strategy
False/missed/delayed alerts dilute confidence in system or interrupt costly machine processes and services	Clearly inform users of system limitations and continue to support USGS in refining system performance
Large earthquake occurs, but signal has not been made available	Aggressively pursue business plan timeline
Slow pace of expanding access to alert undermines political will for funding	Plan and meet benchmarks for expanding access
Funding based on estimate proves to be inadequate to support California EEW	Work to cut costs and find additional funding sources
Lack of participation due to lack of user willingness to invest in EEW	Increase outreach, education, and publicity
People do not respond to alert	Refine and enhance outreach and education
Middlemen reduce data quality and dilute confidence in system	Enforce contractual terms to prevent misuse
Strong interest in accessing signal from ineligible users during limited public rollout phase	Work with USGS to expand signal access to excluded groups
User demand exceeds administrative capacity resulting in difficulty accessing and using signal	Develop plan to expand access in response to strong demand; invest in technical support and help desk resources
Cyber security fails to protect CEEWS from cyber threat	Invest in ongoing security upgrades
Technology for real time cell phone alerts is delayed	Work with providers to accelerate timeline; adjust public awareness campaign timing as needed
CEQA permitting process stalls progress	Continue to work on global CEQA solution

7 BENEFITS AND COSTS OF EARTHQUAKE EARLY WARNING

Before committing the state's resources to an investment in EEW, Californians and their elected representatives may well ask what any prudent investor would: does the expected benefit exceed the likely costs? The short answer to this question is an unambiguous "yes." While the actual benefits from EEW cannot be determined with precision as they will depend on the location and magnitude (among other factors) of any relevant earthquakes, it is nevertheless possible to anticipate likely benefits. These benefits may stem from reduced injuries and deaths, avoided damage to equipment, or lower clean-up costs in the aftermath of a major quake. And, research suggests that if EEW can save even a handful of lives, help to avoid just a fraction of the injuries otherwise likely to result from a quake, or prevent a single train derailment, the benefits would far exceed the costs of the system.[40]

7.1 Benefits of EEW

A report prepared by Pacific Earthquake Engineering Research Center (PEER) for Cal OES in 2016 concluded that surveyed organizations "unanimously perceived the overall societal benefits from having a statewide EEWS as very high."[41] Specifically, those interviewed by the PEER study authors "perceived that the benefit value, both to society and individual organizations, comes first and foremost from those potential applications that provide for occupational safety, public safety in a particular facility, and general public safety."[42]

Beyond this general discussion of benefits, the PEER study authors identified fourteen specific types of potential benefits from an EEW system:

1. Notification for Occupational Safety
2. Notification for Public Safety in a Particular Facility
3. Broadcast Notification for General Public Safety
4. Activation of Emergency Response Plans and Situational Assessment
5. Large-Scale Utility Control
6. On-Site (Facility) Utility Control
7. High-Speed Mass Vehicle Control
8. Low-Speed Mass Vehicle Control
9. Independent Vehicle Control
10. Industrial Equipment, Assets, and Process Control
11. Industrial Chemical Control
12. Commercial Equipment, Assets and Process Control
13. Large-Scale Access Control
14. On-Site Access Control

The PEER study provides a detailed overview of the types of potential benefits from a statewide EEW system. This study is complemented by a recent report by the Jennifer Strauss and Richard Allen of the U.C. Berkeley Seismology Lab which identified and quantified several classes of benefits stemming from EEW and compared those benefits to expected costs. The report's authors identified benefits to hospitals and schools, passengers in elevators or on trains, manufacturers and workers working with hazardous materials, among other classes of potential benefits.

[40] Strauss, Jennifer and Richard Allen, "Benefits and Costs of Earthquake Early Warning." *Seismological Research Letters* Volume 87, Number 3 May/June 2016 pp. 765-772.
[41] Pacific Earthquake Engineering and Research Center, 2016, p.xii.
[42] Ibid.

Perhaps the largest category of potential benefit relates to avoided injuries. During a major earthquake, many injuries result from falling debris or other objects. With a few seconds of warning, most people will be able to move to a safe location away from windows or other dangerous objects and drop, cover and hold on. These benefits apply to individuals at home as well as to people in public places such as schools or airports. While it is not known precisely how many injuries can be avoided by such actions, it is likely that many injuries could be avoided by these simple steps. According to Strauss and Allen, “in both the 1989 Loma Prieta and 1994 Northridge earthquakes, more than 50% of the injuries were caused by falls and falling hazards.”[43] Strauss and Allen conclude that if everyone received adequate warning and took appropriate action (i.e., dropped, covered and held on), the estimated $2 billion to $3 billion in injury related costs stemming from the Northridge earthquake could be reduced by $1 billion to $1.5 in a future similar quake. Even avoiding just one percent of the injuries from a Northridge-like earthquake would potentially save $20 million to $30 million, or more than enough to pay the $16.4 million annual operations and maintenance costs of the EEW system.

Strauss and Allen also highlight the potential benefits to manufacturers, who can “shut down hazardous chemical systems and manipulate sensitive equipment into a safe position.”[44] Strauss and Allen highlight the example of the OKI semiconductor factory in Japan, which has saved an estimated $15 million over the course of two earthquakes. According to the authors, there are over 1,000 semiconductor companies in California alone. Although production processes and methods may differ between California and Japan, if even a handful of these companies (or other similar manufacturers) are able to avoid costly losses stemming from an earthquake, the savings would exceed the expected annual costs of the state’s EEW system.

Strauss and Allen provide one more example of the potential cost savings from EEW: the potential to avoid a train derailment. The San Francisco Bay Area’s BART system is one of the few organizations already utilizing the EEW system. BART has set in place a system to automatically slow or stop trains under certain circumstances to avoid injuries and damage to trains in the event of an earthquake. A single ten-car BART train costs more than $33 million, so preventing one derailment would easily save more than the annual program costs.[45]

In addition to these specific categories of benefits, a few seconds of warnings in advance of a major earthquake could provide numerous other potential benefits. Doctors could temporarily halt surgeries in progress, elevators could be opened at the next available floor, firehouse doors could be automatically opened to allow first responders to exit their facilities, and dangerous or hazardous materials could be secured to avoid injury or costly clean-up following a quake.

[43] Ibid, p. 769.
[44] Ibid, p. 770.
[45] See Rauber, Chris, “Even BART's brand-new railcars are delayed,” San Francisco Business Times, August 8, 2016, who reported that the 775 new BART cars would cost $2.6 billion, or $33.5 million for a ten-car train.

Chronicling all of the many potential benefits of EEW is beyond the scope of this business plan, however, as Strauss and Allen convincingly demonstrate, the likely potential benefits far exceed the modest annual program costs.

8 CONCLUSIONS

Californians are on the cusp of realizing the benefits of earthquake early warning. However, several important steps remain before this goal can be achieved. Technological improvements are still needed, and additional investments in building the necessary infrastructure are still required. An estimated additional investment of approximately $16.4 million in one-time and capital costs is required. In order to achieve the goal of EEW in California, a dedicated financing mechanism capable of supporting the system's estimated $16.4 million annual operations and maintenance costs must be identified. Finally, a well-organized program management system must be put in place based on a formal agreement between Cal OES and USGS with respect to roles and responsibilities.

8.1 Summary of Recommendations

The following are the key recommendations of this business plan:

1. Cal OES and USGS should finalize a formal memorandum of understanding that clearly delineates the roles and responsibilities of each entity with respect to implementing EEW in California.
2. The limited public rollout of the system scheduled for December 2018 should proceed with access granted to the widest possible group of institutional users.
3. Cal OES should work with the USGS to refine the preliminary telemetry plan; to the extent feasible and cost-effective, existing state infrastructure should be utilized in place of new investments in order to minimize costs.
4. The Legislature should approve a stable, ongoing source of funding for the program effective January 1, 2019.

California is on the verge of a scientific advancement that would change earthquake mitigation as we know it. Although several important steps remain, California is poised to join Mexico, Japan, Turkey, Romania, China, Italy, and Taiwan in receiving a warning in advance of a major earthquake. Research shows that the relatively modest costs of this system will be more than outweighed by the benefits in terms of avoided injuries and reductions in damage to equipment and machinery resulting from earthquakes.

9 APPENDICES A–F: METHODS FOR ESTIMATING ONE-TIME AND ONGOING COSTS

These appendices provide a more detailed explanation than that found in the main body of this plan of the methods used to estimate both one-time and ongoing costs for the California Earthquake Early Warning System.

9.1 Appendix A: Capital Costs of Seismic Stations

To develop cost estimates for funding the installation of an additional 283 seismic stations, a budget framework was developed that identified individual tasks and specified costs for each type of equipment. This framework was developed in consultation with network operators that have past experience installing seismic stations in California (USGS, UC Berkeley, and Caltech). Current quotes from seismic instrument vendors were used to identify equipment costs.

9.1.1 Input Parameters

A framework was developed that itemized cost categories involved with installing a new station. Costs were divided between personnel and equipment. For personnel costs, individual categories of tasks were identified, including project management, site identification, station permitting, and equipment calibration and testing, among others. The network operators were consulted to identify the number of hours required for each task and the corresponding hourly cost for salary and benefits. The institution specific salary and benefits information and the number of hours required for each task were used to calculate the labor costs involved with installing one seismic station. Labor costs per station were averaged across the institutions to arrive at an overall estimate for all stations.

Travel costs associated with installing a station were estimated using inputs and assumptions made in consultation with the network operators for average miles travelled per site (for purposes of site identification, supervision of construction, and equipment installation), mileage reimbursement, and per diem costs. Travel costs per station were averaged across the institutions.

Station equipment categories were itemized and costs estimated using a quote from the supplier, Kinemetrics, dated August 2017. Smaller categories of supplies and equipment were included based on estimate developed in consultation with the network operators. Equipment and supply costs include those necessary to link the station to the telemetry network. Adjustments to these costs were made to include institutional overhead, bulk purchase discount, and sales tax where applicable.[46] Equipment and supply costs were averaged across institutions.

Finally, lease or permit fees for use of the land that stations occupy were estimated based on UC Berkeley and USGS contracts. These costs vary by station location, therefore an average cost per station was calculated based on current contracts assuming new contracts would have similar costs.

9.1.2 Station Types

The framework differentiated between station types with various characteristics that influence costs. Stations placed outdoors are more expensive than indoors and stations that use broadband technology are more expensive that those using strong motion only. Once completed, an overall cost was developed by multiplying the estimated per station costs by the number of unfunded stations for each station type. Ultimately the network operators determined that only two of the seven station permutations will be needed to complete the network: 1) New stations using only strong motion instrumentation that are placed outdoors, and 2) New stations using strong motion and broadband (all are placed outdoors). In developing these estimates, economies of scale were considered in terms of discounts on supplied equipment. In addition, costs for building stations going forward were estimated based on the most recent (as opposed to initial) experience of station operators in terms of the anticipated costs of construction. Table 4 and Table 5 below display the costs associated with installing the 283 additional unfunded stations.

[46] Assumptions for sales tax include: UC Berkeley pays 50% of the 9.25% sales tax, USGS pays 0% sales tax, and Caltech/SCSN-USGS pay 50% of 9.50% sales tax on supplies and equipment. Assumptions for general overhead and overhead on supplies, labor, travel, and subcontracts include: 25% for UC Berkeley (which may increase after 2017), 44.36% for USGS, and 65% for Caltech/SCSN-USGS. Assumptions for benefits as a percent of salary costs include: 48% for UC Berkeley personnel, 48% for USGS personnel, and 28% for Caltech/SCSN-USGS personnel. For equipment, UC Berkeley and Caltech/SCSN-USGS pay no overhead, and it is assumed that the current USGS overhead rate of 6 percent negotiated for seismic equipment will continue (USGS typically charges the full overhead rate of 44.36% on equipment). Kinemetric's bulk purchase discount of 10 percent for purchases of 25-49 units at a time was applied to equipment costs.

TABLE 4: PER STATION CAPITAL COST ESTIMATE FOR SEISMIC STATIONS*

Cost Category	Strong Motion Outdoor, New	Strong Motion & Broadband, New
Personnel		
Project management	$2,018	$2,018
Site identification	$767	$767
Obtain permit	$1,856	$1,856
Complete environmental review	$1,541	$1,541
Install equipment	$716	$716
Calibrate and test equipment	$1,074	$1,074
Telemetry and data integration	$384	$384
Supervise station construction	$848	$848
Data quality review	$822	$822
Travel	$404	$404
Permits	$3,988	$3,988
Equipment		
Site infrastructure subcontract strong motion (outdoor)	$14,056	$0
Site infrastructure subcontract strong motion + broadband	$0	$20,534
Broadband sensor	$0	$5,440
Accelerometer	$3,051	$3,051
Data logger	$11,013	$11,013
Cables	$1,419	$1,419
Misc./Other(Kinemetrics)	$421	$421
Batteries	$1,318	$1,366
A/C Battery charger/controller	$17	$17
Cell modem	$273	$273
Radio	$2,869	$2,869
Solar power system	$1,298	$1,298
Ping Devices	$273	$273
Fencing	$102	$102
Misc./Other	$2,084	$2,084
Total per station	***$52,613***	***$64,579***

* Includes overhead. Excludes contingency.

TABLE 5: TOTAL CAPITAL COST ESTIMATE FOR SEISMIC STATIONS*

	Strong Motion Outdoor, New	Strong Motion & Broadband, New	Total
Per station cost	$52,613	$64,579	
Number of stations	185	98	283
TOTAL	***$9.7 Million***	***$6.3 Million***	***$16.1 Million***

* Includes overhead. Excludes contingency.

9.2 Appendix B: Ongoing Costs for Seismic Stations and Central Site Operations

9.2.1 Operation and Maintenance of Seismic Stations

To estimate ongoing costs for earthquake early warning in California, historical CISN funding data was collected for personnel, supplies, travel, leases, and last mile telemetry for operating and maintaining CISN stations. These spending amounts were summed for each institution and divided by the number of CISN stations to which they applied to arrive at an historical per station cost for each institution. Historical per station spending in Table 6 below varies by institution due to variation in annual lease/permit costs, last mile telemetry costs, the ratio of personnel to stations, salaries and benefits, variation in supply costs by type of station, and distance and frequency of travel for maintenance. Overhead was added after estimating costs and considering revenue sources discussed below.

Adjustments to Historical Spending

Adjustments were made to the historical funding, where necessary, to arrive at an estimated ongoing cost for EEW stations. For example, adjustments were made to UC Berkeley's historical spending to account for anticipated increases in efficiency as the institution's operation grows from 30 stations to 130 stations. By building a model of estimated personnel needed for 130 stations rather than multiplying historical spending per station by 130, estimated personnel costs per station were reduced by half. In addition, adjustments to historical CGS and USGS spending were made to exclude non-EEW related costs such as post-earthquake information products and costs included elsewhere in the budget such as leases for backbone telemetry.

Additional adjustments were made to account for historical underfunding of relevant CISN functions. A fully operational earthquake early warning network with continuously functioning seismic stations requires adherence to a maintenance schedule to prevent service interruptions and funding that keeps pace with inflation. To account for historical underfunding, the historical per station costs were adjusted by approximately 20 percent (equivalent to 2 percent annually for 10 years).[47,48]

A fully operational early warning system requires regular equipment replacement to prevent service disruption. To estimate equipment amortization, the same cost information from a Kinemetrics quote dated August 2017 used for capital costs was applied to the distribution of station types across

[47] UC Berkeley anticipated ongoing costs were modeled using FY 2015-16 dollars, therefore per station costs were increased by 2 percent for two years to develop an estimate in current dollars.

[48] Last mile telemetry was separately estimated for all institutions and therefore excluded from this general increase.

institutions.[49] As with capital costs, adjustments to these costs were made to include institutional, a bulk purchase discount, and sales tax (overhead was added after estimating costs and considering revenues sources discussed below).[50] Ten percent of the estimated equipment costs were included in the annual cost estimate to account for equipment replacement every ten years.

For purposes of situational awareness, CISN previously did not require the same level of speed and reliability for real-time telemetry for every station. Paying for real-time last mile telemetry increases annual costs above historical spending levels. Historical spending levels reported by the CISN partners were adjusted to develop an estimate for EEW capable last mile telemetry. The difference between historical and expected telemetry costs was added to the per unit costs.

For each institution, the total annual cost per station was multiplied by the number of EEW seismic stations expected to be operated by that institution to arrive at the total annual cost. Table 6 and Table 7 and display these costs.

TABLE 6: ANNUAL PER STATION ONGOING COSTS FOR CEEWS SEISMIC STATIONS

	CGS	NCSS USGS	SCSN USGS	Caltech	UC Berkeley
Historical Spending					
Total annual budget for CISN seismic stations*	$347,802	$1,533,071	$986,926	$599,864	$209,225
Number of CISN stations in historical budget	400	585	230	150	30
Historical per station annual cost	$870	$2,621	$4,291	$3,999	$6,974
Adjustment for Inflation and Historical Underfunding					
Number of years with flat funding	10	10	10	10	2
Annual inflation	2%	2%	2%	2%	2%
Per Station Adjustment	$125	$541	$891	$771	$249
Adjustment for Last Mile Telemetry					
Additional last mile telemetry per station per year	$540	$600	$800	$540	$0
Adjustment for Equipment					
Per station equipment cost with sales tax	$15,467	$15,510	$17,247	$18,885	$20,063
Frequency of equipment replacement	10	10	10	10	10
Annual station equipment cost	$1,547	$1,551	$1,725	$1,889	$2,006
Total cost per station	***$3,081***	***$5,312***	***$7,707***	***$7,198***	***$9,229***

*Includes adjustments to UC Berkeley, CGS, and USGS as described in the text. Excludes overhead and contingency.

[49] CGS expects to operate a total of 100 strong motion only stations; UC Berkeley expects to operate 130 stations with broadband; USGS expects to operate 116 stations with broadband and 349 strong motion only stations; Caltech expects to operate 98 stations with broadband and 62 strong motion only stations; and SCSN USGS expects to operate 159 stations with broadband and 101 strong motion only stations.

[50] Assumptions for sales tax include: CGS pays 8.25% sales tax, UC Berkeley pays 50% of a 9.25% sales tax, USGS pays 0% sales tax, Caltech pays 9.50% sales tax, and SCSN-USGS pays 0% sales tax on supplies and equipment. Kinemetric's bulk purchase discount of 15 percent for purchases of 100-149 units at a time was applied to equipment costs (10% of 1,115 stations).

TABLE 7: TOTAL ANNUAL ONGOING COSTS FOR CEEWS SEISMIC STATIONS*

	CGS	NCSS USGS	SCSN USGS	Caltech	UC Berkeley	Total
Per station cost	$3,081	$5,312	$7,707	$7,198	$9,229	
Number of stations	100	465	260	160	130	1,115
TOTAL	***$.3 Million***	***$2.5 Million***	***$2. Million***	***$1.2 Million***	***$1.2 Million***	***$7.1 Million***

* Excludes overhead and contingency.

9.2.2 Anticipated Ongoing Costs of Central Site Operations

Two regional central processing facilities receive and process data from seismic stations using computer applied algorithms. Alert system computers coordinate between the regional facilities to issue the alert to system users. In addition, a central processing facility for the entire system monitors the system as whole, performs quality control, testing and certification, research and development, and central project management. To estimate ongoing costs for these central site operations, historical budget information was collected from the site operators and adjusted to reflect likely costs once the EEW system is fully operational. The regional central processing sites, located at USGS Menlo Park and Caltech, require personnel, including software developers, network engineers, system administrators, and data scientists. Other costs include servers and supporting infrastructure, cloud services, and secure IT communication. Adjustments were made to the relevant cost categories in order to account for the additional data from a larger number of stations and higher IT security needs for a system that the public will rely on, among other factors Table 8 shows the ongoing costs for the regional central sites and central site.

TABLE 8: TOTAL ONGOING COSTS OF REGIONAL AND CENTRAL SITE OPERATIONS* *(Millions)*

Cost Categories	Regional Central Site Operations				Central Site USGS	Total
	NCSS USGS	SCSN USGS	Caltech	UC Berkeley		
Personnel & benefits	$1.15	$.51	$1.47	$.68	$1.4	$5.21
Servers & supporting infrastructure	$.02	$.03	$.02	$.02	$.02	$.1
Computers	$.002	$.01	$.02	$.002	$.02	$.04
Cloud computer services	$.01	$.01	$.01	$.01	$.05	$.09
IT Security	$.25	$.2	$.15	$.16	$.5	$1.26
Other costs	$0	$0	$.01	$0	$.74	$.75
TOTAL	***$1.4***	***$.8***	***$1.7***	***$.9***	***$2.7***	***$7.5***

* Excludes overhead and contingency.

9.2.3 Existing Funding Available for EEW

Currently, both the state and federal governments provide ongoing funding which supports EEW. The budget estimates presented in this business plan assume that these existing funding sources continue and then estimate the amount of additional ongoing funding that is needed to support EEW operations and maintenance.

The California Integrated Seismic Network (CISN) is part of the national network, the Advanced National Seismic System (ANSS), that delivers information to emergency personnel for purposes of targeting response efforts immediately after an earthquake. ANSS consists of many partnerships, but is largely funded with federal funds in California. As part of ANSS, CISN receives annual federal funding for operating and maintaining stations, processing data, and producing information quickly after an earthquake. The early warning system overlaps heavily with CISN but will require additional funding because not all CISN funding applies to early warning and early warning carries additional costs not covered by CISN.

ANSS funding to the partners involved in early warning totals $8 million. Of this total, roughly 80 percent is estimated to support existing stations and functions that can be used by both ANSS and CEEWS. The state of California also contributes nearly $1.5 million to annual operations and maintenance of CISN, an estimated 75 percent of which supports existing stations that contribute to CEEWS. In addition, the federal government is expected to continue annual EEW funding in the amount of $12.9 million. This total supports the entire west coast, with an estimated 68 percent supporting California and central site EEW activities. Finally, a small contribution from a university partner is expected to continue (included as "Other" in Table 9).

Existing funding from federal and state sources are expected to continue to cover much of the ongoing costs for seismic stations and central sites, and it is assumed that the remaining unfunded portion will be covered with a state revenue source. Existing funding amounts provided included overhead, but the estimated costs did not, so overhead was removed from existing funds as shown in Table 9.[51] The existing funds without overhead were subtracted from the ongoing cost estimate to produce the amount of unfunded ongoing costs without overhead ($2.7 million). Overhead was added to these costs utilizing institution-specific state overhead rates adjusted according to equipment and non-equipment expenses. The total amount of state funding needed including overhead totals is $3.8 million as shown in Table 9. The total estimated budget to cover ongoing costs for CEEWS seismic stations and central processing facilities totals $20 million (also presented in Table 9). Of this total, the new state revenue source will cover about 20 percent of the costs. Including existing state CISN funding, California will cover an estimated 25 percent of ongoing costs.

[51] See Appendix E: Overhead on Capital and Ongoing Costs for the overhead rates used in the calculations for Table 9.

TABLE 9: TOTAL UNFUNDED ONGOING COSTS FOR SEISMIC STATIONS AND CENTRAL SITE OPERATIONS*

(Millions)

	CGS	*NCSS USGS*	*SCSN USGS*	*Caltech*	*UC Berkeley*	*Central Site*	*Sum*
Ongoing Costs (w/o overhead)							
Total Annual Ongoing Costs for CEEWS Seismic Stations	$.3	$2.5	$2.	$1.2	$1.2	$0	$7.1
Total Ongoing Costs of Central Site Operations	$0	$1.4	$.8	$1.7	$.9	$2.7	$7.5
Subtotal (A)	*$.3*	*$3.9*	*$2.8*	*$2.8*	*$2.1*	*$2.7*	*$14.6*
Existing EEW Funding Expected to Continue (w/ overhead)							
CISN (ANSS)	$0	($2.5)	($1.9)	($1.3)	($.4)	$0	($6.2)
CISN (Cal OES)	($.1)	$0	$0	($.7)	($.3)	$0	($1.1)
Federal EEW	$0	($.8)	($.7)	($1.4)	($2.)	($3.9)	($8.8)
Other	$0	$0	$0	($.1)	$0	$0	($.1)
Subtotal (B)	($.1)	($3.4)	($2.6)	($3.6)	($2.7)	($3.9)	($16.3)
Existing EEW Funding Expected to Continue (w/o overhead)							
CISN (ANSS)	$0	($2.)	($1.5)	($.8)	($.3)	$0	($4.7)
CISN (Cal OES)	($.1)	$0	$0	($.5)	($.2)	$0	($.8)
Federal EEW	$0	($.7)	($.5)	($.8)	($1.5)	($2.7)	($6.3)
Other	$0	$0	$0	($.1)	$0	$0	($.1)
Subtotal (C)	($.1)	($2.7)	($2.1)	($2.3)	($2.)	($2.7)	($11.9)
Subtotal Unfunded Ongoing Costs w/o overhead (A+C)	*$.2*	*$1.2*	*$.7*	*$.6*	*$.*	*$0*	*$2.7*
Overhead	*$.05*	*$.4*	*$.3*	*$.3*	*$.*	*$0*	*$1.1*
TOTAL State funds needed (D)	***$.3***	***$1.6***	***$1.***	***$.9***	***$.1***	***$0***	***$3.8***
Overhead included in existing funds w/overhead (B-C)	($.02)	($.6)	($.5)	($1.3)	($.7)	($1.2)	($4.4)
TOTAL O&M Budget (B+D)	***$.4***	***$5.***	***$3.5***	***$4.5***	***$2.8***	***$3.9***	***$20.1***

* Excludes contingencies. Inclusion of overhead varies throughout the table.

9.3 Appendix C: Capital and Ongoing Costs of GPS Stations

A framework was developed to estimate unfunded capital costs for upgrading GPS stations in a similar fashion to the framework utilized for seismic station capital costs. Like seismic stations, initial costs vary by the specific characteristics of the station. In consultation with USGS, costs were estimated separately for stations that: 1) need to be upgraded to operate in real time, 2) need telemetry upgrades in the Cascadia region of Northern California, 3) need telemetry upgrades in the region north of the Bay Area, 4) need receiver upgrades statewide, and 5) need clock corrections to enable on-board positioning.

Most of these GPS sites need to be upgraded to the Global Navigation Satellite System (GNSS), which involves equipment costs for the receiver and a one-time subscription fee. Some of these sites will require antennae replacements. Some sites require equipment purchases of radios or cell modems. Travel costs, field personnel costs, an average per station permit cost were included based on invoices submitted to USGS as well as overhead.[52] Unfunded capital costs for GPS stations are displayed in Table 10.

TABLE 10: UNFUNDED CAPITAL COST ESTIMATE FOR GPS STATIONS*
($ in Millions)

	Number of GPS Sites	Total cost of sites with old receiver	Total cost of sites with new receiver	Sum
Upgrade Non-Real Time to Real Time	65	$.05	$1.12	$1.18
Cascadia Telemetry Upgrades	40	$.03	$.63	$.66
North of Bay Area Telemetry Upgrades	16	$.05	$.14	$.2
Statewide Receiver-Only Upgrades	143	N/A	$1.55	$1.55
Statewide Clock Corrections	30	N/A	$.17	$.17
TOTAL	***294***			***$3.76***

* Includes overhead. Excludes contingency.

9.3.1 Ongoing GPS costs

Similar to the method used to estimate ongoing costs for seismic stations, total GPS costs were estimated by making adjustments to historical funding. The difference between total GPS costs and existing funds expected to continue comprise the unfunded portion of GPS ongoing costs.

Data from GPS stations do not currently contribute to the beta early warning alert. USGS anticipates that 570 GPS stations that are currently operated by other organizations for research purposes may ultimately contribute to the California's EEW system. Historical spending for these research-oriented stations requires adjustments to meet operational standards. Adjustments include correcting for historically flat funding, increasing telemetry costs to account for real-time data transmittal, and adding personnel. Additional operational staff is necessary to meet station maintenance schedules, which require a lower ratio of stations to staff members than currently exists. Further, additional data

[52] USGS general overhead rate of 44.36% was applied to labor and fees. USGS overhead rate of 6% on equipment for CEEWS was applied to equipment.

management staff is needed at the central sites to manage the geodetic data, and additional funds are need for IT security.

Historical spending is based on the USGS SCSN budget of $537,958 for 140 GPS stations. The per station cost of $3,843, based on this budget, was assumed to be reflective of current spending on the 570 stations that will ultimately contribute to CEEWS. The historical per station cost was inflated by 2 percent annually over 10 years, increased for real-time telemetry costs (including overhead on the difference in telemetry costs), and increased for additional personnel (including overhead).[53] Table 11 summarizes these adjustments.

TABLE 11: ESTIMATE OF TOTAL ONGOING COSTS PER GPS STATION*

Cost Categories	GPS Station Cost
Historical Spending	
Historical annual spending per station	$3,843
Adjustment for Inflation	
Number of years with flat funding	10
Annual inflation	2%
Adjustment for historical flat funding per station	$785
Adjustment for Last Mile Telemetry	
Additional last mile telemetry per station per year	$841
Overhead on additional telemetry per station per year	$373
Additional last mile telemetry costs per station per year	$1,215
Adjustment for Additional Personnel	
Additional salary & benefits costs per station	$1,432
Additional IT support per station	$571
Additional personnel costs per station	$2,003
TOTAL	***$7,846***

*Includes overhead. Excludes contingency.

9.3.2 Existing Funds Expected to Continue

Assuming existing funding of approximately $2.2 million annually to maintain 570 GPS stations will continue, $2.3 million of the $4.5 million total ongoing costs necessary for GPS to contribute to CEEWS remains unfunded, as shown in Table 12. Historically, the National Science Foundation (NSF) has largely funded the annual operational and maintenance costs for the 570 GPS stations expected to contribute to CEEWS as part of the Plate Boundary Observatory (PBO). PBO is the geodetic component of the EarthScope Facility, a program to explore the 3-dimentional structure of North America. As a research-oriented funding agency, NSF may require cost recovery for CEEWS use of these stations. In that case, additional ongoing funds will be needed to replace some of the existing $2.2 million.

[53] Currently one staff member maintains 140 stations. A network functioning in operational mode rather than research mode requires one staff member to maintain 80 stations. Assumptions for additional personnel to operate 140 stations include: an additional 0.57 FTE, an additional 0.5 FTE for data management at the central site, and an additional $80,000 for IT security.

TABLE 12: ESTIMATE OF UNFUNDED ONGOING COSTS FOR GPS STATIONS*

	Number of GPS Sites	Per Station	Total
Total Ongoing costs	570	$7,846	$4.5
Existing Funding Expected to Continue	570	($3,843)	($2.2)
TOTAL Unfunded Ongoing Costs		***$4,003***	***$2.3***

* Includes overhead. Excludes contingency.

9.4 Appendix D: Capital and Ongoing Costs for Backbone Telemetry

To develop a plan to improve the reliability of backbone telemetry in the West Coast region, USGS organized a Telemetry Working Group in the fall of 2017 with members from the USGS, Berkeley Seismological Laboratory, Caltech Seismological Laboratory, the Pacific Northwest Seismological Laboratory (University of Washington), the University of Oregon, and the Nevada Seismological Laboratory (University of Nevada).[54] The Telemetry Plan developed metrics for improved reliability, determined the investments necessary to improve those metrics in each region, and separately estimated the costs for each region.

The Telemetry Plan and cost estimate is a highly technical endeavor. The Telemetry Working Group analyzed multiple alternatives with different implications for reliability and cost, and ultimately decided on the plan determined to have the best value. The following sections that describe the Telemetry Plan and associated budget estimate summarize material presented in the Telemetry Working Group's internal report titled, "Telemetry Improvement Plan, Earthquake Early Warning Project: A Report of the Telemetry Working Group, 12/11/2017 Draft."

Cal OES and the Blue Sky Consulting Group reviewed the Telemetry Improvement Plan developed by the working group and suggested several refinements. Specifically, the original draft telemetry plan was designed to minimize ongoing costs (for which an ongoing funding mechanism would be needed) and instead relied relatively more on building new infrastructure with a low ongoing operating cost. The USGS originally determined that, in some cases, it would have been less expensive to build new dedicated EEW telemetry infrastructure than to rely on the state microwave network. However, Cal OES subsequently determined that ongoing costs for use of the state microwave network could be reduced. As a result, adjustments were made to the original draft USGS telemetry plan to reflect greater use of the state network and a lower ongoing cost for using that network.

The resulting modified telemetry plan relies to the greatest extent feasible on the state microwave network and is based on an updated, lower ongoing operations costs for use of the network. In addition, certain costs were adjusted relative to the original draft USGS plan in order to reflect just

[54] Costs for connecting stations to the telemetry network, or the "last mile," were included in the cost estimates for seismic and GPS stations as discussed previously. Costs for the rest of the telemetry network, referred to as "backbone" or "backhaul" telemetry, were estimated separately.

those costs for providing telemetry for California seismic stations (i.e. excluding any construction in or connection to the Pacific Northwest).

9.4.1 Telemetry Plan

An early warning alert system requires a telemetry network to be functioning at all times. A reliable telemetry network requires a diversity of modes (e.g. cell, microwave, internet, fiber cable) and redundancy (i.e. more than one mode). Diversity and redundancy prevent network failures from problems such as an excavator accidentally severing a fiber cable during construction, an earthquake disrupting cell networks, a maintenance need for a microwave tower, or a bad actor hacking the Internet. Currently, the telemetry network is not well diversified, relying primarily on cell modems and the internet to transmit data. Further, many geographic areas have insufficient redundancy, which will result in delaying the alert if one mode is out of service during an earthquake (up to 12 seconds in some areas).[55] The draft Telemetry Improvement Plan seeks to prevent network outage and reduce alert delays associated with failure of a single mode.

The draft Telemetry Improvement Plan utilizes an array of components to diversify and improve network redundancy (see Table 13 and Table 14 for an itemized list and descriptions of the components). The primary strategy for improving network reliability is increasing the use of microwave telemetry. Though the existing USGS microwave network is very reliable with redundant paths, the network does not extend far enough.[56] The current telemetry network relies too heavily on cell and Internet telemetry making the network vulnerable to failure during an earthquake. The Telemetry Plan (as revised for this Business Plan) for the north involves utilizing primary microwave (via the state network). In remote or less hazard-prone areas, the plan accepts more risk relative to primary microwave by installing cheaper region-built microwave sites or utilizing fiber and partner microwave in these areas.[57]

Northern California Seismic System

The Telemetry Working Group organized by the USGS considered alternative plans that made use of state microwave in the NCSS plan, but initially decided against it because of the lack of control over

[55] The USGS-organized Telemetry Working Group analyzed how the time-to-alert would be affected under the scenario of a disruption in cell service during an earthquake. Their 2017 report, "Telemetry Improvement Plan," displayed a map of southern California that showed the time-to-alert under the scenario of no cell service. Areas with redundant telemetry show 1 to 2 seconds to alert under this scenario and areas that rely heavily on cell service show a time-to-alert of up to 12 seconds in the event of no cell service during an earthquake. The "Telemetry Improvement Plan" is designed to add a redundant telemetry mode to the areas where a significant delay to the alert would occur during an earthquake if one telemetry mode fails.

[56] The USGS-organized Telemetry Working Group has determined that with the redundant paths, the USGS microwave network is available nearly 100 percent of the time (99.9999), which means that the network will most likely be working when an earthquake occurs (as discussed in the "Telemetry Improvement Plan," 2017).

[57] Telemetry Working Group, "Telemetry Improvement Plan, Earthquake Early Warning Project: A Report of the Telemetry Working Group (Draft)" December 11, 2017.

reliability combined with uncertain cost savings in the long-run. However, based on conversations with Cal OES and the Blue Sky Consulting Group, it was determined that use of the state microwave network was a preferred alternative relative to construction of new primary microwave sites. Based on revised state pricing for EEW's use of the state microwave network, it was determined that use of the state network would result in improved system performance and lower costs relative to construction of new primary microwave sites.[58] The resulting system is expected to be highly reliable with high uptime and little delay in alert time in important areas if an earthquake occurs while one telemetry mode is out of service.

The state microwave system covers most of the state, but additional towers need to be installed in some areas that the state network does not cover. In the northern region, the plan recommends installation of one additional primary microwave tower and nine additional secondary (also known as region-built) towers. The infrastructure of primary and secondary towers differs in expense and reliability, factors which the telemetry workgroup participants weighed when determining the type of tower for each location. Ultimately, the workgroup decided secondary, or region-built, towers provided sufficient reliability in the context of the entire telemetry plan in all but one case.

Southern California Seismic Network

The station build-out is more complete in the south than the north; therefore, the Telemetry Plan for the south makes adjustments to current telemetry to improve the reliability of the SCSN. The SCSN Plan addresses the following problems: too many stations depend on the open Internet, hazard-prone areas have only one mode of telemetry, and the current cell telemetry is not on a private network. The Plan (including the Cal OES and Blue Sky Consulting Group modifications) primarily uses the state microwave network as well as 23 new region-built/secondary microwave sites to connect stations to the currently underutilized primary microwave network and to fill concentrated areas solely reliant on cell telemetry. The Plan also moves most cell stations to a private IP network with priority. The SCSN plan includes costs for connecting the NCSS to the SCSN. Like the plan for the north, the SCSN plan increases uptime and lowers latency in the event of an earthquake during failure of a single telemetry mode.[59]

The revised telemetry plan seeks to make maximum use of the state microwave system. Because the telemetry plan is still subject to considerable uncertainty, Cal OES should continue to work with USGS to develop a system that with needed reliability characteristics at the lowest cost. A substantial contingency was identified in the Telemetry Improvement Plan (and included in the cost estimates presented in this report) to account for this uncertainty.

[58] The budget estimated in this business plan assumes a mileage rate charge of $11.25 per mile provided by Cal OES.
[59] Telemetry Working Group, "Telemetry Improvement Plan, Earthquake Early Warning Project: A Report of the Telemetry Working Group (Draft)" December 11, 2017.

9.4.2 Budget Assumptions

The budget for the backbone telemetry has been developed before many of the precise locations for stations have been finalized or particulars of the plan engineered. As a result, the budget is a preliminary cost estimate and could change based on practicalities specific to individual locations. For example, practical challenges may impede construction of a microwave site at an ideal location resulting in an increase in the number of sites needed. The plan may also need to be adjusted as seismic station locations are finalized. Though actual rates and prices were used where possible, assumptions involved in calculating costs could be over- or underestimated, such as distances assumed for calculating partner microwave and fiber costs and the number of outdated cell modems requiring replacement. Unforeseen challenges with construction could arise and increase costs. Further, labor costs may be underestimated to the extent training days, pre- and post-site visit tasks, time off, other costs are added. Contingencies were added to account for uncertainty surround costs after location decisions, engineering, under-estimated labor, and experience with similar projects.[60]

The telemetry plan did not consider the locations of GPS stations that are neither co-located with seismic stations or out of reach of the current plan. Potential additional costs for connecting these GPS stations to the backbone could further increase the estimated budget.

9.4.3 Budget

According to the USGS Telemetry Improvement Plan, estimated unfunded capital costs for improving the backbone telemetry network total $5.9 million (before contingencies). After including a 50 percent contingency to account for the preliminary nature of the telemetry plan, the cost estimate increases to $8.8 million as shown in Table 13. Estimated unfunded ongoing costs for supporting the operation and maintenance of backbone telemetry total $2.9 million, and increases to $3.6 million after including a 25 percent contingency, as shown in Table 14.[61]

[60] *ibid*

[61] Note that this ongoing cost estimates assumes pricing of $11.25 per mile for EEW use of the state microwave network.

TABLE 13: CAPITAL COST ESTIMATE FOR BACKBONE TELEMETRY[1, 2]
(in Millions)

Cost Categories	NCSS Capital Costs[3]	SCSN Capital Costs[4]	Total Capital Costs
State Microwave[5]	$.8	$.54	$1.34
USGS Microwave[6]	$.84	$0	$.84
Partner Microwave[7]	$.05	$.2	$.25
Region Built Microwave[8]	$.47	$1.35	$1.82
Ring closings and Lines[9]	$.1	$.06	$.16
Cell Private IP Network[10]	$.04	$.19	$.23
Rebalance Spatial Coverage[11]	$.22	$1.03	$1.25
Subtotal	*$2.53*	*$3.36*	*$5.89*
Contingency	*$1.27*	*$1.68*	*$2.95*
TOTAL	***$3.8***	***$5.05***	***$8.84***

TABLE 14: ONGOING COST ESTIMATE FOR BACKBONE TELEMETRY[1, 12]
(in Millions)

Cost Categories	NCSS Ongoing Costs[3]	SCSN Ongoing Costs[4]	Total Ongoing Costs
State Microwave	$.8	$514,843	$1.31
USGS Microwave	$.05	$0	$.05
Partner Microwave	$.05	$.19	$.24
Regional Built Microwave	$.11	$.21	$.32
Ring closings and Lines	$.05	$.05	$.1
Cell Private IP Network	$.07	$.12	$.19
Rebalance Spatial Coverage	$0	$.2	$.2
Partner Intranet[13]	$0	$.002	$.002
Lifecycle equipment replacement[14]	$.19	$.29	$.48
Subtotal	*$1.31*	*$1.59*	*$2.9*
Contingency	*$.33*	*$.4*	*$.72*
TOTAL	***$1.64***	***$1.99***	***$3.62***

Footnotes for Table 13 and Table 14:

[1] The preliminary cost estimates presented in these tables are based on the USGS-organized Telemetry Working Group's internal draft report, "Telemetry Improvement Plan, Earthquake Early Warning Project: A Report of the Telemetry Working Group (Draft)," December 11, 2017 as adjusted by the Blue Sky Consulting Group. Overhead costs were applied. See the subsequent section on overhead for further discussion.

[2] Excludes overhead for primary microwave sites, connection to partner microwave systems, and private IP network set up. Includes overhead for region-built microwave sites, fiber ring closings, and rebalancing spatial coverage.

[3] NCSS refers to the telemetry network in the northern region of California, the Northern California Seismic System.

[4] SCSN refers to the telemetry network in the southern region of California, the Southern California Seismic Network.

[5] State microwave sites involve the fewest vulnerabilities of any single mode. The state microwave is composed of over 380 microwave towers that are controlled by state and private entities. The towers support antennas that transmit data from

one site to another as a part of the radio spectrum. These large-scale sites meet reliability standards for telecommunications infrastructure, but may require contracted construction due to the skill and scale involved, and require significant personnel time for site permitting and other support services to the extent new sites are needed.

[6] USGS microwave refer to sites built by USGS for ShakeAlert data transmission.

[7] Partner microwave backhaul refers to systems or facilities operated by third parties such as local governments and large utilities. Use of partner microwave systems may afford a faster start-up, but has a few drawbacks in the long-term. Reliance on partner microwave systems typically does not result in cost savings because most agencies operate under cost recovery rules realized in significant recurring charges for use. Further, EEW network partners cannot directly monitor data flow and must rely on a third party for maintenance and repair.

[8] Region-built (or secondary) microwave sites are much smaller than primary sites, have a shorter range of connection, and have more vulnerabilities. These sites are also cheaper and simpler to build and permit.

[9] Ring closings and dedicated lines provide redundant routes for microwave systems. Closing fiber rings around a microwave path allow data to travel around a break should a break occur in the middle of the serial microwave path.

[10] Stations use a wireless cell modem radio to communicate to a local cell tower owned by a commercial cell provider. Unless a private network is implemented, cell backhaul data includes paths over the open Internet with no delivery priority, which has security vulnerabilities and potential latency problems during high Internet and cell usage following an earthquake.

[11] In order to achieve diversity and redundancy, some modes currently in use by some stations need to be changed. Some changes will involve relatively cheap supplies while others will be more expensive to alter, such as building an additional microwave tower.

[12] Excludes overhead for partner microwave systems, a private network with a cell company, and partner Intranet costs. Includes overhead for primary USGS and state microwave sites, region-built microwave sites, fiber ring closings, rebalanced sites, and replacing equipment.

[13] Independent wireless internet service providers, DSL, and wired connections. These methods provide options for the seismic network, but are little enough used to not materially affect the overall telemetry plan.

[14] As the system ages, equipment will periodically need to be replaced.

9.5 Appendix E: Overhead on Capital and Ongoing Costs

The partner institutions building and operating many of the components of the CEEWS charge overhead on revenues they receive. The budget presented in this business plan assumes that, where possible, Cal OES can negotiate lower overhead rates or manage financial contracts paid for with state funding in order to avoid overhead charges that would apply if those contracts passed through the partner institutions.

Overhead rates vary by institution, revenue source, and the type of expense (equipment or non-equipment). Assuming unfunded capital costs for seismic and GPS stations will be covered by a state revenue source, institution-specific overhead rates for state funds were applied to equipment and non-equipment expenses included in the cost estimates.[62] Assuming that ongoing costs for GPS stations will be partially covered by funding from the National Science Foundation and partially covered by state funds, the USGS overhead rate of 44.36 percent was applied in the estimate of GPS ongoing costs.[63]

Existing funding from federal and state sources are expected to continue to cover much of the ongoing costs for seismic stations and central sites, and it is assumed that the remaining unfunded portion will be covered with a state revenue source. To apply the appropriate rate, an average overhead rate weighted by the type of expense was calculated for each institution for each type of funding source. Generally, the USGS general overhead rate for federal funds appropriate by Congress is 28.0768 percent and the equipment overhead rate negotiated between Cal OES and USGS is 6 percent.[64] NCSS USGS ongoing costs for labor, supplies, and subcontracts were estimated to be 81 percent of the costs and ongoing costs for equipment replacement were estimated to be 19 percent of the costs. The weighted average of these rates is 24 percent for NCSS USGS, as shown in Table 15. These calculations were performed to develop institutional weighted average overhead rates for state funding sources as well.[65,66]

TABLE 15: AVERAGE INSTITUTIONAL OVERHEAD RATES BY FUNDING SOURCE*

	CGS	*NCSS USGS*	*SCSN USGS*	*Caltech*	*UC Berkeley*	*Central Site USGS*
Federal Funding Sources	24%	24%	24%	62%	37%	43%
State Funding Sources	24%	37%	38%	60%	30%	44%

*Each average institutional overhead rate is weighted by the type of expense.

Overhead was applied somewhat differently on the estimated unfunded costs for improving the backbone telemetry network. Though USGS likely will manage the technical aspects of one-time

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[62] General institutional overhead rates for labor, subcontracts, supplies, and travel used to estimate capital costs include: 25% for UC Berkeley, 44.36% for USGS, and 68% for Caltech. The rate of 25% for UC Berkeley is the current rate negotiated between UC Berkeley and the state, but that rate is expected to increase to 35% over the next few years. Therefore, the rate of 35% was used for ongoing costs. Equipment overhead rates that were applied to capital costs included: 6 percent for USGS and 0% for Caltech and UC Berkeley. Caltech and UC Berkeley do not charge overhead on equipment purchases greater than $5,000.

[63] This rate is the USGS "reimbursable" rate that would apply to state funds or federal funding not appropriate directly to USGS.

[64] USGS typically charges the full general overhead rate on equipment purchases, but Cal OES negotiated a 6 percent overhead charge for the seismic station equipment purchased with the state funding provided in 2017. It is assumed this agreement will continue. If institutions decide to charge more overhead on equipment than assumed in this budget, Cal OES could purchase the equipment on behalf of the partners, thereby avoiding additional overhead charges.

[65] Unweighted institutional general overhead rates for federal funds appropriated by Congress and disseminated by USGS are as follows: 24% for CGS, 28.0768% for USGS, 40% for UC Berkeley plus 2.5% charged by USGS, and 67.5% for Caltech plus 2.5% charged by USGS. General overhead rates for state funds applied to ongoing costs include: 24% for CGS, 44.36% for USGS, 67.5% for Caltech, and 35% for UC Berkeley. Equipment overhead rates applied include: 24% for CGS, 6% for USGS, and 0% for Caltech and UC Berkeley.

[66] Currently, UC Berkeley is charging the on-campus general overhead rate of 57% on federal EEW funds and 40% for ANSS funds. Currently, UC Berkeley considers EEW funded activity as a research project and the ANSS funded network operations as a special project. Going forward, EEW will be used to cover ongoing network operations just like ANSS, therefore it is assumed that the 40% special project overhead rate for general expenses will apply to EEW funds as well.

projects and ongoing contracts, the budget estimates in this business plan are based on the assumption that Cal OES would either be able to negotiate a lower overhead rate or make purchases directly in order to avoid overhead charges. Assuming that Cal OES will manage the financial contracts for capital costs associated with using contractors to build primary microwave sites, connecting to partner microwave systems, and setting up the private IP network, no overhead was added to these cost categories. Costs associated with region-built microwave sites, fiber ring closings, and rebalancing spatial coverage, however, involve more hands-on work by USGS personnel and are therefore more analogous to costs involved with building seismic stations. The estimate for seismic stations applied general overhead rates to 70 percent capital costs and equipment overhead rates to 30 percent of capital costs. The USGS general overhead rate for state funds of 44.36 percent and an equipment overhead rate of 6 percent were applied accordingly to the cost estimates for these telemetry components.[67]

For ongoing costs, it is assumed that Cal OES will manage the ongoing financial contracts with partner microwave systems, the cell company for a private network, and partner Intranet costs, thereby avoiding overhead charges. The costs for replacing equipment were separately estimated, and a 6 percent overhead rate was applied. Since USGS personnel will be responsible for ongoing operations and maintenance of primary microwave sites, region-built microwave sites, fiber ring closings, and rebalanced sites, the USGS general overhead rate for state funds of 44.36 percent was applied to these costs.

9.6 Appendix F: One-Time and Ongoing Outreach and Education Costs

Estimated costs for a one-time public campaign and ongoing outreach and education were developed based on an analysis of previous, analogous public campaigns as well as interviews with individuals experienced in managing public campaigns and outreach and education programs. Experts from government agencies in California and Florida, public relations firms, the Joint Committee of Communication, Outreach, and Education (JCCEO), and outreach staff at Cal OES were consulted in developing these estimates.

The estimated budget amount of $9 million in one-time costs is based on the average cost for three public campaigns in California inflated to 2017-18 dollars: H1N1 Flu prevention in 2009-10 by the California Department of Public Health ($9.3 million), Save our Water Campaign in 2015 ($7.4 million), and Flex Alert ($10.5 million). These campaigns are analogous to early warning because they encouraged behavioral changes, sought to elicit a response to an alert, and reached Californians in multiple languages and cultural contexts. Existing funds of $2 million applicable to the one-time public campaign push reduces the total amount of funding needed to $7 million.

[67] USGS typically charges an overhead rate of 44.36% for equipment but agreed to a 6 percent rate for equipment with state funds in FY16/17. The rate of 6 percent assumes this agreement carries forward. If USGS begins charging 44.36% on equipment, then capital costs and ongoing costs would be higher.

9.6.1 Ongoing Outreach and Education Costs

The estimate for ongoing outreach and education costs was based on interviews with Cal OES personnel, JCCEO members, state government agencies in California and Florida, and public relations firms in California. The estimated annual cost of $2 million for ongoing research, creative development, and media buys for the public awareness campaign averages ongoing costs of three analogous campaigns inflated to 2017-18 dollars: 1) average annual spending on the Save Our Water campaign in the years surrounding the one-time push ($2.5 million), 2) average annual spending on Caltrans' ongoing campaign to encourage drivers to slow down in work zones (Give 'em a break, Slow for the Cone Zone, and Be Work Zone Alert) from 2000-2015 ($2.1 million), and 3) Florida's ongoing per capita spending for outreach on severe weather warnings adjusted to reflect to California's larger population ($1.5 million). These campaigns annually encourage behavioral changes and remind the public of optimal responses to specific situations and warnings.

10 APPENDIX G: ACRONYMS

AFN - Access and Functional Needs

ANSS - Advanced National Seismic System

BSL - Berkeley Seismological Laboratory

Cal OES - California Governor's Office of Emergency Services

Caltech - California Institute of Technology

Caltrans – California Department of Transportation

CEEWP - California Earthquake Early Warning Program

CEEWS - California Earthquake Early Warning System

CEO - Communication, Education, and Outreach

CEQA - California Environmental Quality Act

CGS - California Geological Survey

CISN - California Integrated Seismic Network

CSMIP - California Strong Motion Instrumentation Program

EEW - Earthquake Early Warning

EULA - End User Licensing Agreement

FEMA - Federal Emergency Management Agency

GNSS - Global Navigation and Satellite System

GPS - Global Positioning System

IT - Information Technology

JCCEO - Joint Committee for Communication, Education, and Outreach

MOA - Memorandum of Agreement

MOU - Memorandum of Understanding

NCSS - Northern California Seismic System

NOE - Notice of Exemption

NSF - National Science Foundation

O&M - Operation and Maintenance

PA – Public Address

PEER - Pacific Earthquake Engineering Research Center

PBO - Plate Boundary Observatory

PMG – Project Management Group

SCSN - Southern California Seismic Network

SSC - Alfred E. Alquist Seismic Safety Commission

UC - University of California

USGS - United State Geological Survey