LLOYD'S

Emerging Risk Report – 2015

NATURAL ENVIRONMENT

California Flood

Central Valley risk analysis

JBA consulting

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Disclaimer

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Executive summary

Although California is enduring its worst drought for 1,200 years, parts of the state remain highly and increasingly vulnerable to flooding.

Lloyd's commissioned JBA Consulting to estimate the likelihood and impact of a severe flood in California's Central Valley, which covers 19 counties, is home to 6.9 million people and contains $1 trillion of insurable assets, mostly agricultural.

Based on current estimates of population and assets, we assess that a 1-in-100-year event could result in $24.1 billion of damage, excluding demand surge or business interruption losses, which would likely be significant.

This estimate is made without considering the mitigating impact of defences. The Central Valley contains over 20,000km of levees and flood control structures, and around 150 reservoirs on tributaries.

However, we note that the standard of flood protection offered by these defences is highly variable. Generally, defences have a standard of protection for less than the 1-in-100-year flood. This level of protection will be eroded if infrastructure is not maintained. Analysis of the available data for some counties suggests that current budgets are insufficient to cover present and projected operation and maintenance costs.

We assess that, even if upkeep programmes maintain the 1-in-100-year protection, such protection will be gradually eroded by climate change. Climate change is likely to result in adjustments to the flood probabilities assigned to much of the Central Valley, with the 1-in-100 and 1-in-200-year floodplains enlarged.

Climate change will have implications for the US National Flood Insurance Program (NFIP), which provides subsidies to support take-up of flood insurance. The rising cost of climate change could add further costs to the programme.

The insurance industry can play a role in helping businesses and communities to better understand the potential risks they face from flooding and assist in mitigating these risks. The private insurance market currently provides 'surplus flood' cover above the NFIP limits and force placed cover, which is offered in conjunction with banks.

California is typically considered a potential growth market for flood insurance, but the Central Valley, in particular the Sacramento Valley, remains a challenging area to insure. The industry needs more sophisticated catastrophe modelling for the region and more investment in flood infrastructure.

We hope that the analysis in this report will support insurers to achieve more accurate risk-based pricing. This will ensure claims can be paid, and encourage responsible risk management. When this approach is combined with advanced modelling and forward-looking analysis, as outlined in this report, the private (re)insurance sector can and should play a major role in sustainable flood resilience.

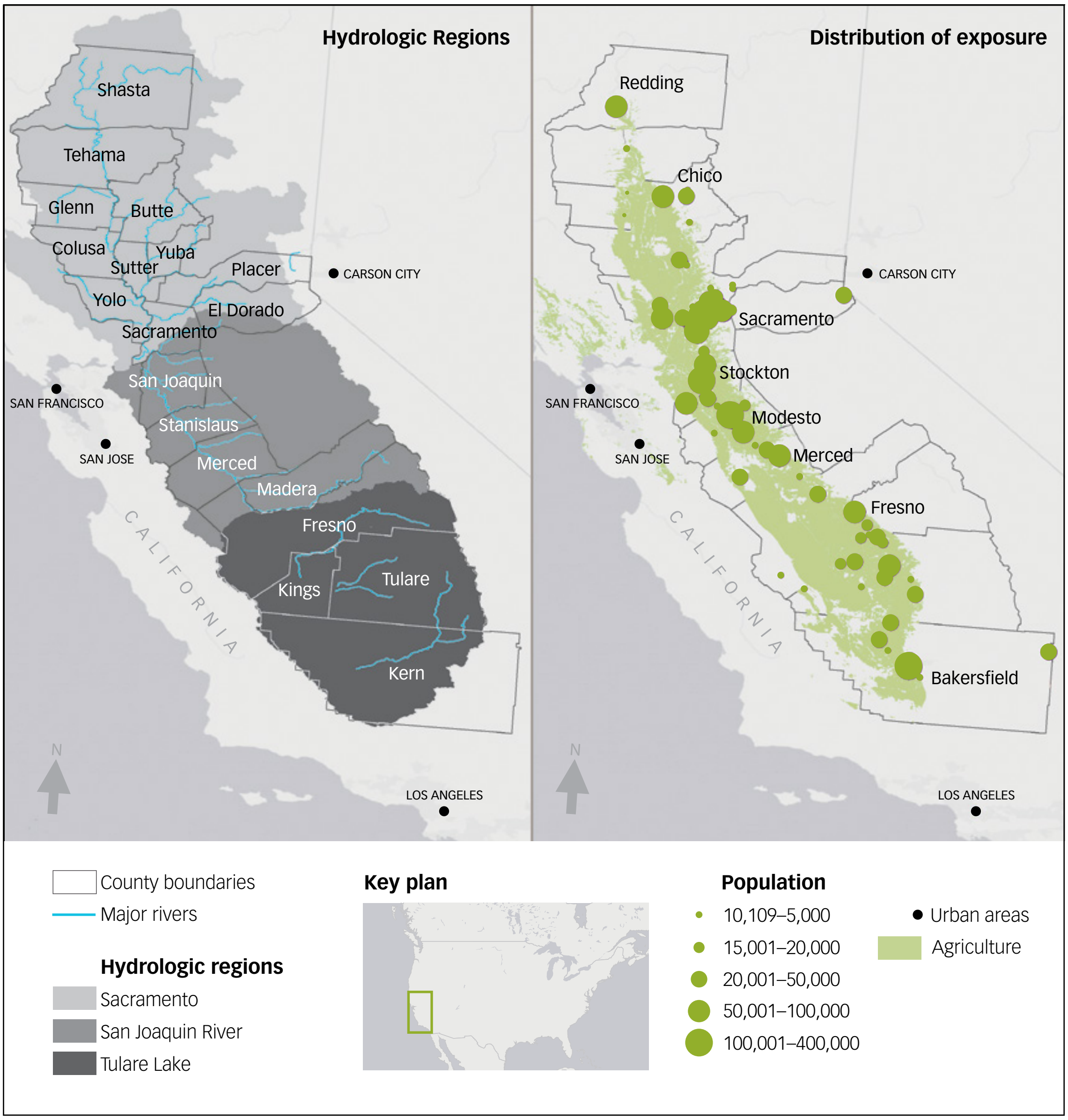
1 Exposure

California represents a considerable concentration of insured risk exposure, and over the last 60 years it has experienced more than 30 major flood events. These events have resulted in more than 300 lives lost, over 750 injuries and billions of dollars in disaster claims. Today, more than 7 million Californians, 20% of the state's population, live in the 1-in-500-year floodplain.[1]

The Central Valley dominates the state of California, covering 58,000km^2. It is 60–100km wide, 720km at its longest, covers 19 counties and mostly comprises highly productive agricultural land. The biggest centres of population are the cities of Fresno (509,000 residents), Sacramento (479,000 residents), Bakersfield (363,000 residents) and Stockton (298,000 residents).[2] The Sacramento River and San Joaquin River drain the northern and southern parts of the valley to San Francisco Bay; both have extensive floodplains reclaimed by raised flood banks.

Despite a long history of flood management and improvement throughout California, and in particular The Central Valley, significant floods in 1995 and 1997 generated over $1 billion in economic damage,[1] indicating both considerable risk and the potential for significant catastrophe losses.

Figure 1: Counties and hydrologic regions within the Central Valley (left) and distribution of exposure (population 2000 census) and agricultural land (right)



Exposure by line of business

Exposure information has been obtained from the Federal Emergency Management Agency (FEMA) Hazards United States (HAZUS) dataset.[3] This dataset provides the replacement value of buildings and contents at census block resolution. There are over 185,000 census blocks in the Central Valley, covering a population of approximately 6.9 million people and a total exposure value of over $1 trillion. The distribution of exposure across each line of business is provided in Table 1 below.

Residential/commercial/industrial

Residential and commercial exposure in the Central Valley is highly clustered in the main cities and in particular around Sacramento at the base of the Sacramento Valley (see Figure 1). Industry is spread across the Central Valley, though it represents only 16% of the California total as the majority of industry is located along the Californian coast.[1]

Agriculture

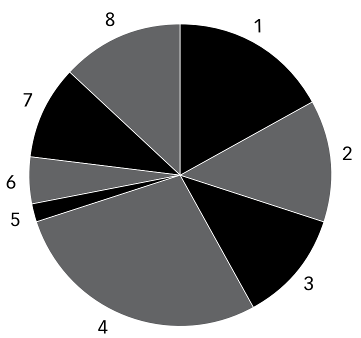
Agricultural production is a significant exposure element in the flat, fertile land of the Central Valley. In addition to the building and content replacement values in Table 1, crops are valued at $14 billion and are spread over 7.8 million acres of land.[1] Owing to the significance of agriculture in the region, major flooding in the Central Valley could severely impact the Californian economy, and both national and international food supplies. California provides reliable, affordable food domestically and globally and accounts for 12% of the US total, and exports $10.9 billion in agricultural goods worldwide.[4]

Agriculture is historically and currently an important part of the Central Valley's economy, but the economy is gradually diversifying into renewable energy, pharmaceuticals and service industries. Between 2000 and 2006, about 52,000 hectares of land in the Central Valley were converted into urban use. Of this, 28% was prime farmland.[4]

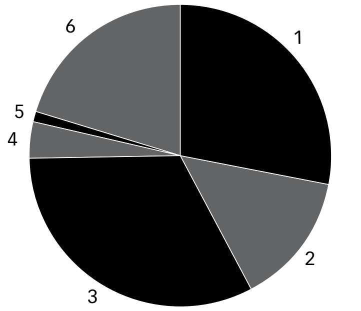
Table 1: Distribution of exposure by line of business, Central Valley California

Line of business	Number of buildings	Replacement value buildings and contents ($)
Residential	2,099,872	771.3bn
Commercial	27,359	165.5bn
Industrial	4,191	47.4bn
Agricultural	1,700	11.6bn
Municipal	5,271	39.4bn
Total	2,138,393	1,035.2bn

Figure 2: Distribution of commercial and industrial exposure by occupancy type



	Distribution of commercial exposure ($) by occupancy type	%
1	Retail trade	17
2	Wholesale trade	13
3	Personal and repair services	12
4	Professional and technical services	28
5	Banks	2
6	Hospitals	5
7	Medical offices and clinics	10
8	Entertainment and recreation	13



	Distribution of industrial exposure ($) by occupancy type	%
1	Heavy industry	28
2	Light industry	14
3	Food/drugs/chemicals	32
4	Metal/minerals pricing	4
5	High technology	1
6	Construction	20

2 Hazard

The Central Valley is the extensive floodplains of the San Joaquin and Sacramento Rivers which, prior to reclamation for agriculture and human habitation, were subject to regular and prolonged seasonal inundation.

Variations in weather, climate, hydrological conditions, soils, vegetation, land use and topography affect the type and severity of flood peril across California. Warning time, flood duration, water depth and damage caused vary with the type of flooding. Principal sources of flood peril in the Central Valley include:

- Failure of engineered structures, for example a dam or levee. This can have a possibly catastrophic impact depending on the volume of water released and downstream land use.
- Debris flow floods, consisting of water, liquid mud and debris. Common on de-vegetated burned hillsides, these can move quickly and travel great distances.
- Slow rise floods caused by heavy rain or snowmelt. Water levels take several days to peak, gradually overflowing river banks.
- Flash floods, often caused by intense storm rainfall on steep slopes or impermeable ground. Deep water can accumulate and disperse rapidly.
- Flooding on flat land where mountain rivers reach floodplains (areas known as alluvial fans), typically caused by locally intense rainfall. This leads to shallow flow with high velocity and sediment transport.
- Surface water flooding in urban areas, often from blocked or inadequate drainage. This is localised, and smaller in extent than other types of flooding.

The historical record over the last 100 years shows that the most catastrophic floods occur when heavy rainfall is combined with spring snowmelt. The result is high flows along the main river, causing levees/defence structures to overtop or breach.

JBA's Global Flood Hazard Maps for California have been used to quantify the potential exposure at risk to major river flooding. Design return period hazard maps are available for the 1-in-20, 1-in-50, 1-in-100, 1-in-200, 1-in-500 and 1-in-1,500-year return periods. While these maps represent only an approximation, and do not include defences, they do delineate the areas expected to flood with a given annual frequency and are widely used by insurers to assess potential exposures. Table 2 indicates the top five counties by percentage of area affected for the 1-in-100, 1-in-200 and 1-in-500-year return periods. While Sutter, Kings and Yolo counties are sparsely populated, San Joaquin and Sacramento contain major exposure concentrations.

Note that there is very little difference in the area flooded between return periods, indicating the large, flat nature of the Central Valley. Here, due to the topographical constraints (similar to a bathtub), the area affected does not significantly increase, though depths, and consequently damage, will increase with return period.

Table 2: Area and proportion flooded for top five counties in Central Valley for 1-in-100, 1-in-200 and 1-in-500 year return period hazard maps

		1-in-100 year		1-in-200 year		1-in-500 year	
County	Area (ha)	Area flooded (ha)	%	Area flooded (ha)	%	Area flooded (ha)	%
Sutter	362,851	136,404	37.6	138,112	38.1	141,831	39.1
Kings	899,634	274,874	30.6	282,697	31.4	294,585	32.7
Yolo	707,343	186,670	26.4	189,470	26.8	193,188	27.3
San Joaquin	929,516	206,284	22.2	214,795	23.1	228,047	24.5
Sacramento	592,197	118,028	19.9	119,969	20.3	122,698	20.7

3 Exposure at risk

By analysing the HAZUS data at census block resolution against JBA's Global Flood Map it is possible to calculate the potential exposure at risk to flooding within the Central Valley, as shown for the 1-in-200-year flood in Figure 3. The values presented do not indicate damage; instead the value exposed is a function of the proportion

Figure 3: Central Valley counties with proportion of area flooded by 1-in-200-year flood (based on JBA Global Flood Map data)

of area affected multiplied by the total values exposed. Furthermore, values are for an 'undefended' case, ie they assume that flood defence systems either fail in the case of flooding, or do not exist. Such a case can be viewed as extremely conservative, but nonetheless can be used to illustrate a worst case scenario from an insurance perspective. The values do not consider demand surge or business interruption losses.

Given the Central Valley's geographical size and shape, it is split into three hydrologic regions (see Figure 1). While historical events have shown that all counties across the Central Valley may be affected by the same storm, they are unlikely to be affected simultaneously.

Typically, prevailing westerly winds bring moisture-laden storms over the California coastal range and then eastward towards the Sierra Nevada mountains. Flooding across California can therefore last for several weeks. This issue is further compounded by repeated winter storms – locally termed the 'Pineapple Express' – bringing repeated heavy rainfall in saturated catchments. This process has been responsible for a number of major historical flood events and may lead to potentially complex (re)insurance event definitions. Having said this, it is more likely that (re)insurance events will be limited to individual or perhaps neighbouring hydrologic regions.

Table 3: Number and value of exposure at risk to flood in the 1-in-100 and 1-in-500-year return period

1-in-100-year flood extent

Line of business	Number of buildings at risk	% of total buildings in area	Replacement value ($) of buildings and contents at risk	% of total replacement value in area
Residential	134,133	6.4%	49.3bn	6.4%
Commercial	1,660	6.1%	9.8bn	5.9%
Industrial	280	6.7%	3.6bn	7.5%
Agricultural	180	10.6%	1.1bn	9.6%
Municipal	247	4.7%	2.0bn	5.2%
Accumulation	136,501	6.4%	65.8bn	6.4%
With crops			70.1bn	

1-in-500-year flood extent

Line of business	Number of buildings at risk	% of total buildings in area	Replacement value ($) of buildings and contents at risk	% of total replacement value in area
Residential	151,034	7.2%	55.4bn	7.2%
Commercial	1,940	7.1%	11.4bn	6.9%
Industrial	311	7.4%	3.9bn	8.3%
Agricultural	215	12.6%	1.3bn	11.4%
Municipal	313	5.9%	2.5bn	6.2%
Accumulation	153,813	7.2%	74.5bn	7.2%
With crops			80.4bn	

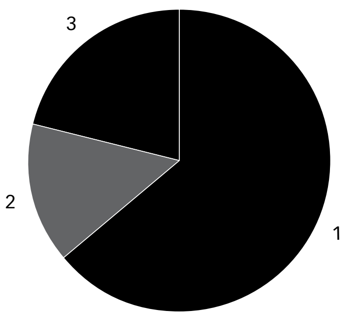
4 Potential accumulations

The figures presented in Section 3 consider the financial impact of a flood of a given frequency occurring simultaneously across the Central Valley. As the flood event of January 1997 demonstrates, while simultaneous flooding is possible, the severity of flooding and event timing may vary significantly. In reality, flood events vary spatially and temporally such that no single return period can predict the losses of a single event (although multiple smaller events may have a cumulative impact once flood storage capacity is filled). Given this, a more realistic accumulation is likely to occur within individual or neighbouring hydrologic regions. A breakdown of exposure by hydrologic region is provided in Table 4; a detailed breakdown of residential and agricultural crop exposure by region is at Figure 4. Here buildings and structure exposure is mostly concentrated within the Sacramento River region with $41.5 billion exposed to the 1-in-100-year flood extent.

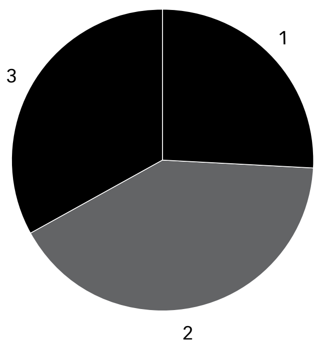
Table 4: Number and value of exposure at risk in the 1-in-100 and 1-in-500 year return period by hydrologic region

		Sacramento River hydrologic region		San Joaquin River hydrologic region		Tulare Lake hydrologic region	
		Number of risks	Value $	Number of risks	Value $	Number of risks	Value $
1-in-100-year flood extent	Residential	78,578	31.2bn	26,227	10.2bn	28,104	7.6bn
	Commercial	1,056	6.3bn	302	1.6bn	290	1.7bn
	Industrial	176	2.2bn	35	0.9bn	66	0.4bn
	Agricultural	82	0.5bn	64	0.2bn	33	0.4bn
	Municipal	157	1.2bn	47	0.4bn	43	0.5bn
	Accumulation	**80,049**	**41.5bn**	**26,675**	**13.3bn**	**28,536**	**10.6bn**
	With crops		**42.6bn**		**14.7bn**		**12.3bn**
		Number of risks	Value $	Number of risks	Value $	Number of risks	Value $
1-in-500-year flood extent	Residential	84,101	33.3bn	34,857	12.6bn	30,528	9.1bn
	Commercial	1,145	6.9bn	374	2.1bn	404	2.3bn
	Industrial	186	2.3bn	78	1.1bn	44	0.5bn
	Agricultural	93	0.6bn	41	0.2bn	79	0.5bn
	Municipal	196	1.4bn	58	0.5bn	59	0.6bn
	Accumulation	**85,721**	**44.5bn**	**35,408**	**16.5bn**	**31,114**	**12.9bn**
	With crops		**46.2bn**		**18.4bn**		**15.2bn**

Figure 4: Value at risk in the 1-in-100 year flood extent by hydrologic region



	Distribution of residential exposure by hydrologic region 1-in-100-year	%
1	Sacramento	64
2	Tulare Lake	15
3	San Joaquin River	21



	Distribution of crop exposure by hydrologic region 1-in-100-year	%
1	Sacramento	26
2	Tulare Lake	41
3	San Joaquin River	33

In order to rationalise these potential accumulations, present exposure is compared against the size and severity of flooding for a number of historical events. Ground-up losses have been estimated by applying indicative damage ratios based on the United States Army Corps of Engineers (USACE) depth damage functions[5] and JBA's modelled water depths. These ratios give typical damages of between 20 and 40% of the total property value. Exposure and a range of potential loss given these ratios is provided in Table 5 below. Insurance penetration, event windows, crop losses and (re)insurance terms and conditions are not considered. Two plausible events have also been developed for comparison. Further context is provided by Figure 5 which compares losses for the Lloyd's River Thames flood Realistic Disaster Scenario.

Table 5: Reported loss for historical events with present exposure and potential loss

Date	Affected hydrologic region/counties/cause	Reported economic loss	Exposure/potential loss today
January – March 1995	**Hydrologic region: Tulare Lake, Sacramento, San Joaquin River** Counties: Fresno, Kern, Kings, San Benito, Tulare, Butte, Contra Costa, El Dorado, Lake, Merced, Modoc, Napa, Nevada, Plumas, Sacramento, San Joaquin, Stanislaus, Shasta, Siskiyou, Solano, Tehama, Yuba Cause: An El Niño year contributed a string of subtropical storms that struck the region	$1.1bn	Exposure: $46.2bn Loss: $9.2–18.5bn
December 1996 – January 1997	**Hydrologic region: Tulare Lake, Sacramento, San Joaquin River** Counties: Alpine, Amador, Calaveras, Butte, Colusa, El Dorado, Glenn, Fresno, Lake, Madera, Mariposa, Merced, Modoc, Napa, Nevada, Placer, Plumas, Sacramento, San Joaquin, Stanislaus, Shasta, Sierra, Siskiyou, Tehama, Yolo, Sutter, Yuba, Kern, Kings, San Benito, Tuolumne, Tulare Cause: Prolonged high flows cause engineering failure	$1.8bn	Exposure: $60.3bn Loss: $12.1–24.1bn
February – May 1998	**Hydrologic region: Tulare Lake** Counties: Fresno, Kern, Kings, San Benito, Tulare Cause: El Niño conditions produced flooding throughout the spring	$0.041bn	Exposure: $10.7bn Loss: $2.1–4.3bn
December 2005 – January 2006	**Hydrologic region: Sacramento** COUNTIES: Alameda, Amador, Butte, Contra Costa, El Dorado, Fresno, Lake, Modoc, Napa, Nevada, Plumas, Sacramento, Shasta, Siskiyou, Solano, Yuba Cause: Sustained winter storms	$0.129bn	Exposure: $31.6bn Loss: $6.3–12.6bn
Plausible event 1	**Hydrologic region: Sacramento** COUNTIES: Butte, Colusa, El Dorado, Glenn, Placer, Nevada, Sacramento, Shutter, Yolo, Yuba CAUSE: Heavy rain in the Northeast Sacramento valley	N/A	Exposure: $38.0bn Loss: $7.6–15.2bn
Plausable event 2	CAUSE: Heavy rain in the east of Central Valley	N/A	Exposure: $27.8bn Loss: $5.6–11.1bn

Figure 5: River Thames, UK, Realistic Disaster Scenario

Source: Lloyd's Realistic Disaster Scenarios 2015

Comparison:
The River Thames, UK
Realistic Disaster Scenario

Residential	$6.7bn
Commercial/industrial	$2.4bn
Agriculture	$0.07bn
Motor	$0.07bn
Industry property loss of	$9.2bn

5 Mitigation

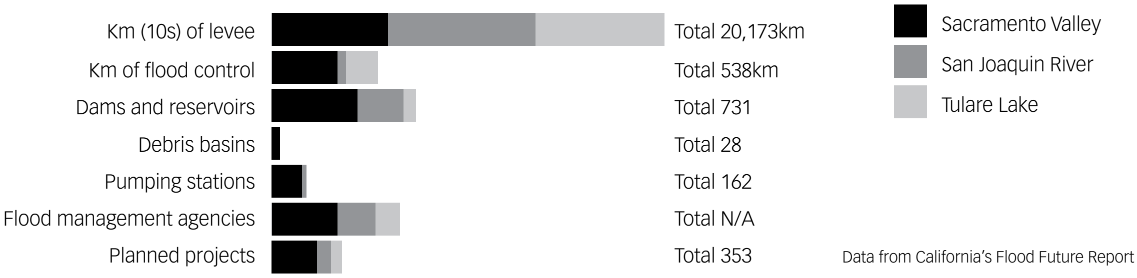
Despite having over 20,000km of levees and flood control structures, and some 150 reservoirs on tributaries, significant flood exposure remains in the Central Valley. Most watercourses draining catchments larger than 500km^2 in total are protected on both banks by levees, but the standard of protection is variable. Figure 6 summarises the existing flood protection infrastructure. Flood infrastructure must be maintained to perform to its design standard, which requires sufficient funding for operation and maintenance from federal or state partnerships with local agencies. Analysis of the available data for some counties in the Central Valley suggests that, given current and projected operation and maintenance costs, major budget deficits could arise if all ongoing and planned infrastructure projects are built.[1]

Expenditure on flood management reached a high in 2007 at $2.3 billion but slowly declined between 2008 and 2013. This has resulted in the available funding for flood infrastructure being directed more towards operating expenses than to new construction.[1]

Ten major reservoirs in the Central Valley are operated according to rules for flood control set out by USACE; generally these ensure that storage volume is available during the flood season so that run-off from the upper catchment does not overwhelm downstream channels. Specific adjustments to the rules may be made according to recent rainfall, soil moisture and snowpack. During a flood event the state, federal and local agencies work together to forecast river levels and run-off volumes, manage dam releases, maintain levees and operate weirs, pumps and other flood infrastructure.

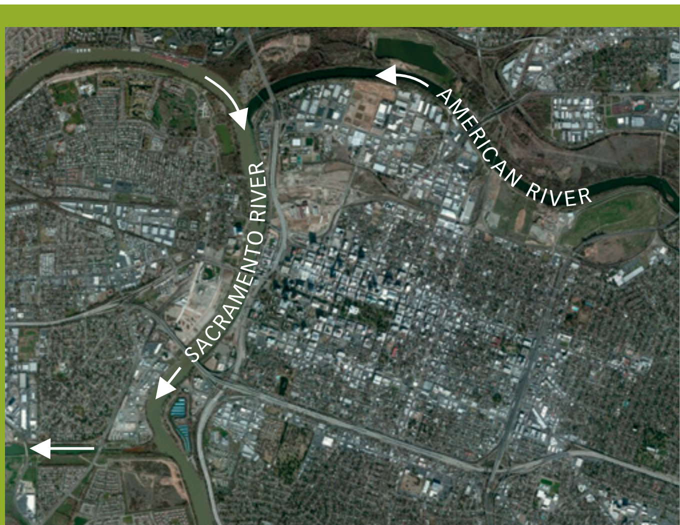
Management of flood infrastructure may be the responsibility of one or more local agencies, meaning overall control is complex and fragmented. Within the Central Valley hundreds of agencies have flood management responsibilities, including Irrigation Districts, Flood Control Districts, Conservation Districts, Levee Districts, city and county authorities.

Figure 6: Summary of flood management infrastructure in the Central Valley



Focus: Sacramento City

The flood infrastructure provides Sacramento City with protection against flood events with a 1-in-85-year return period. This is lower than for similar US cities. Levees protecting the city are old (some may be 100 years old) and were built gradually rather than to a uniform standard of protection. Flood defence relies on reservoir storage capacity and large bypass channels. Flood risk is expected to increase as climate change and an expanding population (to 900,000 by 2025) lower Sacramento's flood protection standard.



6 Insurance market

The National Flood Insurance Program

In 1968 the US Congress passed the National Flood Insurance Act, enabling property owners in participating communities to buy flood protection insurance backed by the federal government. This insurance scheme (the National Flood Insurance Program or NFIP), is managed by FEMA. Its primary intention was to reduce government liability for flood damage by replacing public disaster aid with pay-outs funded by insurance premiums from those living in risk areas. The programme was also designed to encourage development away from floodplains, and to require improved building standards and flood resilience for properties in floodplains.

Under the scheme, communities are eligible to participate in the NFIP if they agree to abide by floodplain management practices which will reduce future flood risks.[6] In the event of flood damage to their homes, insured owners that have purchased NFIP coverage can make a claim to cover flood-related losses. Together with the community commitment to reduce flood risk, this should limit federal aid costs from flood damage. Within Special Flood Hazard Areas (SFHAs),[7] purchase of NFIP insurance is mandatory to obtain a mortgage.

Some critics of the scheme believe it has failed to discourage building in SFHAs because flood control measures have actually encouraged further ill-advised floodplain development.[8]

Climate change is likely to result in adjustments to the flood probabilities assigned to much of the Central Valley, with the 1-in-100 and 1-in-200-year floodplains enlarged. This will have implications for the NFIP in terms of flood insurance costs, floodplain development and the economic viability of floodplain communities.[9]

In recent years borrowing from the US Treasury to cover the cost of NFIP claims has increased up to an estimated $24 billion.[10] A variety of factors contribute to this financial ill health, notably the losses incurred due to Hurricane Katrina and Superstorm Sandy. Ironically, when more property owners buy the insurance, the NFIP debt may increase as it must then make more payments following a flood. Although the law requires occupiers of all properties in the 1-in-100-year floodplain to buy flood insurance in order to obtain a mortgage from a federally backed lender, this does not always occur. Therefore, uninsured flood losses can be much higher than predicted. Additionally, the FEMA flood maps may under-represent flood risk from sources such as storm water or groundwater, resulting in uninsured claims for aid. NFIP premiums do not reflect real flood risk to a property, as they are based on historical claims information as opposed to catastrophe modelling, so the programme frequently pays out claims well in excess of the premium collected. Properties built before 1974, when flood mapping began, are eligible for lower premiums; however, these are often properties at high risk. If a property suffers repeated flood losses, a subsidised premium may even be applied, in some cases, despite previous claims exceeding the property value.

The NFIP has been subject to reform through the 2012 Biggert-Waters Flood Insurance Reform Act, which phased in risk-based premiums for certain properties including where flood mapping has been updated, and the 2014 Homeowner Flood Insurance Affordability Act, which repealed some of the steep premium increases authorised under Biggert-Waters but retained requirements for a gradual phasing-in of risk-based premiums.

Private insurance market

Private insurers are playing an increasing role in the US flood insurance market alongside the NFIP. The private insurance market currently provides 'surplus flood' cover above the NFIP limits and force placed cover, which is offered in conjunction with banks. The insurance industry can play a role in helping businesses and communities to better understand the potential risks they face from flooding and assist in mitigating these risks. California is typically considered a potential growth market for flood insurance, but the Central Valley, in particular the Sacramento Valley, remains a challenging area to insure. The industry needs more sophisticated catastrophe modelling for the region and more investment in flood infrastructure.

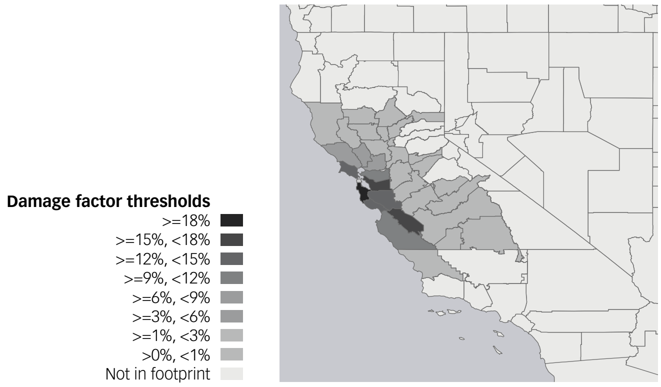
Flood compared with other perils

Due to a number of high profile events and high exposure in the San Francisco and Los Angeles area, there has been large investment in earthquake catastrophe modelling in this region. California overlies two tectonic plates, and the United States Geological Survey estimates that there is more than a 99% chance of the state experiencing a serious earthquake (magnitude 6.7 or greater) in the next 30 years.[11] Figure 7 below gives a comparison of potential Central Valley flood loss against potential earthquake losses from the Lloyd's Realistic Disaster Scenarios (RDS).[12]

Figure 7: Comparison of potential losses – Lloyds RDS 2015 – San Francisco and Los Angeles earthquake, vs. potential Central Valley flood

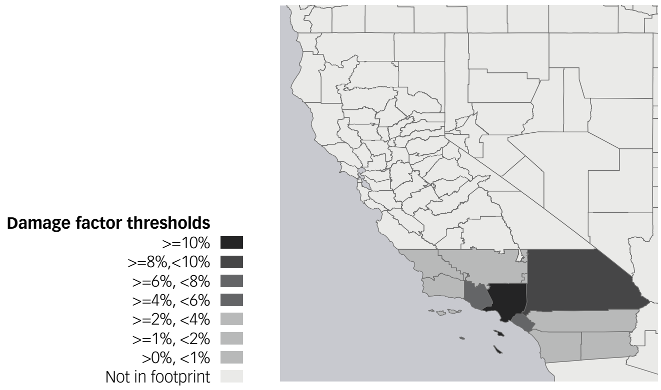
California earthquake: San Francisco

Residential property	$39.0bn
Commercial property	$39.0bn
Workers' compensation	$5.5bn
Marine	$2.25bn
Personal accident	$1.0bn
Auto	$1.0bn
Total	**$78bn**



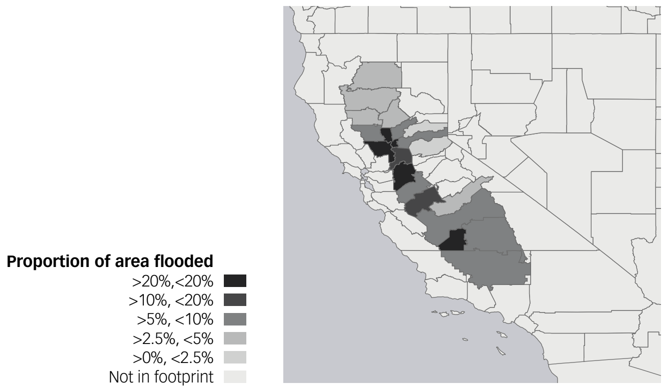
California earthquake: Los Angeles

Residential property	$36.0bn
Commercial property	$42.0bn
Workers' compensation	$5.5bn
Marine	$2.25bn
Personal Accident	$1.0bn
Auto	$1.0bn
Total	**$78bn**



Central Valley flood: Sacramento River

Residential property	$9.1–18.2bn
Commercial property	$1.8–4.5bn
Industrial	$0.7–1.3bn
Agricultural	$0.2–0.4bn
Municipal	$0.4–0.7bn
Total	**$12.1–24.1bn**



Note: RDS results give losses based on the Lloyd's suggested property distributions and modelled damage factors. Central Valley losses are based on the HAZUS exposure data and indicative damage estimates.

7 Conclusion

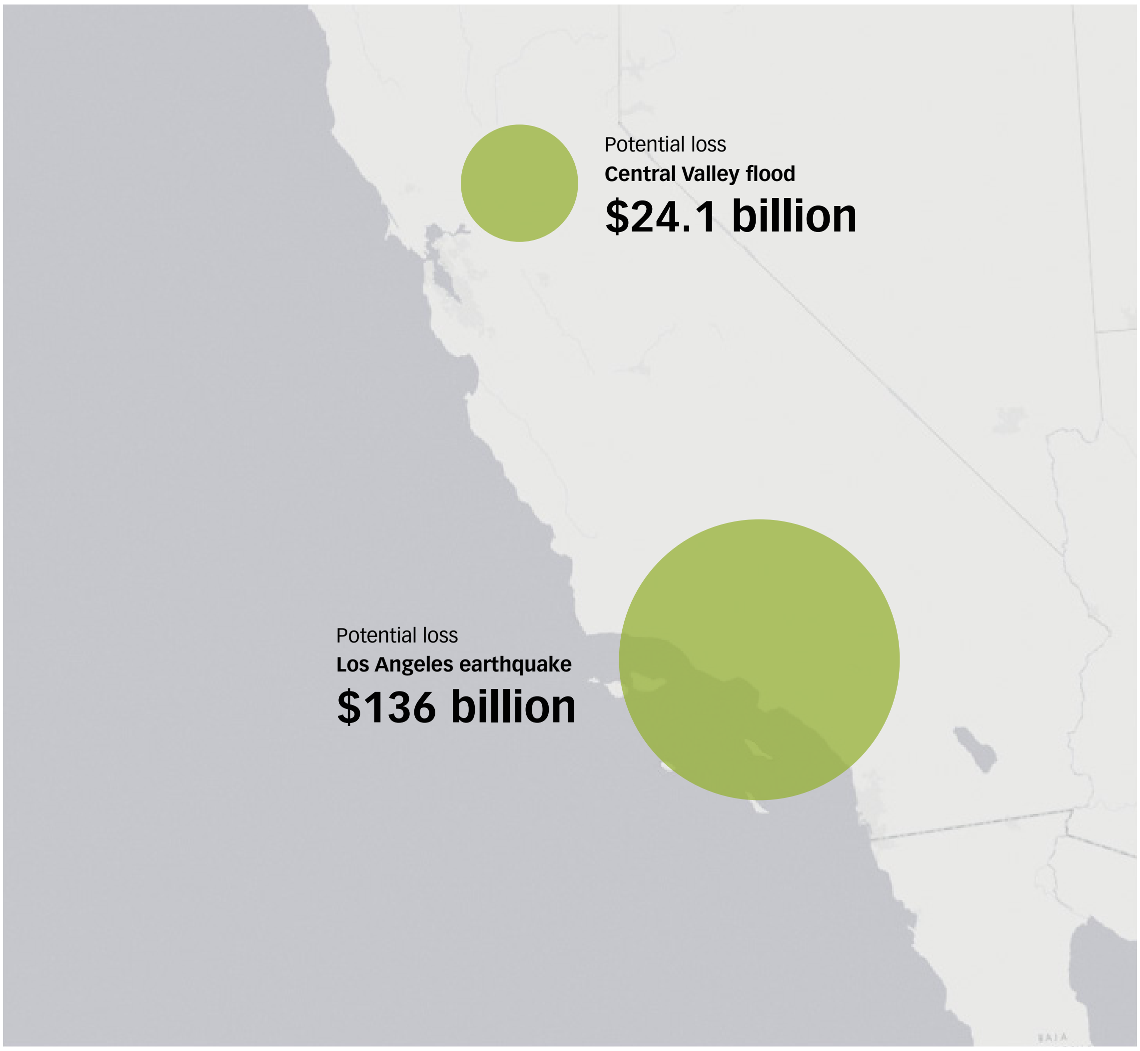
Flooding remains a significant natural peril in Central Valley, California. Although there are extensive flood defences in place, these generally have a standard of protection less than the 1-in-100-year flood; even if upkeep programmes maintain this protection, it is likely to be gradually eroded by climate change. Further, population expansion is likely to cause pressure for urban development on protected floodplains, thereby increasing risk.

With the benefit of recent flood modelling and mapping, it is relatively straightforward to estimate in detail the population at flood risk in Central Valley. It is much harder to assess the protection available against this risk and potential losses for property and agriculture.

Based on current estimates of population and assets, a likely event with an approximate 1-in-100-year return period could result in $24.1 billion of damage to floodplain assets in Central Valley. This can be compared with the estimate of damage from a severe earthquake of $136 billion (direct liability, 2010 property values)[13] (Figure 8).

In order to examine the potential exposures in more detail, a deterministic scenario could be developed or a full probabilistic catastrophe model could be used to build up a broad picture of potential losses and examine the uncertainty.

Figure 8: Comparative damages from Central Valley flood and Los Angeles earthquake



8 Endnotes

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