Background Document on Best Management Practices (BMPs) for Site-specific Non-water Release Corrective Action Plans
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California Department of Resources Recycling and Recovery (CalRecycle)

<u>Introduction</u>

The owners and operators of all disposal facilities required to be permitted as solid waste landfills and operating on or after July 1, 1991, are required to provide financial assurance for corrective action based on the highest amount of either the water release corrective action or non-water release corrective action. The regulations, Title 27, California Code of Regulations (CCR), Section 22100 et seq. allows a landfill owner or operator to determine the value of the non-water release corrective action fund through one of three methods: the site-specific non-water release Corrective Action Plan (CA Plan); the cost for replacement of the final cover; or the closure cost estimate for the landfill. If a landfill owner or operator selects to prepare a CA Plan, it requires an update in accordance with the regulations.
(http://www.calrecycle.ca.gov/lea/Regs/Implement/Postclosure/default.htm)

This document provides best management practices (BMPs) to assist owners and operators in developing sound cost estimates for corrective action in the CA Plan. The BMPs also assist CalRecycle and local enforcement agencies in minimizing resources needed for the regulatory review of the CA Plan. The plan is required to provide an assessment of the reasonably foreseeable impacts due to causal events and the costs to remediate those reasonably foreseeable impacts. Specific causal events identified in the regulations include earthquake, flood, precipitation, tsunami, seiche, and fire. This document includes:

- Definition and characterization of causal events;
- Consideration of what impacts ought to be considered for each causal event;
- Consideration of known releases;
- Evaluation of the final cover system;
- Requirements for containment and environmental monitoring and control systems to be maintained to standards; and
- Responses to frequently asked questions.

The BMPs do not change the required minimum standards for the siting, design, and operation of a solid waste landfill and do not provide recommendations on the methods for determination of the potential damage, required corrective action activities, and associated costs. It is expected that standard practices and methods will continue to be used to determine the potential damage, the required corrective action activities, and associated costs. The CA Plan requires evaluation of the potential impacts and associated corrective action activities based on causal events as shown in Table 1.

The BMPs do not address potential releases to groundwater or surface water from the disposal site that are part of the water release corrective action plan under the jurisdiction of the Regional Water Quality Control Boards.

General Scope and Applicability of BMPs

Best management practices (BMPs) are practical and effective processes, practices, or techniques to achieve a desired outcome. They are offered as “good ideas” that may need to be adjusted to account for individual needs or site-specific circumstances. BMPs are **not** rules, regulations, or mandatory standards. The scope of the BMPs is guidance for preparing the site-specific non-water release CA Plan prepared in lieu of using the cost estimates for final cover replacement. (http://www.calrecycle.ca.gov/Laws/Rulemaking/Postclosure/Phase2/default.htm)

The desired outcome for the BMPs for the CA Plan is to develop cost estimates based on sound science, engineering, and professional standards of practice to establish financial assurances to ensure that known or reasonably foreseeable corrective actions at solid waste landfills are accounted for with minimal financial risk to the state.

Technical Advisory Group

A technical advisory group (TAG) was established to assist CalRecycle staff in the development of the draft BMPs by providing comments, recommendations, and technical analysis and information. The TAG is comprised of stakeholders including the environmental community (Californians Against Waste and Sierra Club), solid waste industry (public and private), local enforcement agencies, the State Water Resources Control Board, and technical experts from state agencies and the consulting industry in the following areas: seismic, slope/soil stability, landfill cap design and repair, systems for monitoring and collecting landfill gases, leachate systems, erosion due to storms and flooding, and landfill fires.

What is Corrective Action?

Corrective Action means an activity, including restoring the integrity or establishing the adequacy of a damaged or inadequate containment structure or environmental monitoring or control system, to bring a landfill into compliance with the applicable requirements, prevent a reasonably foreseeable release, or remediate a known release to the environment. Examples of the structures and systems (as required by Title 14 CCR or Title 27 CCR) that may need corrective action would include, but not limited to, the cap and cover system, landfill gas monitoring and collection system, slopes, roads, run-on and run-off control (drainage) systems, vegetation and irrigation systems, and environmental monitoring and control systems.

Corrective action does not include routine maintenance. Routine maintenance is required to be addressed in the Title 27 CCR postclosure maintenance plan. Includes activities and associated costs for the maintenance and for replacement (when the useful life ends) of equipment and structures, including the final cover. Equipment and structures include the monitoring and control systems for landfill gas, and leachate and drainage systems (27 CCR Sections 21815 and 21840). These activities and estimates are required to be addressed in the CA Plan to ensure that all necessary replacement costs are accounted for and if the item is considered routine postclosure maintenance and not corrective action.

<u>What should be in a CA Plan?</u>

The CA Plan requires the following, pursuant to 27 CCR Section 22102:

- An evaluation of the known or reasonably foreseeable non-water release corrective action needed as a result of each known or reasonably foreseeable causal event;

- Cost estimates, prepared pursuant to 27 CCR Section 22101(c)-(f), for all known or reasonably foreseeable corrective actions described in the plan. The cost estimate with the highest amount must be used to determine the amount of financial assurance required pursuant to 27 CCR Section 22221(b)(2);

- An evaluation of the long-term performance of the final cover system to ensure that it will continue to meet the requirements of 27 CCR Section 21140 without the need for corrective action; and

- Provisions to restore the integrity or establish the adequacy of a damaged or inadequate containment structure or environmental monitoring or control system, to bring a landfill into compliance with the applicable requirements.

The CA Plan requires evaluation of each corrective action needed as a result of each causal event. The CA Plan requires, pursuant to 27 CCR Section 22102(c), to be prepared by a licensed third-party professional. The potential impacts requiring corrective action due to each causal event are identified in Table 1. Each evaluation should include the methodology used and assumptions; address how the systems and structures identified in the tables below will be affected; the corrective action needed to restore the systems and structures (as described in Table 2) to the minimum standards; and the associated costs. Attachment 1 is an example of how the costs can be summarized for each system or structure; a sheet would be used to address each causal event (Note: Attachment 1 provides an overall summary based on cost estimates prepared in accordance with 27 CCR Section 21815: CIWMB General Criteria for cost estimates).

Table 1

Causal Event 27 CCR §22100(c)(2)	Potential Impact Requiring Corrective Action §22100(c)(1)	Design Standards
Earthquake (seismic shaking, liquefaction, ground rupture)	Slope or containment failure with or without breach of cover system, including waste exposure; damage to environmental monitoring and control systems (gas, leachate, drainage).	Class III- MPE; not on Holocene fault; Class II/I- MCE and >200' from Holocene fault.
Flooding (regional flood inundation)	Inundation/washout of monitoring and control systems; erosion; slope failure; increased leachate/gas generation with potential for public contact.	Class III/II/I- 100-year flood.
Precipitation (high intensity storm event)	Washout of monitoring and control systems; erosion; waste exposure; slope failure.	Class III- 100-year 24-hour Class II- 1000-year 24-hour Class I- Probable Maximum Precipitation (PMP)
Tsunami (seismic sea wave) **Seiche** (natural wave in lake or bay)	Similar to earthquake, flooding, precipitation causal events.	NA
Fire (surface wildfire or subsurface landfill fire)	Destruction of monitoring and control systems and release of gas and leachate; subsurface fire may also cause collapse and breach of cover systems and related systems damage.	NA
Degraded/inadequate containment or environmental monitoring and control system	Containment systems and/or monitoring and control systems no longer capable of meeting applicable performance standards. Requires partial or complete replacement and/or upgrade and repair.	CalRecycle applicable Title 27 CCR

Table 2

Seismic Event Non-Water Release Corrective Action Component		Description of Activity	Notes
Cover System	Final Cover Vegetative Layer; Daily and Intermediate Cover	Earthwork and grading to cover waste and repair cracks, settlement, and slope failures. Replacement of vegetative layer.	Estimated quantities (acreage, cubic yards) based on total percentage of landfill footprint estimated to be damaged. Include mobilization, material acquisition, placement, construction surveys, and grading plan costs.
	Final Cover Barrier Layer	Removal and replacement of geosynthetic components (drainage, liner, gas collection) and reconstruction of compacted clay components.	Not applicable to monolithic systems or if site is active and estimates based on active site configuration. De Minimis if permanent deformation is ≤ 12 inches. Requires site-specific engineering plans and specifications and construction quality assurance. Estimate quantities based on portion of system breached and requiring repair.
Landfill Gas Collection and Control System	Extraction wells	Repair and/or removal and replacement of damaged collection system components and repair and restart of treatment device.	Not applicable to sites where landfill gas systems not required. Include disconnect/reconnect of gas collection system to allow for cover repair. Estimate number of wells, connector components, and linear feet of piping to be replaced and unit costs. Evaluate added lump sum operations and maintenance cost to immediately repair and restart treatment system.
	Header piping and connections		
	Flare or other treatment devices		
Drainage System	Open channels, pipes, downdrains, basins, appurtenances	Repair and/or removal and replacement of damaged structures.	Coordinate with cover system repair activities. Estimate as percentage damaged of total linear foot or lump sum drainage structures.
Erosion Control	Soil fills and cover	Seed/mulch and other erosion control structures to prevent erosion of soil exposed from corrective action grading activities.	Estimate acreage of disturbed area and unit costs; add lump sum or number/unit cost of erosion control structures. Include landscaping and irrigation systems if applicable.

BMPs for Causal Events and Known Releases

The following BMPs provide recommendations on how to evaluate the corrective action due to each reasonably foreseeable causal event in the CA Plan. Causal events include earthquake, flooding, tsunami, seiche, fire, and precipitation.

The specific location, design, operation, and maintenance of a landfill are critical factors in determining the impacts, if any, as a result of a causal event. Solid waste landfills, including systems and structures, are required to be designed and engineered to minimum standards. To determine what corrective action is necessary, the evaluation determines if the present design of the landfill can withstand each foreseeable causal event.

For each causal event, the BMP identifies when the causal event is not considered reasonably foreseeable (and the evaluation is not required) and the description of the causal event that should be evaluated in the CA Plan. References and sources of maps regarding each causal event are identified in Attachment 3. Staff considered the following in development of the BMPs:

- The causal event cannot be the required minimum design standards or siting requirements in Title 27 CCR;
- There is documentation that the causal event has occurred in California;
- The causal event is consistent with the state-of-the-practice methodology; and
- Evaluations by other governmental agencies on the likelihood that a causal event would occur in California.

Known Releases

If there is a known corrective action due to a known release, the CA Plan must address the known corrective action and associated costs. The most likely known non-water corrective action is likely to address a long-term landfill gas violation.

State regulations (27 CCR Sections 20917-20945) require all active solid waste landfills to have landfill gas monitoring systems to comply with the more definitive closed site standards. Furthermore, the California Air Resources Board regulations, "Methane Emissions from Municipal Solid Waste Landfills," which was effective on June 17, 2010, require the monitoring and control systems at solid waste landfills to control methane emissions. Compliance with these requirements should minimize reasonably foreseeable landfill gas releases. However, should postclosure land use change, property boundaries be rezoned toward the fill area, or offsite land use changed to more sensitive use, additional landfill gas monitoring and control measures and financial assurances may be required in the CA Plan. Additionally, landfills with long-term landfill gas violations are required to address the gas violations as a 'known release' in the CA Plan.

Landfills with known corrective action may be on the Inventory of Facilities Violating State Minimum Standards (see: http://www.calrecycle.ca.gov/SWFacilities/Enforcement/Inventory/Default.aspx).

Earthquake

An earthquake is a reasonably foreseeable causal event in California. The Working Group on California Earthquake Probabilities predicts that California has more than a 99 percent probability of an earthquake with a magnitude of 6.7 or greater in the next 30 years. Earthquakes can cause damage to a landfill and associated structures due to ground motion, liquefaction, or fault rupture. Fortunately, there are very few disposal facilities that are located within 200 feet of Holocene fault zones where fault rupture would likely result in the need for substantial reconstruction corrective action activities and costs.

Design standards are used to ensure that a structure is designed to withstand the ground movement and shaking resulting from a certain size earthquake taking into consideration the proximity and the geology between the location of the structure and faults. A solid waste landfill may be a Class II or Class III landfill. Pursuant to 27 CCR Section 20370, a Class III landfill must be designed to withstand the Maximum Probable Earthquake (MPE) and Class I and II landfills must be designed to withstand the Maximum Credible Earthquake (MCE). The Los Angeles Regional Water Quality Control Board (RWQCB) has required some Class III landfills to be designed to the MCE.

Use of the MPE or MCE is considered to be a deterministic seismic hazard analysis. The probabilistic seismic hazard analysis is referenced in recent building codes and the California Department of Water Resources (DWR) and consultants have stated that the probabilistic approach represents the state-of-the-practice for seismic evaluations. A critical factor in the probabilistic approach is the return period used in the analysis. The longer the return period, the likelihood of occurrence decreases while the magnitude of the earthquake increases. The California Building Code uses the 475-year return period for the design of most buildings; for hospitals a 950-year return period is used for collapse prevention; and for critical facilities a 2475-year return period is used.

Liquefaction

Another concern associated with earthquakes is liquefaction, when loose granular materials such as sands and silts below the water table behave like a liquid when shaken by an earthquake. The concern arises from the possibility of liquefaction in the soils which support the landfill structure. Soils in the state of liquefaction can liquefy and lose their ability to support structures or experience a loss of bearing strength. The landfill structure itself is composed of compacted soils and should not be saturated with water. The California Geological Survey and U.S. Geological Survey (USGS) have identified areas of California that are susceptible to liquefaction and landslides due to earthquakes. If a landfill in located within a “Seismic Hazard Zone,” a site-specific evaluation should be conducted for liquefaction and landslides.

BMP

CalRecycle staff considered two approaches used to assess the impacts of earthquakes: the deterministic approach as used in the regulations, and the probabilistic approach which is the state-of-the-practice. The BMP for an earthquake as a causal event allows for use of both approaches and takes into consideration the relative risk posed by a landfill in determining the return interval for a probabilistic evaluation. For the high risk landfill, a range of return periods is recommended to address the various factors that may cause a landfill to be considered high risk. Significant factors affecting the stability or impacts associated with failure such as poor engineering design, slope stability, or proximity to groundwater and urban areas may support the use of a higher return period. The BMP for an earthquake as a causal event is comprised of three elements to address the potential for (1) ground motion, (2) liquefaction and (3) fault rupture.

1. (a) Earthquake is not considered a reasonably foreseeable causal event, if a landfill is designed to the MCE or probabilistic evaluation using a 2475-year return period; and ≤ 12 inches of permanent deformation. The required corrective action is considered de minimus for ground motion and the cost estimate for corrective action is not required.

   (b) If the earthquake is considered a reasonably foreseeable causal event, an evaluation is required to determine the potential damage due to ground motion, the required corrective action, and the associated costs. The evaluation compares the design of the landfill to the MCE or uses a probabilistic evaluation using the return periods noted in the table below.

Seismic Design Standard	Not Reasonably Foreseeable	Landfill Risk Category	Return Period for Probabilistic Evaluation
MPE	MCE or a 2,475-year return period; and ≤ 12 inches permanent deformation.	Low (≤35)	200-year return period
		Medium (36-69)	475-year return period
		High (≥ 70)	475 to 950-year return period

2. If the landfill is located in a Seismic Hazard Zone, the CA Plan should evaluate the potential effects of liquefaction; and identify the required corrective action and costs.

3. If the landfill is located within 200 feet of a Holocene fault, the CA Plan should also evaluate for the potential damage from fault ruptures, identify the required corrective action and costs.

To determine the landfill risk, the CA Plan may use the method to rank the potential relative risk for a landfill that was developed as part of study conduct by ICF to assess the potential fiscal and environmental risks posed by landfills. Other methods may be used to determine the potential risk of a landfill. The ICF method considers 13 major characteristics as shown in Attachment 2 and assigns a value for each factor depending on the characteristics of the landfill. The methodology is contained in Chapter 5 of the "Study to Identify Potential Long-Term Threats and Financial Assurance Mechanisms for Long-Term Postclosure Maintenance and Corrective Action at Solid Waste Landfills, Nov. 26, 2007".
(http://www.calrecycle.ca.gov/archive/IWMBMtgDocs/mtgdocs/2007/12/00022762.pdf)

Flooding

Flooding is a reasonably foreseeable causal event, based on the document, "California's Top 15 Weather Events of 1900s" by the National Weather Service Forecast Office (http://nimbo.wrh.noaa.gov/pqr/paststorms/california10.php). Nine of the 15 events were associated with flooding. Potential damage at a landfills caused by a flood include inundation or washout of slopes, drainage systems, and other structures, including soil erosion or structure failure due to the force of the moving water. The location, elevation of the landfill, design (including the capacity of the drainage control system) and the level of maintenance of the run-on and run-off control systems are major factors in determining if a flood will adversely affect the landfill.

Examples of the type of non-water release damage that may result from a flood include severe erosion, destabilization of the landfill, and significance subsidence as discovered at the Crown Vantage Landfill in Alexandria Township, New Jersey. The Crown Vantage Landfill operated in the 1970s, is on the national Priorities List, and would not meet applicable siting criteria and the minimum standards. More information on this landfill and the efforts of U.S. EPA to stabilize the landfill can be obtained from http://nlquery.epa.gov/epasearch/epasearch?typeofsearch=area&querytext=crown+vantage&submit=Go&fld=oerrpage&areaname=Superfund&areacontacts=http%3A%2F%2Fwww.epa.gov%2Fsuperfund%2Fcontacts%2Findex.htm&areasearchurl=&result_template=epafiles_default.xsl&filter=sample3filt.hts

The required design standards for a solid waste landfill to address flooding are:

> 27 CCR Section 20260 (c): New Class III and existing Class II-2 landfills shall be designed, constructed, operated, and maintained to prevent inundation or washout due to floods with a 100-year return period. Solid waste landfills are also subject to additional siting requirements referenced in SWRCB Resolution No.93-62 (i.e., see sections 258.11, 258.12, and 258.16 of 40 CFR 258).

The Federal Emergency Management Agency (FEMA) has defined that moderate flood hazards are in areas between the 100-year and 500-year flood and minimal flood hazards are areas above the depth of the 500-year flood (Reference: 'Definitions of

FEMA Flood Zone Designations'). Flood zone maps may be obtained from the local flood control agency or the FEMA website, at http://www.fema.gov/ .

BMP

CalRecycle staff relied on the FEMA definitions for the flood zone designations to determine minimal and moderate flood hazards.

The BMP for the flood as a causal event is:

- Flooding is not considered a reasonable foreseeable causal event if the landfill is not located in the 500-year flood zone or the lowest elevation of the landfill perimeter is higher than the predicted elevation of the 500-year flood.
- For the purposes of determining corrective action, any landfill located within the 500-year flood zone should assess the potential damage resulting from the 500-year flood.

The evaluation for the flood causal event should include documentation as to the location of the landfill from the 500-year flood zone, shown as C or X (unshaded area) on a flood map. If the landfill is within the 500-year flood zone, the evaluation should include a comparison of the predicted elevation of the flood waters to the elevation of the lowest point of the landfill perimeter and an assessment of the potential for erosion and saturation due to the force of moving water or standing water. Such an evaluation should assess the potential impacts of the flood causal event as identified in Table 1, considering the capacity of the run-on and run-off control systems and the maintenance of the system to minimize blockage. If the capacity of the system is exceeded, an assessment of the potential soil erosion and impacts on the stability of slopes and supporting soils, damage to structures associated with environmental monitoring or control systems, and the landfill cover; and associated costs for replacement or repair should be included.

Tsunami

A tsunami is a sea wave(s) that may be generated by an earthquake, landslide, or volcanic eruption or even by a large meteor hitting the ocean. The California coast has experienced several tsunamis, some causing significant damage. It is anticipated that the types of damage caused by a tsunami would be similar to those resulting from a flood. The most devastating tsunami to affect California in recent history was from the magnitude 9.2 Alaska earthquake in 1964. Areas of Northern California experienced a six-meter (20-foot) tsunami wave that flooded low-lying communities, such as Crescent City, and river valleys, killing 11 people. Tsunamis are considered a reasonable foreseeable causal event as evidenced by historic tsunamis in California.

The regulations, 27 CCR Section 20240 (f), allows new and existing Class II units to be located in areas subject to tsunamis if the units are designed, constructed, and maintained to preclude failure due to the event. There is not a similar provision for Class III landfills.

BMP

CalRecycle staff relied on the evaluation by the Department of Conservation to identify areas of California that may be inundated by a tsunami and considered the siting requirements for Class II units.

The BMP for the tsunami as a causal event is:

- A tsunami is not considered a reasonable foreseeable causal event if the landfill is located in an area that is not designated to be prone to be inundated by a tsunami by the Department of Conservation or local emergency response agency.
- For landfills located in an area that is prone to be inundated by a tsunami, the CA Plan should address the potential impacts and damage that may result.

The evaluation for the tsunami causal event should include documentation that the landfill is not located in an area designated by the Department of Conservation or local emergency response agency. If the landfill is located in an area that may be inundated by a tsunami, the evaluation should include the predicted height of the waves and duration, with an assessment of the potential impacts of the predicted waves given the elevation of the landfill as identified in Table 1. The assessment should address the potential impacts with consideration of the amount of water and the velocity of the water in regards to erosion, instability of slopes, and damage to structures associated with environmental monitoring or control, and the landfill cover; and associated costs for replacement or repair.

Seiche

A seiche is a wave on the surface of a lake or landlocked bay caused by atmospheric or seismic disturbances and may be defined as an occasional rhythmic oscillation of water above and below the mean level of lakes or seas, lasting from a few minutes to an hour or more. Seiches are uncommon but have been known to have occurred in Lake Tahoe and the Great Lakes. Damage anticipated to result from a seiche would be similar to those from a flood or tsunami. In a 2003 report prepared by GeoSyntec Consultants, Inc, it was reported that eight California landfills were located near a bay or estuary. The report can be downloaded at:
http://www.calrecycle.ca.gov/Publications/default.asp?pubid=1046

The regulations, 27 CCR Section 20240 (f), allow new and existing Class II units to be located in areas subject to seiches if the units are designed, constructed, and maintained to preclude failure due to the event. There is not a similar provision for Class III units.

BMP

CalRecycle considered that a landfill requires proximity of a lake or landlocked bay to be affected by a seiche.

The BMP for the seiche as a causal event is:

- Seiche is not a reasonable foreseeable causal event if the landfill is located more than ½ mile away from a lake or a landlocked bay.
- A landfill that is located within ½ mile of a lake or landlocked bay should identify the height of the wave and evaluate if the wave will inundate the landfill and cause any damage.

The evaluation for the seiche causal event should include documentation that the landfill is not located within one-half mile of a lake or landlocked bay.

If the landfill is located within one-half mile of a lake or landlocked bay, the evaluation should include the predicted height of the waves and duration, with an assessment of the potential impacts of the predicted waves given the elevation of the landfill. The assessment should address the potential impacts as identified in Table 1 with consideration of the amount of water and the velocity of the water in regards to erosion, instability of slopes, and damage to structures associated with environmental monitoring or control, and the landfill cover; and associated costs for replacement or repair.

Precipitation

There are case studies that document damage to landfills caused by storms. Damage to the cover, displacement or exposure of waste, damage and clogging of the drainage system, and failure or erosion of slopes and roads can occur due to erosion of soil and inundation by water (Sunrise Mountain in Nevada, Jim Hogg County Landfill in Texas, and the Anderson report). In fall 2001 Jim Hogg County experienced several major rain events that caused serious flooding in the area. The floodwaters cut a trench, approximately 1,200 feet long, 30 feet wide and 15 feet deep through a disposal area of the landfill, displacing approximately 12,000 tons of waste material. These examples were primarily of closed landfills that may not have been maintained, but they are indications that storms are capable of causing significant damage to a landfill. Although every landfill is unique in its design and location, precipitation is a reasonable foreseeable causal event.

Landfills are required to maintain systems to control run-on and run-off due to precipitation during its active life and into the postclosure period. The systems are required to protect against a 100-year, 24-hour storm event (Class III landfills). Class I landfills are required to be designed to withstand the Probable Maximum Precipitation rain event and Class II landfills are designed to withstand the 1,000-year, 24-hour storm event. The 1,000-year 24-hour storm event is also used by DWR as a design standard for some dams. (http://www.water.ca.gov/damsafety/docs/fitz-paper.pdf

The Department of Water Resources, Bulletin 69-95, California High Water, October 2003) documents that 1,000-year 24 hour storm events have occurred in California on several occasions, thus the 1,000-year 24-hour storm event is a reasonably foreseeable causal event. (http://www.water.ca.gov/floodmgmt/docs/Bul69-95/00-bull69-95front.pdf)

BMP

CalRecycle staff considered that 1,000-year, 24-hour storm events have occurred in California and solid waste landfills that are Class II landfills are now required to be designed to withstand the 1,000-year, 24-hour storm event.

The BMP for precipitation as a causal event is the 1,000-year 24-hour storm event.

The evaluation for the precipitation causal event should include documentation for determination of the 1,000-year, 24-hour storm event. The evaluation should include the assessment of the capacity of the drainage system to properly manage the estimated quantity of water. If the capacity of the drainage system is exceeded, the assessment should address the potential impacts regards to erosion, instability of slopes, run-off, and damage to structures associated with environmental monitoring or control and the landfill cover, and associated costs for replacement or repair

Fires

Fires at a landfill are a reasonable foreseeable event and can be subsurface fires or wildfires. The intensity of a fire is influence by the location of the landfill, topography, weather conditions, management of wastes that are still smoldering, and vegetation type and density to fuel a fire. The recovery efforts to extinguish the fire and extent at which structural damage can be minimized is dependent on accessibility by firefighting personnel, availability of fire suppressant equipment, establishment of fire breaks, and exposure of environmental systems.

Subsurface fires

The most common cause of subsurface landfill fires is intrusion of oxygen into the waste prism, which increases the aerobic decomposition, resulting in the generation of methane and increased temperatures creating “hot spots” that ignite the methane gas resulting in a fire. Subsurface fires can cause damage to the landfill gas collection systems and potentially the intermediate and final cover. A landfill’s joint technical document and/or postclosure maintenance plan may contain provisions to prevent, monitor, and remediate subsurface fires. If not, subsurface fires should be addressed in the CA Plan.

Wildfires

Wildfires have been documented to destroy or damage all or portions of the landfill gas collection and monitoring systems, vegetation and irrigation systems designed to protect the cap and cover, drainage systems, and utility conveyance systems. The potential damage is dependent on mitigating circumstances such as whether the structures are buried to be protected from fires and if there are engineered mitigation measures such as fire breaks to protect against surface fires.

Staff received information on three recent fires at landfills in California: the Olinda Alpha Landfill in November 2008, Simi Valley Landfill in 2003, and Sunshine Canyon in November 2008. The damage caused by the fires varied significantly, from as little as $500 to more than $2 million. The information showed that highly combustible structures exposed to the fire were damaged or destroyed. At the Olinda Alpha Landfill, the fire encroached on the eastern and southern perimeter of the landfill destroying the above-ground landfill gas collection system piping and wellheads. Afterwards, the replaced landfill gas piping system was placed below ground as protection against future fires. It is interesting to note that although the fire burned for several days, other portions of the landfill did not sustain damage. The interior of the landfill was unaffected due to fire breaks and lack of vegetation. The potential damage to a landfill caused by fires can vary significantly depending on location, terrain, weather conditions, design, and mitigation factors.

<u>BMP</u>

CalRecycle staff considered the evaluation by California Department of Forestry and Fire Protection (CAL FIRE) and local fire agencies on the potential fire hazard for various portions of California, information on three recent landfill surface fires, and information on the CalRecycle website and in the literature regarding subsurface fires. The potential for surface fires is dependent on the proximity of the landfill to areas designated as moderate or very high/high fire hazard zones, as well as the design of the landfill. The design may mitigate the potential for surface fires or resulting damage through the installation of engineered fire breaks or by burying combustible structures. Other mitigating circumstances may include a vegetation control program or having firefighting equipment, water tanks, and trained firefighting staff at the landfill.

The BMP for a fire as a causal event is that landfills located within or adjacent to fire hazard zones determined by CAL FIRE, federal, or the local fire control agency as moderate/medium, or high/very high. Should evaluate the potential damage to structures that are required by Title 14 CCR or Title 27 CCR, vegetation and irrigation systems, and utilities; and other potential impacts as identified in Table 1.

- It is recommended that a baseline assumption that 50 percent***** of the combustible surface structures within 300 feet***** zone at or near the landfill cell boundaries are destroyed if the landfill is located in a high/very high fire hazard zone.

- It is recommended that a baseline assumption that 25 percent***** of the combustible surface structures within 200 feet***** zone at or near the landfill cell boundaries are destroyed if the landfill is located in a moderate/medium fire hazard zone.

- For landfills not located in the above zones, provide a contingency for repair or replacement of the combustible surface structures within 50 feet***** at or near the landfill cell boundaries.

*****The percentage of structures potentially destroyed and the extent at which the fire spreads should be discounted if there are mitigation measures including engineered systems such as berms or fire breaks; the combustible structures are buried; the presence of on-site personnel trained in fighting fires with the proper equipment and vehicles; or if there is routine maintenance plan to remove vegetation and ground debris that would provide fuel to the fire; or different climatic and topographic environment exist that is different than the baseline scenario. Conversely, the extent of combustible structures potentially destroyed should be increased if there is substantial vegetation or ground debris at the landfill interior that would fuel a fire; this may be the situation for a closed landfill that does not have a maintenance plan to control vegetation density.

The CA Plan should also address the potential for a subsurface fire. Subsurface fire prevention and control already reflected in the joint technical document and postclosure maintenance plan and cost estimates will not require duplicative cost analysis in the CA Plan; the BMP for the subsurface fire is to provide the costs necessary to employ one of several methods to extinguish a subsurface fire (as discussed at CalRecycle's website) or to provide a contingency to repair the cover and landfill gas collection system.

Evaluation of the Final Cover System

The regulation (27 CCR Section 22102 (a)(3)), also requires that the CA Plan, including updates and revisions, contain an evaluation of the long-term performance of the final cover system to ensure that the final cover system will continue to meet the requirements of 27 CCR Section 21140 without corrective action. Should the final cover no longer comply with 27 CCR Section 21140, repair or partial to complete replacement may be required. The permeability of final cover systems will likely degrade with time depending on the site and design and potentially to a less protective permeability level than the original design standard. Under such circumstances, non-water release corrective action would not be required unless the degradation results in violation of the applicable 27 CCR Section 21140 final cover performance standards.

The requirements of 27 CCR Section 21140 are:

> (a) The final cover shall function with minimum maintenance and provide waste containment to protect public health and safety by controlling at a minimum, vectors, fire, odor, and litter and landfill gas migration. The final cover shall also be compatible with postclosure land use.

(b) In proposing a final cover design meeting the requirements under 27 CCR Section 21090, the owner or operator shall assure that the proposal meets the requirements of this section. Alternative final cover designs shall meet the performance requirements of (a) and, for MSWLF units, 40 CFR 258.60(b); shall be approved by the enforcement agency (EA) for aspects of (a).

(c) The EA may require additional thickness, quality, and type of final cover depending on, but not limited to the following:

(1) A need to control landfill gas emissions and fires;
(2) The future reuse of the site; and
(3) Provide access to all areas of the site as needed for inspection of monitoring and control facilities, etc.

Degraded/Inadequate Containment or Environmental Monitoring and Control Systems

The regulations require that each CA Plan provide an analysis of the adequacy of the design, capacity, or component useful life of the containment or environmental monitoring and control systems as a causal event. Containment systems (e.g., final cover) and monitoring and control systems (e.g., landfill gas, leachate, and drainage systems) may significantly degrade or have inadequate design to prevent leachate, gas, or waste releases.

Repair or replacement of these systems or components will be required as part of the CA Plan if needed for compliance with applicable performance standards. Applicable standards include: 27 CCR Sections 20917-20945 (landfill gas) for all sites; for active sites, 27 CCR Sections 21600(b) (4) (design), 20790 (leachate), 20820 (drainage); and for closed sites, 27 Sections CCR 21140-21160 (final cover, grading, stability, leachate) and 27 CCR Section 21190 (postclosure land use).

Active vs. Closed Landfills

The financial assurance requirements for corrective action apply to active, closed, and closing solid waste landfills. It may be appropriate to have the CA Plan address the planned closed landfill configuration as defined in the closure and postclosure maintenance plans for the landfill if the landfill is active because of the anticipated long-term or indefinite postclosure maintenance period (when causal events are most likely to occur). Under this approach, the operator would need to demonstrate that the landfill configuration at any time during its active life would not result in a higher CA Plan cost estimate than the closed landfill configuration.

Alternatively, the operator may submit a CA Plan for the active landfill configuration as described in the Joint Technical Document, scaling back from full build out to progressive cumulative development phases provided the CA Plan addresses the configuration prior to the next plan update. Under this approach, an updated CA Plan with likely higher financial assurances would be required for new development phases and upon submittal of final closure and postclosure maintenance plans.

Frequently Asked Questions

A set of Frequently Asked Questions regarding the CA Plan and its preparation (CA Plans are required to be prepared by licensed third-party professionals pursuant to 27 CCR Section 22102(c)) and the responses are provided below:

1. In practice the “entity responsible for the design of the solid waste landfill” usually comprises a team of firms, consisting of a primary consultant, subconsultants, and contractors. The “entity” or engineer of record (PE or CEG) who signs off on the JTD/Closure Plan is typically the primary consultant. In this scenario, would the subconsultants and contractors be excluded from being on the third-party team?

   No. The regulations would only exclude the entity (primary consulting firm) and the engineer of record (PE or CEG).

2. We have had a case where a firm that designed our landfills and is the engineer of record was recently purchased as a subsidiary of another company. Would the parent company be excluded from being a third-party preparer despite not being involved in the design work?

   No, the regulations would not exclude the parent company from being a third-party preparer. The only regulatory restriction related to subsidiary/parental relationships is that associated with the owner/operator (27 CCR Section 22102(c) (1) (D)).

3. Similarly to number 2, a parent company that designed the landfill acquires a firm that was clearly eligible to be a third-party preparer prior to the acquisition. Does the firm lose its eligibility status under the new ownership?

   This one depends on the meaning of “acquires.” If the acquired firm remains a separate entity it would not lose its eligibility. If the acquired firm is subsumed by the “entity responsible for the design of the solid waste landfill” the acquired firm would lose its eligibility.

4. 27 CCR Section 22102 refers to the entity/engineer of record in the JTD/Closure Plan of the most recent SWFP. Throughout the life of a landfill, many different entities/engineers may have played a role in the design of the landfill and signed off on the JTD. Does the phrase “most recently issued SWFP” mean that previous entities/engineers that are not referenced in the most recently issued SWFP are now eligible third-party preparers?

   Yes, previous entities/engineers not referenced in the most recently issued SWFP would be eligible.

5. The design engineer of record would be excluded from being a third-party preparer. However, that engineer does not work alone. Would an individual from the design

team be eligible as third-party preparers assuming they left the entity and worked for another firm? Likewise, if the design engineer of record sought opportunities at another firm, could he/she be on the third-party team provided this individual did not sign off on the corrective action plan?

Yes to both. An individual from the design team would be eligible as a third-party preparer assuming they left the entity and worked for another firm. Likewise, if the design engineer of record sought opportunities at another firm, he/she could be on the third-party team provided this individual did not sign off on the corrective action plan.

6. Although 27 CCR Section 22102 explicitly refers to the JTD and Closure Plan, we assume that the entity/engineer of record for third-party eligibility determination also extends to the PCMP. Is this correct?

   Yes. Although 27 CCR Section 22102 does not explicitly refer to PCM plans it does reference 27 CCR Section 21780, which applies to both closure and PCM plans

7. Should the non-water release Corrective Action Plan address impacts on groundwater or water quality?

   AB 1220/Eastin (1993; PRC 43101) established that the State Water Resources Control Board and Regional Water Quality Control Boards (RWQCBs) are the sole agencies with authority to regulate solid waste for the purposes of water quality protection. The CalRecycle non-water release Corrective Action Plan requirements therefore exclude addressing impacts to water quality. However, the non-water release Corrective Action Plan is required to be submitted to RWQCBs for review. The RWQCBs may conclude that there are potential significant water quality impacts not otherwise addressed in the water-release Corrective Action Plan. The RWQCB may then require revisions to the water-release Plans and related requirements accordingly.

8. What is the timeframe to be addressed as part of the corrective action (what is considered long-term)?

   The requirements for providing financial assurance for corrective action are in effect during the entire period that the landfill is active and/or subject to postclosure maintenance requirements.

9. How are engineering flaws or failures addressed as part of corrective action?

   The regulations require that if an operator chooses to use the non-water release site-specific corrective action plan, the plan requires an analysis of the containment and environmental monitoring and control systems for adequacy with the applicable standards. If there are engineering flaws or failures that would prevent compliance with the applicable standards, the plan would need to address how the standards would be satisfied either through repair or replacement of the systems. If engineering flaws or failures require corrective action, the funds if needed may be used to remediate the flaws or failures.

10. How does one calculate the change from the MPE to the MCE?

An analysis should be completed to estimate the amount of deformation and ground acceleration based on each event and compare that to the design of the landfill to determine if there will be any damage and to what extent. It is not the intent of BMPs to recommend a methodology for this analysis. Methodologies that are standard practice will be considered acceptable.

11. How will the corrective action fund be used if a causal event resulted in both water and non-water corrective action or if the amount in the fund is not sufficient to cover the actual corrective action costs?

In adopting the corrective action financial assurances requirements, CalRecycle considered but did not require financial assurances for <u>both</u> the water release and non-water release Corrective Action Plans. The water release Corrective Action Plan or non-water release Corrective Action Plan cost estimate is required to be funded for the single Plan based on the highest estimate. It is likely that a causal event resulting in both a water release and non-water release requiring corrective action, that the amount in the fund will not cover both water and non-water corrective action. In such cases, CalRecycle and RWQCBs will collaborate, in conjunction with other local, state, and federal agencies to ensure public health and safety and the environment is protected while minimizing the use of public funds. Various potential enforcement and funding strategies are potentially available to CalRecycle and RWQCBs for such purposes and have been used successfully in similar cases.

12. Will there additional challenges to working with the RWQCBs since CalRecycle is no longer part of CalEPA?

The integration of the Integrated Waste Management Board's responsibilities into CalRecycle does not affect the working relationship with the RWQCBs. The provisions of AB 1220 are still in effect, PRC 43101 (c) (11) states that: "Responsibility for establishing and enforcing financial responsibility requirements for solid waste landfills, from operation through to cleanup, shall, to the greatest extent practicable and consistent with applicable federal law, be consolidated into one set of regulations administered by the board, in consultation with the state water board."

13. Should a contingency be used as part of the cost estimates for the non-water corrective action plan, similar to how a contingency is used to determine the closure costs?

The regulations regarding cost estimates for non-water corrective action do not require the use of a contingency. CalRecycle staff would support the use of a contingency in addition to the cost estimates to determine the amount of financial assurance required to address uncertainties such as unforeseen events or needed activities.

Attachment 1

Suggested Cost Estimating Tool
For Each Causal Event

Note: Attachment 1 provides an overall summary based on cost estimates prepared in accordance with 27 CCR Section 21815: CIWMB General Criteria for cost estimates

Damage	**Landfill Cover Corrective Action**	**Drainage System Corrective Action**	**Gas Collection System Corrective Action**	**Gas Monitoring System Corrective Action**	**Leachate Collection System Corrective Action**	**Site Security Corrective Action**	**Other Landfill Infrastructure Corrective Action**
100%	$ (AA)	$	$	$	$	$	$
90%	$	$	$	$	$	$	$
80%	$	$	$	$	$	$	$
70%	$	$	$	$	$	$	$
60%	$	$	$	$	$	$	$
50%	$	$	$	$	$	$	$
40%	$	$	$	$	$	$	$
30%	$	$	$	$	$	$	$
20%	$	$	$	$	$	$	$
10%	$	$	$	$	$	$	$

AA-Title 27, 22101(b) (1) which is the cost of complete replacement of the final cover.

Attachment 2

Landfill Risk Scoring Factors and Weightings

	Factor	Level of Risk			Value			
		High	Medium	Low	Highest Risk	Medium Risk	Lowest Risk	Highest Risk
1	Proximity to Urban Areas	In urban area		Not in urban area	10		0	10
2	Permitted Capacity	Greater than 30,000,000 cu yd	500,000 to 30,000,000 cu yd	Less than 500,000 cu yd	10	5	0	10
3	Type of Waste in Place	Pre-Subtitle D, co-disposal waste	MSW	Monofill, C&D	6	4	2	
4	Hydrogeology (from base of landfill)	Less than 50 ft	50 to 100 ft	Greater than 100 ft	10	5	0	10
5	Seismic Characteristics	No design	Most Probable Earthquake; below 1.5 factor of safety, but at least 1.3	Max Credible Earthquake; 1.5 or above factor of safety	6	4	2	
6	Rainfall Intensity	Not designed for 100 year/24 hour storm	100 year/24 hours storm	1000 year/24 hour storm	10	5	0	10
7	Floodplain (from base of landfill)	Within 100 year floodplain	Location within 500 feet of 100 year floodplain	Location not within 500 feet of 100 year floodplain	6	4	2	
8	Proximity to Sensitive Habitat	Sensitive species at location		No sensitive species at location	6		2	
9	Compliance Status	Current CA, cleanup or abatement orders	Past history of CA or ongoing/repeat violations	Compliant	8	5	2	
10	Engineering Controls	Combination of Subtitle D equivalent and non-Subtitle D equivalent design, or no Subtitle D design	Subtitle D equivalent design	Above Subtitle D design	10	5	0	10
11	Liquids Management/Landfill Bioreactor Technology	Neither	Permitted leachate recirculation	Bioreactor permitted	6	4	2	
12	Slope Stability	Side Slopes 2:1 or steeper, or history of slope failure	Side Slopes between 2:1 and 4:1	Side Slope shallower than 4:1	8	5	2	
13	Fire (intrusion from off site)	Adjacent Land Area with high fire hazard potential	Adjacent Land Area with moderate fire hazard potential	Adjacent Land Area with low fire hazard	4	3	2	
					100	49	16	50

The methodology is contained in Chapter 5 of the “Study to Identify Potential Long-Term Threats and Financial Assurance Mechanisms for Long-Term Postclosure Maintenance and Corrective Action at Solid Waste Landfills, Nov. 26, 2007” http://www.calrecycle.ca.gov/archive/IWMBMtgDocs/mtgdocs/2007/12/00022762.pdf

Attachment 3

Detailed discussion and sources of information for Causal Events

Earthquakes

An earthquake is a reasonable foreseeable causal event in California. The Working Group on California Earthquake Probabilities predicts that California has more than a 99 percent probability of an earthquake with a magnitude of 6.7 or greater in the next 30 years. Earthquakes can cause damage to a landfill and associated structures due to ground motions, liquefaction, or fault rupture. Fortunately, there are very few sites on or within 200 feet of Holocene fault zones where fault rupture would likely result in the need for substantial reconstruction corrective action activities and costs. Design standards are used to ensure that a structure is designed to withstand the ground movement and shaking resulting from a certain size earthquake taking into consideration the proximity and the geology between the location of the structure and faults.

Pursuant to 27 CCR Section 20370, a Class III landfill must be designed to withstand the Maximum Probable Earthquake (MPE) and a Class II landfill must be designed to withstand the Maximum Credible Earthquake (MCE). The Los Angeles Regional Water Quality Control Board (RWQCB) has required the MCE for some Class III landfills. On a voluntarily basis or as required by the RWQCB, more Class III landfills are designed to the MCE standard which minimizes potential corrective action and the associated costs due to damage from an earthquake. For a landfill designed to the MCE, any costs should already be accommodated as part of routine postclosure maintenance.

The MPE is defined in Title 27 as, "The maximum earthquake that is likely to occur during a 100-year interval," and the MCE is defined as, "The maximum earthquake that appears capable of occurring under presently known geologic framework." MCEs are required to be used in the design of structures such as dams, bridges, and hazardous waste landfills.

Use of the MPE or MCE is considered to be a deterministic approach in assessing the effects of an earthquake. In a deterministic approach, the evaluation considered the largest and closest fault to determine the level of ground motion. The probabilistic approach is referenced in the more recent building codes. The California Department of Water Resources (DWR) and consultants have stated that the probabilistic approach represents the state-of-the-practice for seismic evaluations. The probabilistic approach considers all possible faults, including the probability of a rupture, and the ground motion is statistically computed.

The following descriptions of the deterministic approach, probabilistic approach, and MCE are from the "Federal Guidelines for Dam Safety," FEMA, May 2005. Another reference regarding the use of deterministic and probabilistic seismic hazard analysis is

"Guidelines for Evaluating and Mitigating Seismic Hazards in California," California Geological Survey, 2008.

- **"Deterministic Seismic Hazard Analysis (DSHA)** The DSHA approach uses the known seismic sources near the site and available historical seismic and geological data to generate discrete single-valued events or models of ground motion at the site. Typically, one or more earthquakes that will produce the greatest ground motion at the site are specified by magnitude and location with respect to the site. Usually, the earthquakes are assumed to occur on the portion of the source closest to the site. The site ground motion parameters (peak ground acceleration/velocity, spectrum intensities, duration of strong shaking, etc.) are estimated deterministically for each source, given the magnitude, source-to-site distance, and site conditions, using an attenuation relationship and/or theoretical models."

- **"Probabilistic Seismic Hazard Analysis (PSHA)** The PSHA approach uses the elements of the DSHA and adds an assessment of the likelihood that ground motions of a given magnitude would occur. The probability or frequency of occurrence of different magnitude earthquakes on each significant seismic source and inherent uncertainties are directly accounted for in the analysis. The possible occurrence of each magnitude earthquake at any part of a source (including the closest location to the site) is directly incorporated in a PSHA. The results of a PSHA are used to select the design earthquake ground motion parameters based on the probability of exceeding a given parameter level during the service life of the structure or for a given return period. Results from the PSHA approach can also be used to identify which combinations of magnitudes and distances (or specific seismic sources) are the largest contributor to a hazard. Identification of these controlling earthquakes can then be used in scenario or DSHA analyses. Several of the federal agencies are currently developing guidelines on procedures to follow when performing a PSHA study."

- **"Determining Maximum Credible Earthquakes.** The MCE for each potential earthquake source, judged to have a significant influence on the site, is established by a DSHA based on the results of a seismotectonic study (site-specific investigations and/or literature review). The MCE for each seismotectonic structure or source area within the region examined is defined preferably by magnitude, but in some cases in terms of epicentral Modified Mercalli Intensity, distance, and focal depth. Earthquake recurrence relationships (i.e., the frequency of occurrence of earthquakes of different sizes if appropriate for the fault) should also be established for the significant seismic sources. For source zones consisting of random seismicity, an MCE can be determined by finding the magnitude and distance that best matches the equal hazard response spectrum from a PSHA in the design earthquake frequency range appropriate for the structure. Judgments on activity of each potential fault source are generally based on recency of the last movement. For high-hazard potential dams, movement of faults within the range of 35,000 to 100,000 years BP is considered recent enough to warrant an "active" or "capable" classification. All of the above MCE assessments for the various earthquake sources are candidates for one or more controlling MCEs at the site. It is also important to look at earthquakes that have a long duration but not necessarily the highest peak acceleration at the dam site. For embankment dams and foundations subject to liquefaction, this longer duration earthquake may be the controlling event if it triggers liquefaction of the embankment/foundation materials. Other appurtenant structures should be evaluated to determine if a higher magnitude distant earthquake is critical to the overall stability of the structure."

Another concern associated with earthquakes is when liquefaction occurs, when loose granular materials such as sands and silts below the water table can behave like a liquid when shaken by an earthquake. The landfill structure itself is composed of compacted soils and should not be saturated with water. The concern arises from the possibility of liquefaction in the soils which support the landfill structure. Soils in the state of liquefaction can liquefy and lose their ability to support structures or experience a loss of bearing strength. The California Geological Survey and US Geological Survey (USGS) have identified areas of California that are susceptible to liquefaction and landslides due to earthquakes. If a landfill in located within a "Seismic Hazard Zone," a site specific evaluation should be conducted for liquefaction and landslides.

"Seismic Hazard Zones" have been established by the USGS and the California Geological Survey in order to provide the general public, land-use planners, utilities and lifeline owners, and emergency response officials, tools in which to assess their risks from earthquake damage. The hazard zone maps can be found at the USGS and California Geological Survey's website
http://www.conservation.ca.gov/cgs/shzp/Pages/Index.aspx

Damage to landfills from an earthquake may be due to fault displacement or to secondary hazards such as slope instability or liquefaction of the foundation. Potential damage to a landfill resulting from an earthquake includes:

- Liner and cover systems;
- Landfill gas control system;
- Surface water and drainage control systems;
- Foundation due to liquefaction and landslides; and
- Other potential damage may include settlement, slope failure, increased cracking of the final cover, shearing of wells and headers, and failure of structures, roads, irrigation systems and utility systems.

(Reference: RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, EPA/600/R-95/051, April 1995)

Since the deterministic approach is used in the regulations and the probabilistic approach is state-of-the-practice for evaluating potential seismic activity, the BMP for an earthquake as a causal event allows for use of both approaches and takes into consideration the potential risk posed by a landfill in determining the return interval for a probabilistic evaluation.

A method has been developed to rank a landfill as posing a high, medium, or low potential risk. The method was developed as part of study conduct by ICF to assess the potential fiscal and environmental risks posed by landfills. The method considers 13 major characteristics: seismic; rainfall intensity; floodplain; fire (intrusion from off-site); engineering controls; permitted capacity; type of waste in place; slope stability; liquids management/ landfill bioreactor technology; hydrogeology; proximity to urban areas; proximity to sensitive habitat; and compliance status. The methodology is contained in Chapter 5 of the "Study to Identify Potential Long-Term Threats and Financial Assurance Mechanisms for Long-Term Postclosure Maintenance and Corrective Action at Solid Waste Landfills," Nov. 26, 2007
http://www.calrecycle.ca.gov/archive/IWMBMtgDocs/mtgdocs/2007/12/00022762.pdf

Flooding

Flooding is a reasonably foreseeable causal event, based on the document; "California's Top 15 Weather Events of 1900s" by the National Weather Service Forecast Office (http://nimbo.wrh.noaa.gov/pqr/paststorms/california10.php), nine of the 15 events were associated with flooding. Several agencies implement programs regarding flooding, including the USGS, California Department of Water Resources, FEMA, California Emergency Management Agency (Cal EMA), local flood control agencies, or local water districts. These agencies are excellent sources of information on potential flood events and past storm events for a specific location, including the potential height of the flood waters.

Flooding can be caused by storms, spring thaw, heavy rains, and changes in the landscape due to fires or development, failure of engineered designed flood control systems such as levees or dams, or flash flooding. Other than failure of a levee or dam or a heavy spring thaw, usually intense rainfall is the cause of flooding.

Damage at landfills due to a flood is caused by inundation or washout of slopes, drainage systems, and other structures, including soil erosion or structure failure due to the force of the moving water. The location, elevation, and design of a landfill, including capacity and the level of maintenance of the run-on and run-off control systems, are major factors in determining if a flood will adversely affect the landfill.

Examples of the type of non-water release damage that may result from a flood include severe erosion, destabilization of the landfill, and significance subsidence as discovered at the Crown Vantage Landfill in Alexandria Township, N.J. The Crown Vantage Landfill operated in the 1970s, is on the National Priorities List, and would not meet applicable siting criteria and the minimum standards. More information on this landfill and the efforts of U.S. EPA to stabilize the landfill can be obtained from
http://nlquery.epa.gov/epasearch/epasearch?typeofsearch=area&querytext=crown+vantage&submit=Go&fld=oerrpage&areaname=Superfund&areacontacts=http%3A%2F%2Fwww.epa.gov%2Fsuperfund%2Fcontacts%2Findex.htm&areasearchurl=&result_template=epafiles_default.xsl&filter=sample3filt.hts

The required design standards for a solid waste landfill to address flooding are:

27 CCR Section 20260 (c): New Class III and existing Class II-2 landfills shall be designed, constructed, operated, and maintained to prevent inundation or washout due to floods with a 100-year return period. MSW landfills are also subject to any more-stringent flood plain and wetland siting requirements referenced in SWRCB Resolution No.93-62 (i.e., see Sections 258.11, 258.12, and 258.16 of 40CFR258).

The return period is commonly referred to as the recurrence level or for the 100-year return period, also commonly referred to as the “100-year flood.” Flood maps, formally known as Flood Insurance Rate Maps, or FIRMs, for the 100-year and 500-year flood are readily available from FEMA. The FIRMs are used to determine if flood insurance is required and the potential for various degrees of flooding. FEMA, through the National Flood Insurance Program managed and implemented through FEMA in cooperation with local governments and property owners, determines the degree of flood hazard in a given location. FEMA has considered that moderate flood hazards are in areas between the 100-year and 500-year flood and minimal flood hazards are areas above the depth of the 500-year flood. (reference: ‘Definitions of FEMA Flood Zone Designations’) Flood zone maps may be obtained from the local flood control agency or the FEMA website at: www.fema.gov .

Understanding Flood Areas (from the National Flood Insurance Program website http://www.fema.gov/about/programs/nfip/index.shtm)

Flooding can happen anywhere, but certain areas are especially prone to serious flooding. To help communities understand their risk, flood maps (Flood Insurance Rate Maps, FIRMs) have been created to show the locations of high-risk, moderate-to-low risk, and undetermined-risk areas. Here are the definitions for each:

High-risk areas (Special Flood Hazard Area or SFHA)
High-risk areas have at least a 1 percent annual chance of flooding, which equates to a 26 percent chance of flooding over the life of a 30-year mortgage. All homeowners in these areas with mortgages from federally regulated or insured lenders are required to buy flood insurance. They are shown on the flood maps as zones labeled with the letters A or V. The FIRMs identify these shaded areas as Zones A, AO, AH, A1-A30, AE, A99, AR, V, V1-30, and VE.

Moderate-to-low risk areas (Non-Special Flood Hazard Area or NSFHA)
In moderate-to-low risk areas, the risk of being flooded is reduced, but not completely removed. These areas are outside the 1 percent annual flood-risk floodplain areas, so flood insurance isn’t required, but it is recommended for all property owners and renters. They are shown on flood maps as zones labeled with the letters B, C or X (or a shaded X).

Undetermined risk areas
No flood-hazard analysis has been conducted in these areas, but a flood risk still exists.

Flood insurance rates reflect the uncertainty of the flood risk. These areas are labeled with the letter D on the flood maps.

The definitions of the FEMA Flood Zone Designations are provided in the table below:

100-Year Flood: (also called the Base Flood) is the flood having a 1 percent chance of being equaled or exceeded in magnitude in any given year. Contrary to popular belief, it is not a flood occurring once every 100 years.

100-Year Floodplain: The area adjoining a river, stream, or watercourse covered by water in the event of a 100-year flood.

Zone A	The 100-year or base floodplain. There are six types of A Zones: **A** The base floodplain mapped by approximate methods, *i.e.*, BFEs are not determined. This is often called an unnumbered A Zone or an approximate A Zone. **A1-30** These are known as numbered A Zones (*e.g.*, A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format). **AE** The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones. **AO** The base floodplain with sheet flow, ponding, or shallow flooding. Base flood depths (feet above ground) are provided. **AH** Shallow flooding base floodplain. BFEs are provided. **A99** Area to be protected from base flood by levees or Federal Flood Protection Systems under construction. BFEs are not determined. **AR** The base floodplain that results from the decertification of a previously accredited flood protection system that is in the process of being restored to provide a 100-year or greater level of flood protection.
Zone V and VE	**V** The coastal area subject to a velocity hazard (wave action) where BFEs are not determined on the FIRM. **VE** The coastal area subject to a velocity hazard (wave action) where BFEs are provided on the FIRM.
Zone B and Zone X (shaded)	Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from the 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile.
Zone C and Zone X (unshaded)	Area of minimal flood hazard, usually depicted on FIRMs as above the 500-year flood level. Zone C may have ponding and local drainage problems that don't warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood and protected by levee from 100-year flood.
Zone D	Area of undetermined but possible flood hazards.

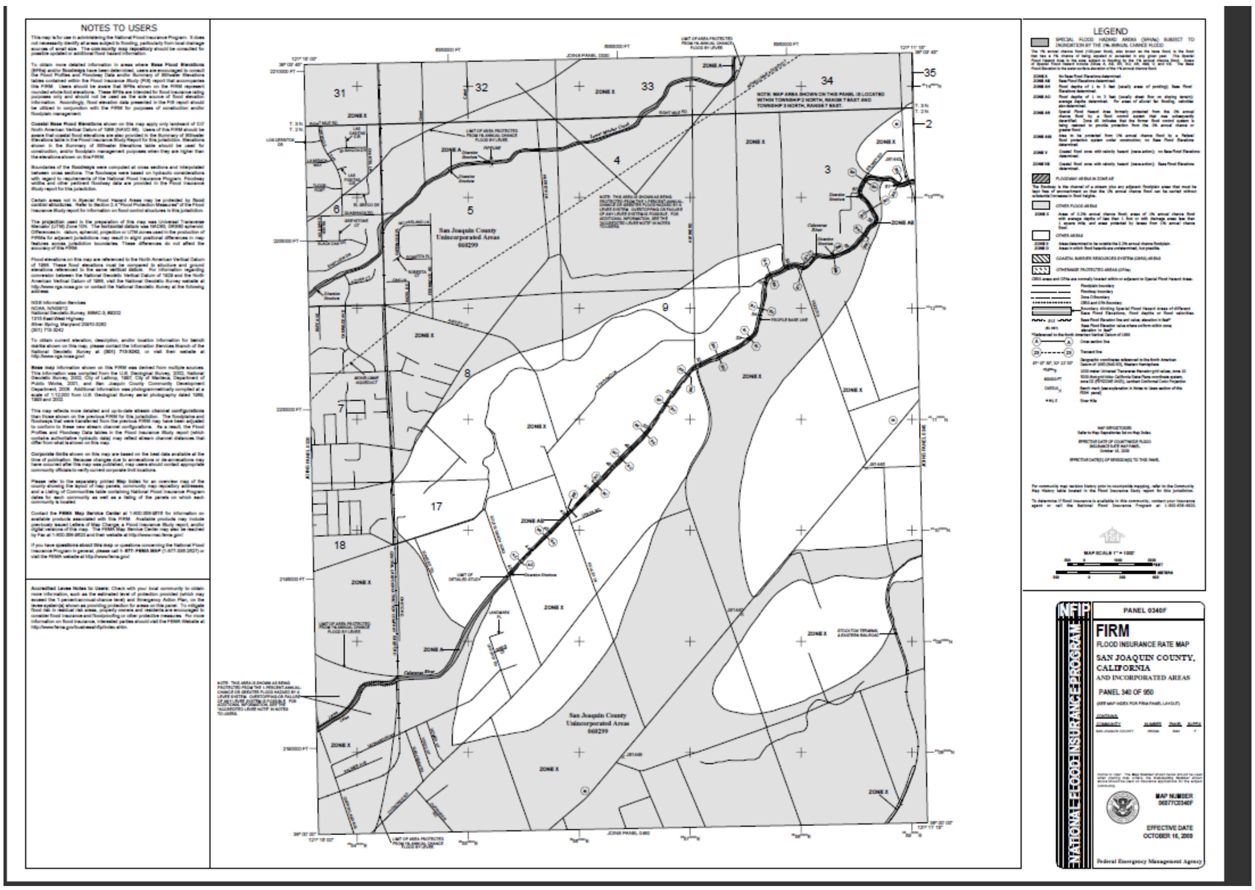
Figure 3-10: Flood Insurance Rate Map Zones

Note that the special Flood Hazard Area (SFHA) includes only A and V Zones.

There are a variety of sources for this information. FEMA maps are available for most communities. The U.S. Army Corps of Engineers will do floodplain delineation on a cost-sharing basis and has information on floodplains and project levees. DWR also has flood-plain information and a floodplain management program, as does the State Reclamation Board in the Central Valley. The California Emergency Management Agency (Cal EMA) and DWR have information on past flooding. Local levee districts and Resource Conservation Districts may also have information to share.

In addition to the location of the landfill in proximity to the flood plain, the elevation of the flood waters is critical to evaluate if a flood will impact a landfill considering the elevation of the landfill to the flood waters. NFIP has computed the elevation to which floodwater is anticipated to rise during the 100-year flood or base flood is the Base Flood Elevation. For each FIRM, NFIP has conducted Flood Insurance Study (FIS) reports for more than 19,000 communities, if a FIS report is available, the predicted elevation for a 500-year flood can be obtained from the report. Four flood levels are typically shown in the FIS report: the 10-, 50-, 100-, and 500-year (10 percent, 2 percent, 1 percent, and 0.2 percent) floods. More information on how to use the FIRMs and other sources from NFIP can be obtained from http://www.fema.gov/library/viewRecord.do?id=2108

The following is an example of a flood map illustrating how various zones are mapped:



(reference: http://www.co.san-joaquin.ca.us/pubworks/pdfs/P0340.pdf)

The evaluation for the flood as a causal event should include documentation if the location of the landfill is outside of the 500-year flood zone, shown as C or X (unshaded area) on the flood map. If the landfill is within the 500-year flood zone, the evaluation should include a comparison of the predicted elevation of the flood waters to the elevation of the lowest point of the landfill boundary, an assessment of the potential for erosion and saturation due to the force of moving water or standing water, including a comparison of the potential depth of water to the lowest elevation of the landfill. Such an evaluation should consider the capacity of the run-on and run-off control systems and the maintenance of the system to minimize blockage. If the capacity of the system is exceeded, an assessment of the potential soil erosion and impacts on the stability of slopes and supporting soils need to be included, damage to structures associated with environmental monitoring or control, and the landfill cover; and associated costs for replacement or repair.

Damage at landfills due to a flood is caused by inundation or washout of slopes, drainage systems, and other structures; including soil erosion or structure failure due to the force of the moving water. The location, elevation and design of a landfill, including the level of maintenance of the run-on and run-off control systems, are major factors in determining if a flood will adversely affect the landfill.

Tsunami

(References: California Geological Survey, County of San Diego Guidelines for Determining Significance (July 30, 2007)

Tsunamis are sea waves that may be generated by an earthquake, landslide, volcanic eruption, or even by a large meteor hitting the ocean. The California coast has experienced several tsunamis, some causing significant damage. It is anticipated that the types of damage caused by a tsunami would be similar to those resulting from a flood. An excerpt from the Department of Conservation website illustrates the impacts of a tsunami resulting from an earthquake in Alaska in 1964. The most devastating tsunami to affect California in recent history was from the magnitude 9.2 Alaskan earthquake of 1964. Areas of Northern California experienced a six-meter (20-foot) tsunami wave that flooded low-lying communities, such as Crescent City, and river valleys, killing 11 people.

Tsunamis are considered a reasonable foreseeable causal event as evidenced by the chart below of historic tsunamis in California. Seismic events at locations thousands of miles away have been documented to impact California's coast. In a 2003 report prepared by GeoSyntec Consultants, Inc, it was reported that 17 landfills were located in a coastal setting. The report can be downloaded at:
http://www.calrecycle.ca.gov/Publications/default.asp?pubid=1046

Historic Tsunamis in California:

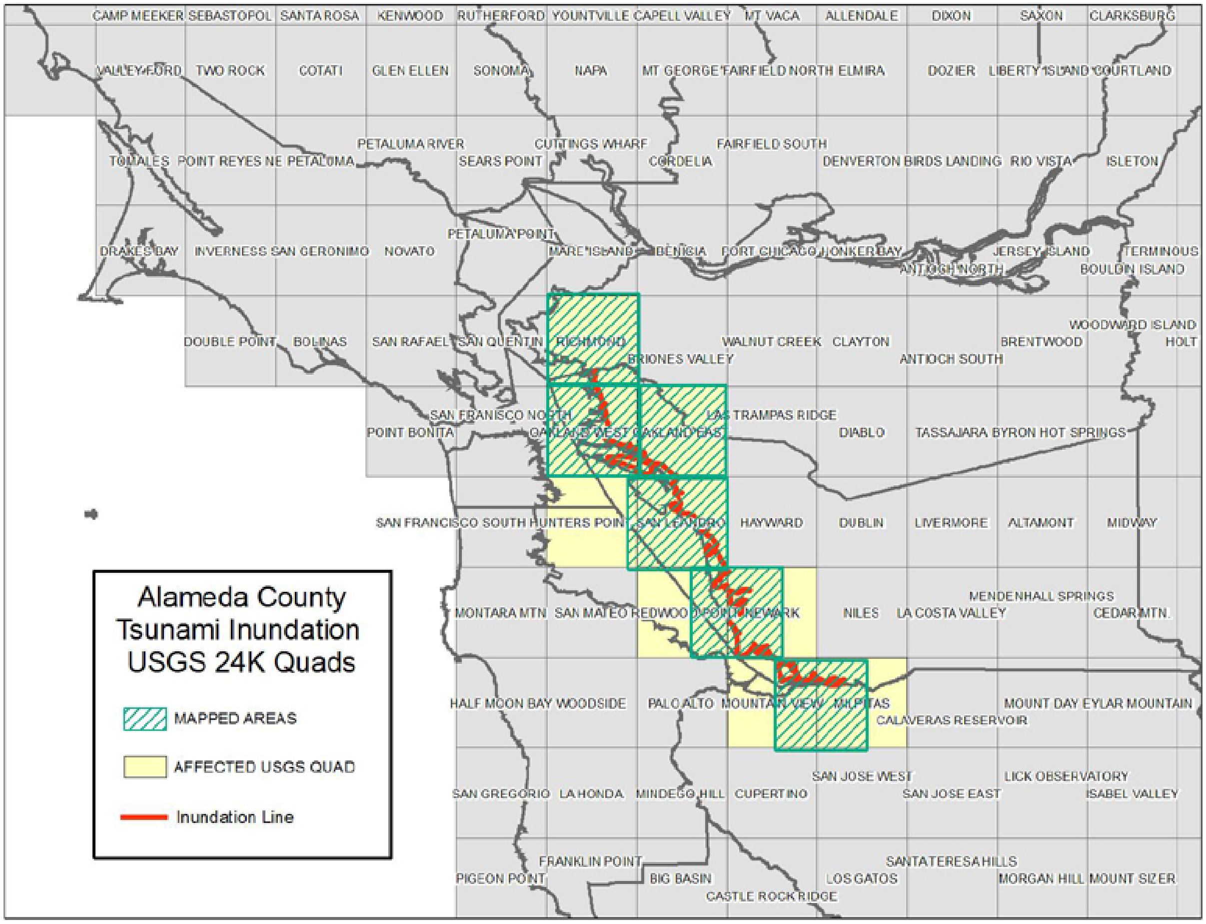
The chart below shows data from some of the tsunamis recorded in Southern California and along the Central Coast from 1812 to 2000 (Reference: http://www.humboldt.edu/~geology/earthquakes/tsunami!/n_coast_tsunamis.html)

year	month	day	travel (hours)	time (minutes)	tsunami location	height (meters)	source location	source event	source magnitude (Ms)	source magnitude (Mw)
1812	12	21			EL REFUGIO (GAVIOTA), CA	3.4	CA	Purisima	7.7	
1812	12	21			VENTURA, CA	2	CA	Purisima	.7.7	
1856	9	24			SAN DIEGO, CA	3.6	Japan	Tokaido		
1859	9	24			HALF MOON BAY, CA	4.6	N. CA			
1862	5	27			SAN DIEGO, CA	1.2	S. CA		5.8	
1868	10	21			SAN FRANCISCO BAY, CA	4.5	SF area		6.8	
1868	8	13			SAN PEDRO, CA	1.8	N. Chile		8.5	
year	month	day	travel (hours)	time (minutes)	tsunami location	height (meters)	source location	source event	source magnitude (Ms)	source magnitude (Mw)
1896	12	17			SANTA BARBARA, CA	2.5	S. CA			
1896	6	15			SANTA CRUZ, CA	1.5	Japan	Sanriku	7.6	
1930	8	31			SANTA MONICA, CA	6.1	S. CA		5.2	
1934	8	21			NEWPORT BEACH, CA	12	S. CA			
1964	3	28			MARTINS BEACH, CA	3	Alaska	Gulf of Alaska		9.2
1964	3	28	5	6	SAN FRANCISCO, CA	1.1	Alaska	Gulf of Alaska		9.2
1964	3	28			SEA VIEW, CA	3.8	Alaska	Gulf of Alaska		9.2
1975	11	29			SANTA CATALINA ISLAND, CA	1.4			7.2	
1989	10	18			MOSS LANDING, CA	1	CA	Loma Prieta	7.1	
2000	11	4			POINT ARGUELLO, CA	unknown	CA	Pt. Arguello		

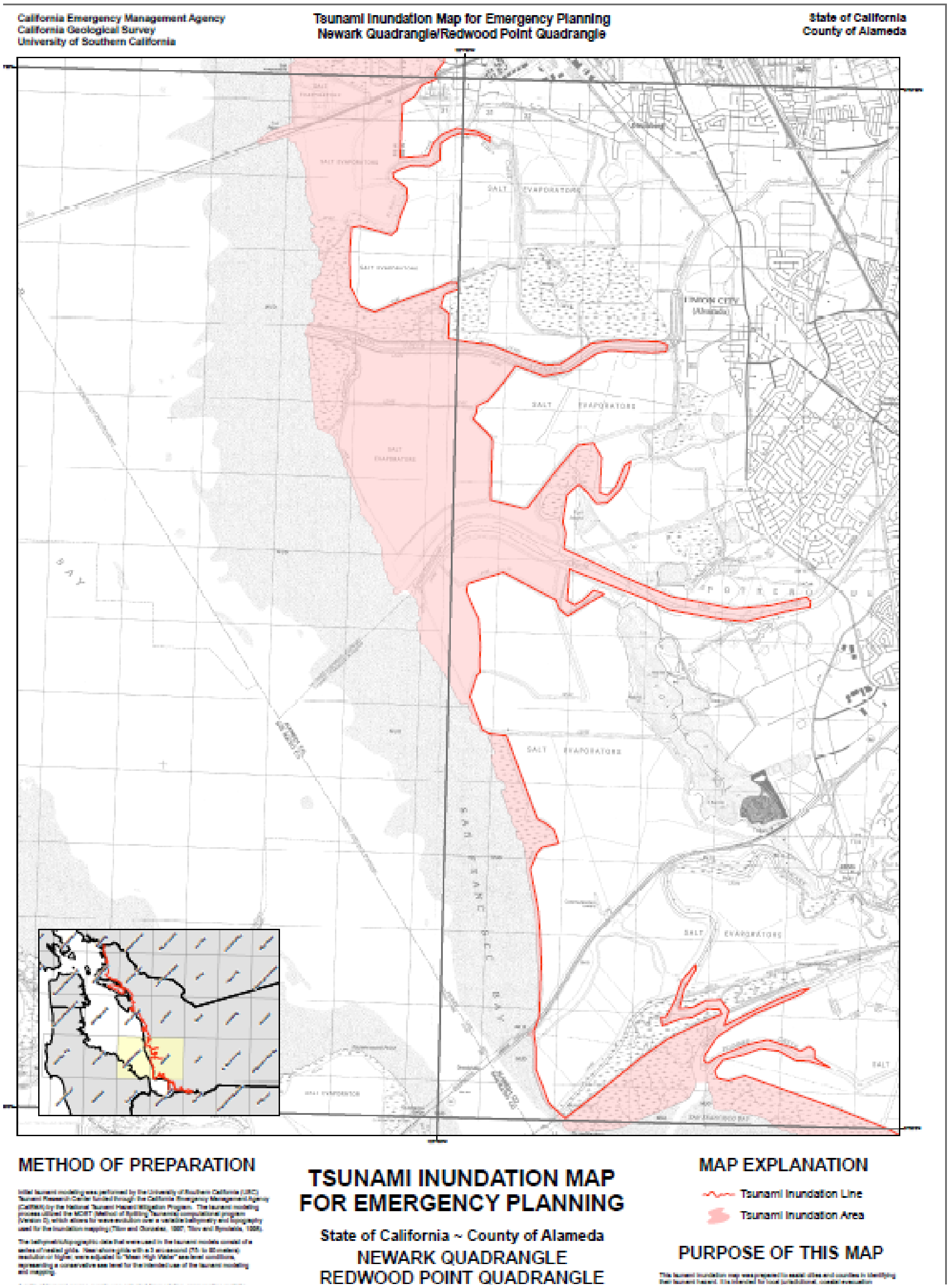
The Department of Conservation has generated maps for the 20 counties located along the California coast, identifying areas that may be affected by a tsunami. These maps are developed for all populated areas in California at risk to tsunamis, and represent a combination of the maximum considered tsunamis for each area. The intended uses for the maps are for emergency planning (such as coastal evacuation planning) purposes and to assist cities and counties in identifying their tsunami hazard. The maps identify areas that may be inundated by a tsunami. The maps can be obtained from http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Pages/Statewide_Maps.aspx

The following illustrates the counties that have tsunami maps generated by the Department of Conservation:

From the statewide map, one can highlight the county as shown below:



Highlight the quadrant map to get the detailed map of the inundation zone as illustrated on the next page:



The maps identifying the inundation areas in California can be downloaded at http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Pages/Statewide_Maps.aspx

General information on tsunamis can found at
http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Pages/About_Tsunamis.aspx

For information about the National Tsunami Hazard Mitigation Program, please visit the following website: http://nthmp.tsunami.gov/

Other Tsunami related links:

- California Emergency Management Agency – http://www.calema.ca.gov/WebPage/oeswebsite.nsf/Content/3F07513B078EE8A78825741F0060B548?OpenDocument
- Tsunami Research Center at University of Southern California - http://www.usc.edu/dept/tsunamis/2005/index.php
- National Ocean and Atmospheric Administration Tsunami page - http://www.tsunami.noaa.gov/
- U. S. Geological Survey Tsunami page - http://walrus.wr.usgs.gov/tsunami/
- Redwood Coast Tsunami Work Group - http://www.humboldt.edu/~geology/earthquakes/rctwg/index.html

The evaluation for the tsunami causal event should include documentation that the landfill is not located in an area designated by the Department of Conservation. If the landfill is located in an area that may be inundated by a tsunami, the evaluation should include the predicted height of the waves and duration, with an assessment of the potential impacts of the predicted waves given the elevation of the landfill. The assessment should address the potential impacts with consideration of the amount of water and the velocity of the water in regards to erosion, instability of slopes, and damage to structures associated with environmental monitoring or control, and the landfill cover, and associated costs for replacement or repair.

Seiche

A seiche is a wave on the surface of a lake or landlocked bay caused by atmospheric or seismic disturbances and may be defined as an occasional rhythmic oscillation of water above and below the mean level of lakes or seas, lasting from a few minutes to an hour or more. Seiches are uncommon but have been known to have occurred in Lake Tahoe and the Great Lakes. Damage anticipated to result from a seiche would be similar to those from a flood or tsunami. In a 2003 report prepared by GeoSyntec Consultants, Inc, it was reported that eight California landfills were located near a bay or estuary. The report can be downloaded at
http://www.calrecycle.ca.gov/Publications/default.asp?pubid=1046

The evaluation for the seiche causal event should include documentation that the landfill is not located within one-half mile of a lake or landlocked bay.

If the landfill is located within one-half mile of a lake or landlocked bay, the evaluation should include the predicted height of the waves and duration, with an assessment of the potential impacts of the predicted waves given the elevation of the landfill. The assessment should address the potential impacts with consideration of the amount of water and the velocity of the water in regards to erosion, instability of slopes, and damage to structures associated with environmental monitoring or control, and the landfill cover, and associated costs for replacement or repair.

Precipitation

There are case studies that document damage to landfills caused by storms. Damage to the cover, displacement or exposure of waste, damage and clogging of the drainage system, and failure or erosion of slopes and roads can occur due to erosion of soil and inundation by water (Sunrise Mountain in Nevada, Jim Hogg County Landfill in Texas, and the Anderson report). In fall 2001 Jim Hogg County experienced several major rain events that caused serious flooding in the area. Floodwaters cut a trench, approximately 1200 feet long, 30 feet wide and 15 feet deep, through a disposal area of the landfill, displacing approximately 12,000 tons of waste material. These examples were primary of closed landfills that may not have been maintained, but they are indications that storms are capable of causing significant damage to a landfill. Although every landfill is unique in its design and location, precipitation is a reasonable foreseeable causal event.

Landfills are required to maintain systems to control run-on and run-off due to precipitation during their active life and into the postclosure period. The systems are required to protect against a 100-year, 24-hour storm event (Class II landfills). Class I landfills are required to be designed to withstand the Probable Maximum Precipitation rain event and Class II landfills are designed to withstand the 1,000-year, 24-hour rain event. Since solid waste landfills can be either a Class II or Class III as determined by the RWQCB, staff recommends that the Class II design standard be used to define the causal event.

The theoretical return period is the inverse of the probability that the event will be exceeded in any one year. For example, a 10-year flood has a 1/10 = 0.1 or 10 percent chance of being exceeded in any one year and a 50-year flood has a 0.02 or 2 percent chance of being exceeded in any one year.

While a 10-year event will occur, on average, once every 10 years and that a 100-year event is so large that it is expected only to occur every 100 years, based only on statistics or probability. It does not mean that 100-year floods will happen *regularly*, every 100 years, despite the connotations of the name “return period.” In any *given* 100-year period, a 100-year storm may occur once, twice, more, or not at all, and each of outcomes has a probability that can be computed.

The Department of Water Resources, Bulletin 69-95, California High Water, October 2003) documents that 1,000-year 24 hour storm events have occurred in California on several occasions, thus the 1,000-year 24-hour storm event is a reasonably foreseeable causal event. (http://www.water.ca.gov/floodmgmt/docs/Bul69-95/00-bull69-95front.pdf)

The 1,000-year 24-hour storm event is also used by DWR for some dams. (http://www.water.ca.gov/damsafety/docs/fitz-paper.pdf

The difference between a 100-year and 1,000-year storm event is not a tenfold increase in the amount of water, but may vary to less than one inch to several inches, as illustrated in conditions for the following Central Valley RWQCB documents:

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD CENTRAL VALLEY REGION

ORDER NO. R5-2005-0024
WASTE DISCHARGE REQUIREMENTS FOR MUSCO FAMILY OLIVE COMPANY AND THE STUDLEY COMPANY CLASS II SURFACE IMPOUNDMENTS TRACY PLANT San Joaquin County

> 16. The 100-year, 24-hour precipitation event is estimated to be 2.5 inches, based on the California Department of Transportation Intensity-Duration-Frequency Rainfall Curve Program for the Tracy 2 SSE Station No. 116. The 24-hour, 1,000-year storm event is 3 inches.

ORDER NO. R5-2008-XXXX WASTE DISCHARGE REQUIREMENTS FOR COUNTY OF SHASTA FOR OPERATION OF REDDING REGIONAL SEPTAGE DISPOSAL FACILITY SHASTA COUNTY

> 12. The 100-year, 24-hour precipitation event is estimated to be 5.5 inches, based a map published by the National Oceanic and Atmospheric Administration (NOAA) in *NOAA Atlas 2, Volume XI, Isopluvials of 100-Year 24-Hour Precipitation for Northern Half of California in Tenths of an Inch*.
>
> 13. The 1,000-year, 24-hour precipitation event is estimated to be 6.86 inches, based on data for Station Anderson STP (DWR #A00 0201 30) for the years 1976 through 2000, compiled and analyzed by the Department of Water Resources, Red Bluff. For the same station and the same years of record, the 100-year wet season precipitation is 59.84 inches.

Fires

References: CalRecycle Guidance on Landfill Fires at http://www.calrecycle.ca.gov/SWFacilities/Fires/LFFiresGuide/default.htm**, and Landfill Fires by FEMA** at http://www.usfa.dhs.gov/downloads/pdf/publications/fa-225.pdf

Fires at landfills are either surface or subsurface fires The potential for these fires to occur is dependent on the location of the landfill for wildfires, management of wastes that are still smoldering, accidents or arson, and availability of vegetation or fuel for a fire. The most common cause of subsurface landfill fires is an increase in the oxygen content of the landfill, which increases bacterial activity (aerobic decomposition) and raises temperatures creating “hot spots” that come into contact with pockets of methane gas, resulting in a fire.

Subsurface fires are caused due to the presence of oxygen and can cause damage to the landfill gas collection systems and potentially the cap. The postclosure maintenance plan should contain provisions for subsurface fires. If not, subsurface fires should be addressed in the CA Plan.

Wildfires

Wildfires have been documented to destroy or damage all or portions of the landfill gas collection and monitoring systems, vegetation and irrigation systems designed to protect the cap and cover, drainage systems, and utility conveyance systems. The potential damage is dependent on mitigating circumstances such as whether the structures are buried to be protected from fires and if there are engineered mitigation measures such as fire breaks to protect against surface fires.

The California Department of Forestry and Fire Protection (CAL FIRE) and the Office of the State Fire Marshal (OSFM) and local agencies have prepared maps that identify areas of the state have a very high or moderate fire hazard. The maps are a result of implementation of Government Code Sections 51175–51189. The purpose of this chapter is to classify lands in accordance with whether a very high fire hazard severity is present so that public officials are able to identify and require mitigation measures to reduce the spread and potential intensity of uncontrolled fires that can destroy resources, life, or property. The objective of the fire hazard maps is to determine which areas are subject to requirements affecting construction materials and for defensible space to minimize losses from a fire.

The science-based fire hazard model used to generate the maps considers the wildland fuels. Fuel is that part of the natural vegetation that burns during the wildfire. The model also considers fire history, topography (especially the steepness of the slopes), existing and potential fuel or natural vegetation, and typical weather for an area. Fires burn faster as they burn up-slope. Weather (temperature, humidity, and wind) has a significant influence on fire behavior. The model recognizes that some areas of California have more frequent and severe wildfires than other areas. Finally, the model considers the production of burning fire brands (embers), how far they move, and how receptive the landing site is to new fires.

Hazard map uses

- Building construction standards on building permit;
- Natural hazard disclosure at time of sale;
- Defensible space clearance around buildings;
- Property development standards such as road widths, water supply, address signs; and
- Considered in city and county general plans.

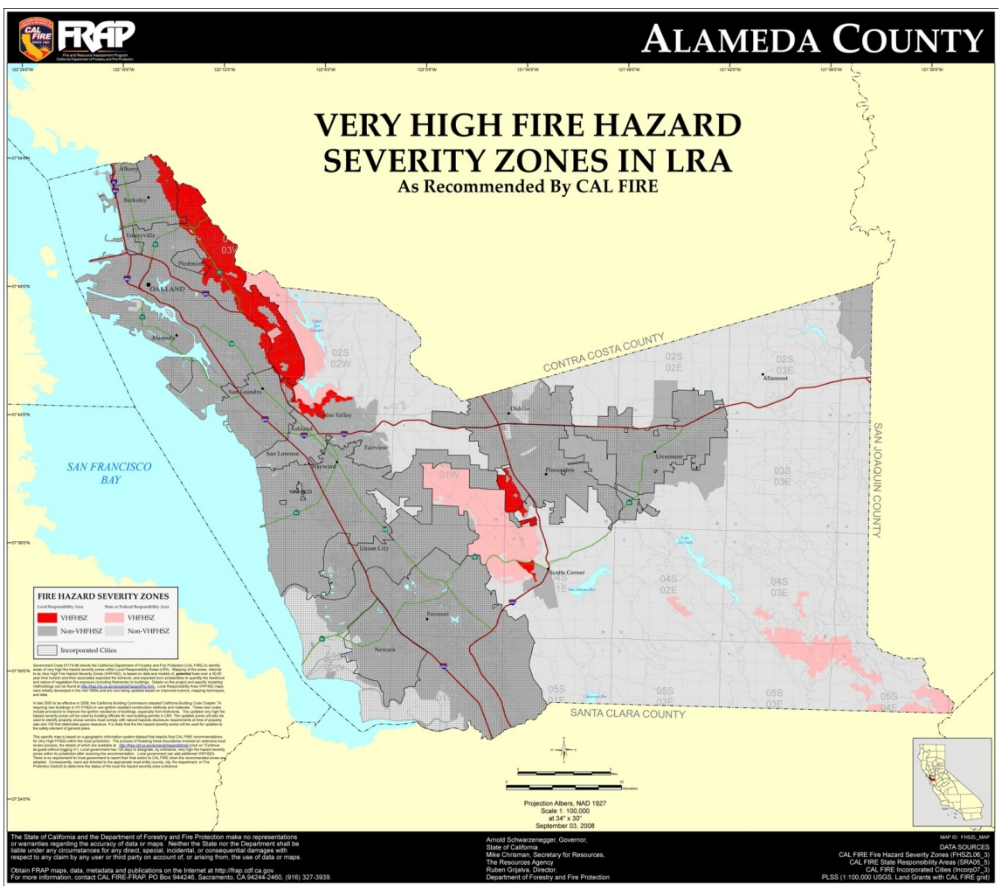
Hazard Severity Zones are not intended for

- Tactical fire fighting
- Seasonal fire severity
- Insurance
- Setting project priorities

More information on the responsibilities of the CAL FIRE and local agencies, as well as the fire hazard maps, can be obtained at
http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland.php

From the website of the Department of Forestry and Fire Protection
http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_development.php

There are three jurisdictions that have responsibilities: the federal, state and local responsible agencies. This map from the state identifies which areas is the responsibility of the federal, state, or local fire agency:



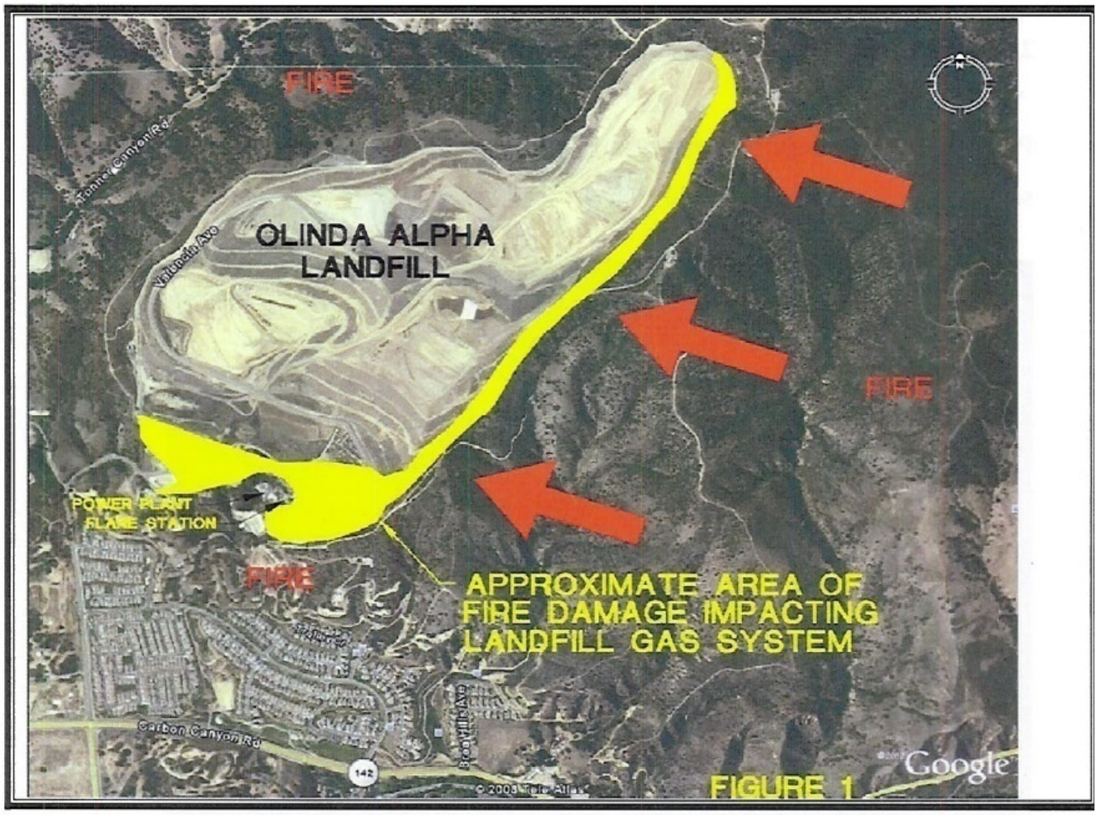
The fire plans for all counties can be obtained at this website
http://cdfdata.fire.ca.gov/fire_er/fpp_planning_plans

Subsurface fires

CalRecycle website
http://www.calrecycle.ca.gov/SWFacilities/Fires/LFFiresGuide/default.htm

The fire hazard zone maps can be downloaded at
http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_maps.php

Staff received information on three recent fires at landfills in California: the Olinda Alpha Landfill in November 2008, Simi Valley Landfill in 2003, and Sunshine Canyon in November 2008. The damage caused by the fires varied significantly, from as little as $500 to more than $2 million. The information showed that highly combustible structures exposed to the fire were damaged or destroyed. At the Olinda Alpha Landfill, the fire encroached on the eastern and southern perimeter of the landfill, destroying the aboveground landfill gas collection system piping and wellheads (as illustrated in the figure below). Afterwards, the replaced landfill gas piping system was placed below ground to protect against future fires. It is interesting to note that although the fire burned for several days, other portions of the landfill did not sustain damage. The interior of the landfill was unaffected due to fire breaks and lack of vegetation. The potential damage to a landfill caused by fires can vary significantly depending on location, terrain, weather conditions, design, and mitigation factors.


FIRE
OLINDA ALPHA
LANDFILL
FIRE
POWER PLANT
FLARE STATION
FIRE
APPROXIMATE AREA OF
FIRE DAMAGE IMPACTING
LANDFILL GAS SYSTEM
Carbon Canyon Rd
Google
FIGURE 1