1959 SUPER TYPHOON VERA: 50-YEAR RETROSPECTIVE

RMS Special Report

INTRODUCTION

On September 26, 1959, Super Typhoon Vera[1], also known as Typhoon Isewan, made landfall along the southern coast of Japan, striking the Kushimoto region in the Wakayama Prefecture. The storm was the most destructive typhoon to impact the country in recent history, causing over US$260 million (1959 dollars) worth of damage, which translates to approximately US$1.9 billion in 2009 dollars[2]. The Japan Meteorological Agency (JMA) named the storm "Isewan" after Ise Bay, which was inundated with floodwaters. Due to the strength and extent of the storm's wind field and storm surge, most of the country sustained damaging winds and over 120 mi^2 (310 km^2) of land was inundated, destroying thousands of homes, leaving more than 5,000 people dead and injuring an additional 39,000 individuals. Super Typhoon Vera made landfall with peak gusts of 160 mph (258 km/hr), while the strongest sustained wind speed was recorded in the city of Nagoya at over 100 mph (161 km/hr). Sustained wind speeds of over 50 mph (81 km/hr) were recorded along the length of Japan from Kyushu to Hokkaido (JWF, 2005).

The maximum storm surge was close to 13 ft (4 m) above Tokyo Pile (T.P.)[3] which inundated defenses along the coastline and flooded low-lying land (Figure 1). The city of Nagoya, which is located on the northern coastline of Ise Bay, was one of the worst hit areas, sustaining heavy flood damage. The inundated areas were difficult to drain, which led to poor sanitary conditions and dysentery infections. Moreover, the effects of the disaster were exacerbated due to the lack of communication. At the time, only around 20-30% of households had television or telephone access, relying instead on radio transmissions as the principal form of communication. Due to the extremely strong winds, telephone and power lines were severed, resulting in only intermittent communication about the impending storm (JWF, 2005).

Figure 1: Flooding following Super Typhoon Vera in September 1959 in Nagara Kitamachi, north of Gifu City (Source: http://www.pref.gifu.lg.jp/pref/s11117/saigai_siryo/1959isewan/isewan-2.htm)

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[1] The term "Super Typhoon" is used by the Joint Typhoon Warning Center (JTWC) to describe typhoons that reach maximum sustained 1-minute surface winds of at least 150 mph (241 km/hr), which is equivalent to a strong Saffir-Simpson Category 4 or Category 5 hurricane in the Atlantic Basin.

[2] Using the Consumer Price Index (CPI) as a basis.

[3] T.P. or Tokyo Pile is the mean sea level in Tokyo Bay, which is the elevation baseline of Japan.

Fifty years following Super Typhoon Vera, Risk Management Solutions (RMS) revisits the event, reflecting on the impacts and the aftermath of the storm, which highlighted the need for an improved disaster management system in Japan. Following the event in 1960, Japan established the Soil Conservation and Flood Control Urgent Measures Act, and in 1961 the Disaster Countermeasures Basic Act was passed. These agreements aimed to coordinate disaster prevention measures at the highest level of government. In essence, Vera became a turning point for disaster prevention in Japan, as comprehensive plans for soil conservation and flood control were implemented nationwide (Tatano, 2008a).

This report also presents a reconstruction of this event and discusses the financial impacts of a storm of similar size hitting the region in 2009. As flooding was the primary driver of damage in 1959, the role of flood defenses in reducing loss is highlighted, as is the role of the Japanese insurance market in managing wind field and storm surge losses in future typhoon events.

1959 SUPER TYPHOON VERA

Development and Synopsis of the Storm

Super Typhoon Vera originated as a low pressure system that formed in the Western Pacific Ocean near Guam before slowly transitioning to a tropical storm on September 21, 1959. It tracked northwest the following day, developing into a storm named “Vera” by the Joint Typhoon Warning Center (JTWC) of the United States, and designated as T5915 on an international basis. According to the JTWC (1959), there were “65 tropical disturbances over the Pacific Ocean west of 140 degrees west and north of the equator” that year.

On September 22, 1959, Vera developed rapidly, with an enormously expanding diameter of 155 mi (250 km) and a quickly decreasing central pressure that reached a maximum low of 896 millibars (mb) (JWF, 2005). Peak winds of 190 mph (306 km/hr) were recorded on September 23, 1959, as the storm developed into a Super Typhoon, measuring as a Category 5 on the Saffir-Simpson Hurricane Scale (i.e., sustained winds greater than 155 mph or 249 km/hr) due to the strong divergence aloft and the continued warm waters of the Pacific Ocean. Beginning on September 23, rain began to fall across the Tokai region on the mainland. The storm remained very strong, only slightly weakening as it continued northward over the next few days (Figure 2). Heavy rainfall preceded the storm, with 4 in (10.4 cm) recorded in the city of Nagoya and nearly 8 in (20 cm) in certain areas of the Mie, Gifu, Aichi, and Shizuoka prefectures from September 23 through September 26 (Tsuchiya and Yasuda, 1980). As the storm progressed, this heavy rainfall caused flooding along various river basins in the region.

Figure 2: The path of Super Typhoon Vera in September 1959: full path and sustained wind speeds within the Pacific Ocean (upper left) and wind speed times (local time) and path across Japan (main graphic); for example, at 8:00 p.m. local time on September 26, 1959, the storm was just northwest of Nagoya

Super Typhoon Vera struck Japan on the coast of Wayakama Prefecture west of Shionomisaki on September 26, 1959 at approximately 6:00 p.m. local time, with peak gusts measuring 160 mph (258 km/hr). As the storm approached Ise Bay at the mouth of the Kiso River, between the prefectures of Mie and Aichi, water levels rose across the bay (Figure 3). Maximum storm surge levels (as measured by tide gauge stations) were around 6.6 ft (2 m) above Tokyo Pile (T.P.) at the mouth of the bay, close to 13.1 ft (4 m) above T.P. along the inner part of the bay near Nagoya and 9.8 to 11.5 ft (3 to 3.5 m) above T.P. at the inner part of Mikawa Bay (Tsuchiya and Yasuda, 1980).

The storm passed over the main island of Honshu in about six hours, entering the Sea of Japan east of Toyama City. The storm's center moved through the Sea of Japan south of Sado Island, off the coast of the Hokuriku region in Niigata and the Tohoku region in the Aomori Prefecture on the evening of September 26, before it rapidly continued in a northeast direction over land once again. On its path over the northernmost section of Honshu, it weakened and re-emerged over ocean waters in the early hours of September 27 as a weak Category 1 storm shortly before decreasing to tropical storm intensity. On its path eastward, it continued to weaken and dissipated in the Pacific Ocean on September 28, 1959.

Figure 3: Storm surge levels (measured in meters above Tokyo Pile or T.P.), and times of measurements, around Ise and Mikawa bays on the evening of September 26, 1959 due to Super Typhoon Vera; for example, at the port of Nagoya City, the water level measured 12.8 ft (3.9 m) above T.P. at 9:35 p.m. local time (Source: Tsuchiya and Yasuda, 1980)

Wind Impacts

On the east side of Ise Bay, the entire Aichi Prefecture experienced sustained wind speeds close to 70 mph (113 km/hr). In areas such as Nagoya City, the Chita Peninsula and the southwestern Mikawa Plain, the sustained wind speeds reached 90 mph (145 km/hr) (Ishizaki et al., 1961). Peak gusts of up to 160 mph (258 km/hr) were experienced throughout the Aichi and Mie prefectures. As a result, wind damage to wooden and non-wooden structures, as well as infrastructure such as power lines, was widely observed (Figure 4). According to damage studies published following the event (e.g., Ishizaki, 1965), the most severely damaged areas were 12 to 37 mi (20 to 60 km) east (or right) of the path of the storm. In the northern hemisphere, the winds on the right of the eye of the storm tend to be stronger and drive the storm's forward motion. This observation is also consistent with a storm with a radius of maximum winds (R_{max}) of no more than 75 mi (120 km). Moreover, regions several hundred miles from the sea were impacted and significant wind damage to property was observed in areas tens of miles inland, with roofs of homes ripped off in Nagano Prefecture (JTWC, 1959).

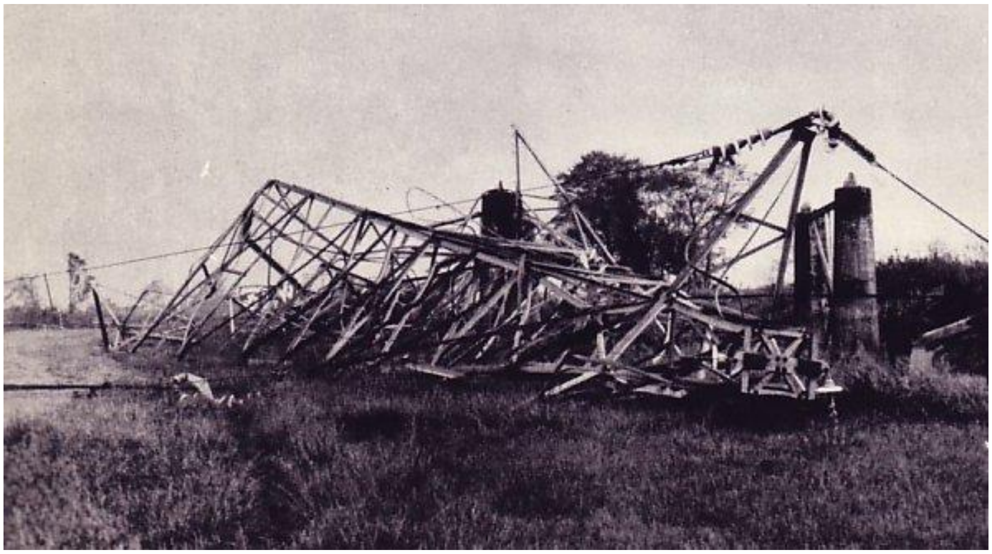

Figure 4: Power lines downed by high winds during Super Typhoon Vera in September 1959 (Source: http://www.pref.gifu.lg.jp/pref/s11117/saigai_siryo/1959isewan/isewan-2.htm)

Storm Surge Impacts

While Super Typhoon Vera had extremely high winds, the most widely chronicled damage from the storm was from the water inundation along the coastlines of Ise and Mikawa bays, which overwhelmed the existing flood defenses and flooded some low-lying, populated areas on the northernmost part of Ise Bay for more than four months (Figure 5). The high storm surge was primarily produced by a decrease in atmospheric pressure and the typhoon passing slightly west of the bay, where the strong winds forced the water to the north of the shallow bay[4] (JWF, 2005).

Tide heights across Ise Bay began to increase on the morning of September 26 before the storm made landfall. Wave heights were recorded every hour in Nagoya Harbor, with heights measuring 0.3 to 0.7 ft (0.1 to 0.2 m) above T.P. in the early afternoon and rising to 7.9 ft (2.4 m) above T.P. at 8:30 p.m. local time (Tsuchiya and Yasuda, 1980). Between 8:00 p.m. and 9:00 p.m. local time on September 26, 1959, the storm surge overwhelmed the flood defenses in some places and breached them in other locations along Ise Bay. With flood defenses primarily consisting of earthen levees constructed from reclaimed land and reinforced with rubble stones, the defenses could not resist the pressure from the waves. Only those flood defenses constructed along the southern part of the bay since 1953, when another typhoon caused serious damage to the coastline, were able to withstand the pressure and height of the flood waters (JWF, 2005).

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[4] At its deepest point, Ise Bay only measures 131 ft (40 m).

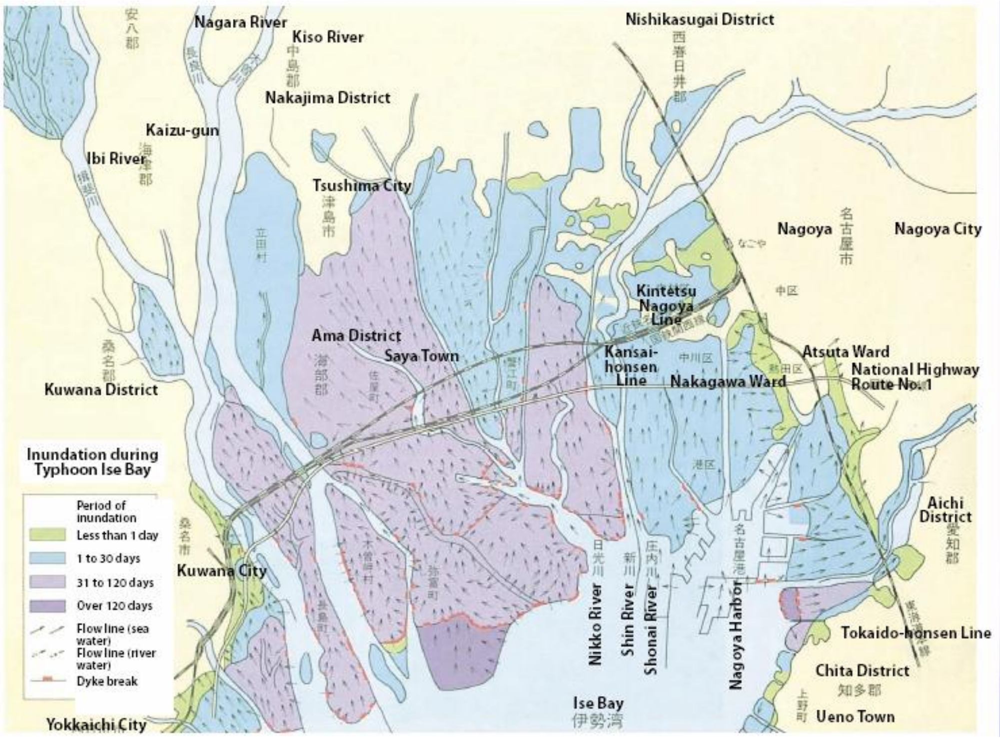

Figure 5: Areas along the northernmost section of Ise Bay inundated by floodwaters following Super Typhoon Vera in September 1959; periods of inundation lasted less than 1 day (in green) to over 120 days (in purple) west of Nagoya City (Source: JWF, 2005)

Heavy rainfall caused additional flooding along the river basins, but the peak of flooding at the mouth of rivers around Ise Bay (e.g., Kiso River) occurred hours after the maximum storm surge levels. If both river and storm surge flooding had occurred simultaneously, the water levels around the bay would likely have been more severe (JWF, 2005).

Property Damage and Casualties

The wind and storm surge from Super Typhoon Vera damaged 834,000 buildings across Japan, causing a total of US$260 million in 1959 dollars (JTWC, 1959). Across the Japanese island of Honshu, crops ready for harvest were ruined; roads, bridges, railways, and other structures were seriously damaged or destroyed. Along the impacted coastline, ships were beached and sea walls were broken. Of the 834,000 damaged or destroyed buildings across Japan, over 40% of the structures were inundated by flood waters (AXCO, 2009). Within the most severely impacted prefectures of Mie, Aichi, and Gifu, close to 160,000 homes were partially or totally destroyed, with over 190,000 homes submerged under flood waters and over 4,600 homes washed away (JWF, 2005).

The most severely impacted prefecture of Aichi experienced a rate of close to 4% of total households being completely destroyed, while an additional 17% of all homes were damaged. Of the approximate 693,500 households in Aichi Prefecture in 1959, 120,000 homes were completely or partly destroyed as a result of the storm's high winds. A further 125,000 homes were flooded, with 8,500 homes being completely destroyed and approximately 54,000 inundated by water 2 to 3 ft (0.6 to 0.9 m) above ground level (Ishizaki et al., 1961).

Within a few hours on the evening of September 26, 1959, the city of Nagoya and its harbor function was destroyed. In 1959, the coastline of Nagoya and the surrounding region was an important industrial zone, due to the abundant water resources and harbors. The region was one of the largest areas of development in Japan after World War II, contributing to the country's economic growth. At the time Super Typhoon Vera made landfall, Nagoya had approximately 250,000 households. Nearly 50,000 structures collapsed or partially collapsed due to the storm, and approximately 70,000 homes were severely damaged by flood waters. Approximately half of the flooded households were inundated above the first level (e.g., 2 to 3 ft or 0.6 to 0.9 m above the ground), and nearly 1,800 homes were completely washed away (Ishizaki et al., 1961). In Nagoya Harbor, materials from the various industrial facilities were washed away by the heavy rainfall and storm surge, entering the city and further damaging property. In particular, the large amount of floating timber from timber yards blocked roadways (Figure 6), destroyed many buildings, and made rescue efforts extremely difficult.

Figure 6: Wood debris on National Highway 1 following Super Typhoon Vera in September 1959 (Source: http://ajapskwn.hp.infoseek.co.jp/saigai/p20.html)

The official number of fatalities from Super Typhoon Vera was close to 5,100 individuals, including 4,700 confirmed deaths and 400 missing people. An additional 39,000 people were injured due to the storm. The majority of fatalities were due to the storm surge, which overwhelmed flood defenses along the coastline. For example, in the city of Handa in Aichi, located southeast of Nagoya, 300 people perished when the waves battered the coastline (JTWC, 1959). The occurrence of the flooding at night hindered attempts to evacuate.

Super Typhoon Vera remains the most deadly typhoon to strike Japan in recent times. It also ranks third in the highest number of casualties from Japanese natural disasters in the 20th century, ranking behind the Great Kanto Earthquake, which decimated Tokyo in 1923 and killed an estimated 100,00 people, and the Great Hanshin-Awaji (Kobe) Earthquake of 1995, which killed close to 6,500 individuals.

THE AFTERMATH OF SUPER TYPHOON VERA

On the morning of September 27, 1959, the magnitude of the damage became clear and local residents began to stem the flow of water through breaches in flood defenses, as well as provide rescue and relief to other survivors of the storm in Nagoya. Similar to what was observed in Hurricane Katrina in New Orleans, flood waters continued to pour through openings in flood defenses in the days following the disaster. For example, it took five days and the strength of 5,000 men, 32,000 sandbags, and bulldozers supplied by the Ministry of Construction to stem the flow from one 93-mi (150-km) breach in a flood defense (JWF, 2005).

On the day following the disaster, local government agencies began providing rescue to those stranded by the flood waters and refuge shelters at various public facilities, including schools and government offices, were opened. On September 28, the National Government of Japan began coordinating the relief operations, establishing the Central Japan Disaster Relief Department in Nagoya. By the next day, the Japan Self-Defense Forces, the military forces of Japan established post-World War II, joined the efforts, evacuating victims and distributing supplies (Figure 7). Across the Ama District in Aichi, coordinated reconstruction of damaged levees, roadways, and other property continued until the end of December 1959, which was unprecedented at the time (JWF, 2005).

Figure 7: Members of the Japan Self-Defense Forces evacuating victims of Super Typhoon Vera in September 1959 (Source: JWF, 2005)

Disaster Preparedness

The severity of the damage produced by Vera shocked the population of Japan, and the government responded by passing legislation aimed to both help re-establish the regions decimated by the storm, as well as reduce the impact of future natural disasters. In October 1959, a special session of parliament was held to pass several measures, coordinated through various ministries across the government and providing special subsidies to individuals impacted primarily by Super Typhoon Vera, but also by other natural hazard events in August and September 1959. For example, through the Ministry of Education, legislation was passed to allow the national government to subsidize three-quarters of the costs of reconstruction to public schools and one-half of the reconstruction costs of private schools damaged from wind and water in August or September 1959 (JWF, 2005).

However, a longer term impact of Super Typhoon Vera was the 1961 passage of the Disaster Countermeasures Basic Act[5], which is considered the cornerstone of legislation on disaster risk reduction in Japan (Tatano, 2008a). This piece of legislation created processes for coordinated disaster prevention at the highest levels of government. First, the law established the Central Disaster Prevention Council, headed by Japan's Prime Minister, which coordinates disaster risk reduction measures and other matters relevant to disaster management. Members of the council include representatives from both the public and private sectors of Japan (e.g., cabinet members and representatives of gas and electricity companies).

Next, the act declared that the cabinet must submit, on an annual basis, an official report of the disaster prevention plan to the Japanese parliament, or the National Diet of Japan. This annual report is helpful in reminding the public of the importance of disaster prevention, as well as establishing a mechanism to allow funds to be earmarked toward disaster countermeasures. Moreover, the act outlined a national basic disaster management plan for disaster prevention, from which regional and local government plans for disaster prevention could be developed. For example, at the regional level, plans include such things as forecast and warning systems, emergency communication procedures, flood fighting strategies, and rescue tactics (Tatano, 2008b).

Finally, the 1961 Disaster Countermeasures Basic Act declared September 1 as Japan's National Disaster Prevention Day. Every year on this day, prevention drills and various events are held across Japan. In 2009, earthquake drills were conducted across eight municipalities in the Tokyo metropolitan area, considering a magnitude 7.3 earthquake with the epicenter off the northern coast of Tokyo Bay. Based on the experiences of the Great Hanshin-Awaji (Kobe) Earthquake in 1995, the national disaster management plan was enhanced, where tangible mitigation plans for different types of disasters were developed. For example, countermeasures for large scale earthquakes impacting urban areas (e.g., on the Tokai segment of the Nankai Trough subduction zone) have been established for Tokyo and other metropolitan regions of Japan.

Coastal Protection

Following Super Typhoon Vera, designated flood hazard areas were established in the city of Nagoya, which regulated the construction of homes and public facilities along the coastline, as well as the levels of ground floors and entrances to underground areas for these structures. However, a broader impact of Super Typhoon Vera was the development of flood defenses in three major bays of Japan—Ise, Osaka, and Tokyo bays—based on Vera's "external force equivalent" (JWF, 2005).

In Japan, the standards for the flood defense heights are drawn up by the Japanese government's Ministry of Land, Infrastructure, Transport, and Tourism. The construction and maintenance of flood defenses are conducted jointly by the Ministry and local governments. In areas where significant floods occurred in the past, the level and location of the defenses are established by historical recordings. In areas with no historical flood hazard, the level and location are established in reference to the calculations of the tidal levels of different return periods (e.g., 100-year, 200-year, and so on), based on the observation records from the tidal stations. In Ise Bay, near where Super Typhoon Vera made landfall, the standard tide height is assumed to be T.P.+4.5 m (or T.P.+14.8 ft), which was set based on observation records from the 1959 storm. This calculation is based on the height of full tide (T.P.+1 m or T.P.+3.3 ft) plus the tidal level deviation by storm surge (3.5 m or 11.5 ft). Based on this, flood defense heights along Ise Bay were reconstructed at a maximum level of T.P.+7.5 m (T.P.+24.6 ft) (Figure 8).

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[5] For more information on the Disaster Countermeasures Basic Act, see Takeshi, 2008.

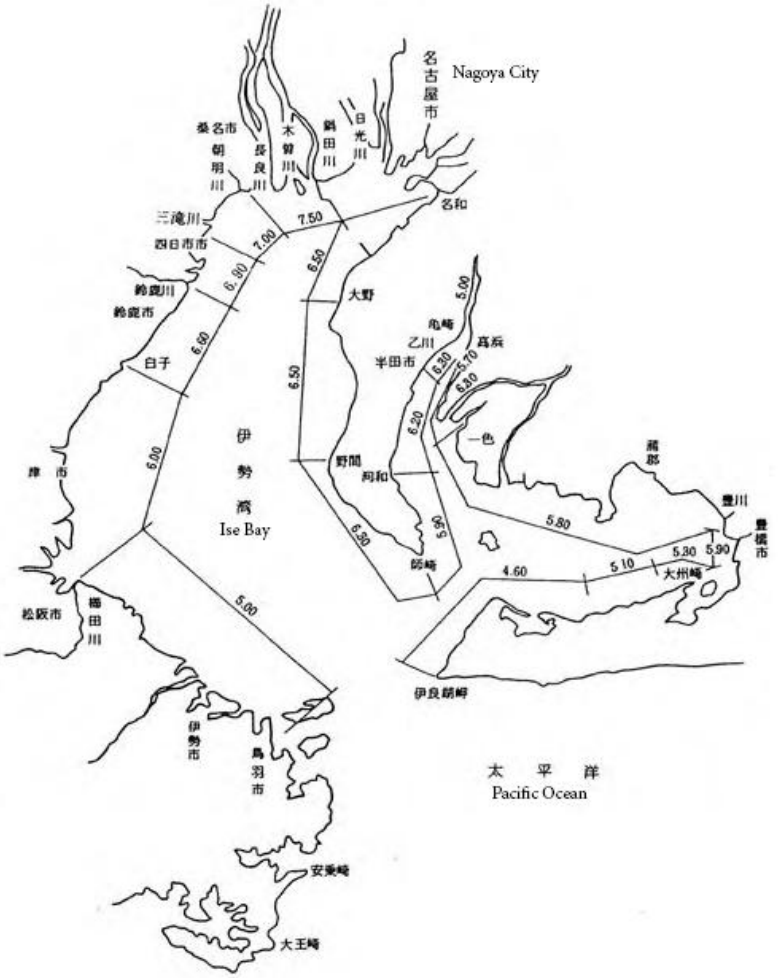

Figure 8: Planned levee heights around Ise Bay, based on the water levels observed during Super Typhoon Vera (Source: JWF, 2005)

In Tokyo, where an estimated 45 mi^2 (116 km^2) of land lies below sea level, flood defenses were installed along the coastline following Super Typhoon Vera, considering further subsidence of the land. For example, the design height of flood defenses was raised in consideration of land subsidence over five years, and these height increases range from 3.9 in to 35 in (10 to 90 cm) (Tagami et al., 1961). Osaka Bay has undergone similar flooding countermeasures to Tokyo Bay, with the construction of various defenses based on the scale of Super Typhoon Vera and considering the worst case scenario. This translates to a typhoon along a path of 1961's Super Typhoon Nancy (Second Muroto Typhoon) at high tide (JWF, 2005).

SUPER TYPHOON VERA IN 2009

For the 50th anniversary of Super Typhoon Vera, RMS investigated the potential impacts of a repeat of the event in 2009 by analyzing the wind field and storm surge of an event of similar size striking Japan and the Ise Bay region, respectively. Insured property losses from the wind peril are based on the historical footprint for Vera, as modeled in the RMS® Japan Typhoon Model. A separate analysis is presented that estimates the flood losses from a "simulated" storm that is slightly stronger than the 1959 historical storm. This simulated storm was developed by Japan's Ministry of Land, Infrastructure, Transport, and Tourism and considers the extent of flooding in Ise Bay with and without the collapse of existing flood defenses.

Wind Field Modeling

Insured loss estimates for a repeat of the 1959 storm were obtained by analyzing property at risk utilizing the RMS® Japan Typhoon Model, which allows a user to run simulations of both historical and possible future windstorms against existing property exposures. The wind field reconstruction includes the broad area of damaging wind speeds, with higher winds generally on the right of the storm's track and the span of damaging wind speeds extending across the island of Honshu (Figure 9). As seen in the 1959 storm, wind gusts along the coast of Wayakama Prefecture at landfall are modeled to exceed 160 mph (258 km/hr), while gusts along Ise Bay in Mie and Aichi prefectures range between 100 mph (161 km/hr) and 150 mph (241 km/hr).

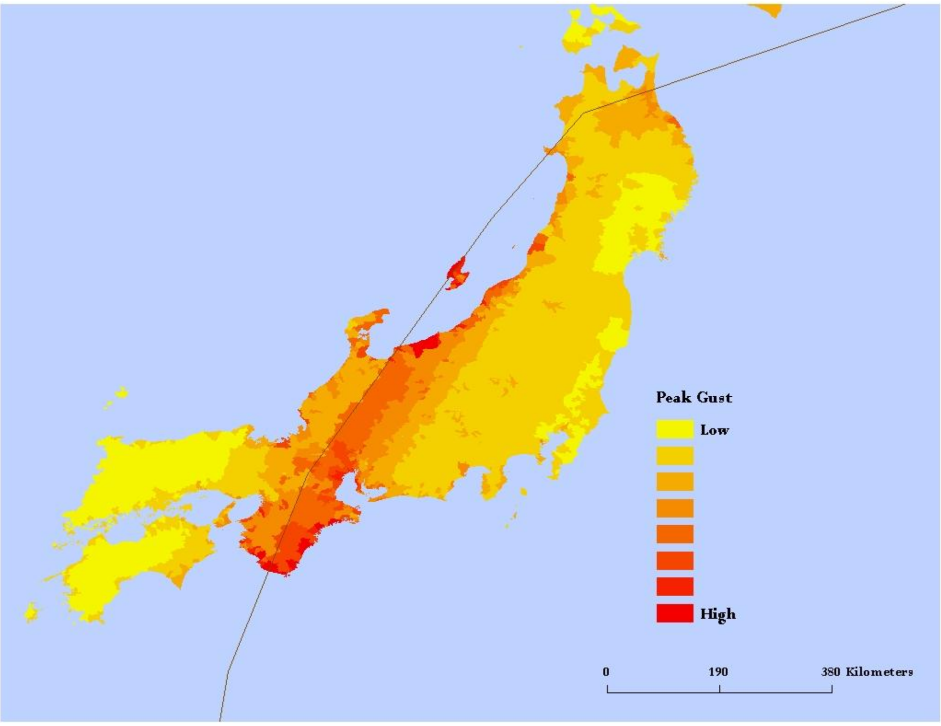

Figure 9: Track and wind field of the historical Super Typhoon Vera across Japan, as modeled by the RMS® Japan Typhoon Model

The insured property at risk from damaging winds is based on the current RMS® Japan Industry Exposure Database (IED), which represents the insured values by peril and by line of business for insured property exposure in Japan. For each city/ward, RMS has developed estimates of total insured values using a variety of sources, including sampled company premium information, census demographics and economics data, building square footage data, and representative policy terms and conditions. The residential, commercial, and industrial lines of businesses are analyzed against the wind field footprint. The residential line of business includes both single family and multi-family dwellings and considers the unique nature of insurance coverage in Japan. For example, occupants of apartment buildings often have coverage for contents only and a large number of homes in Japan obtain insurance coverage through cooperative insurance associations, including Zenkyoren. Both residential and commercial policies, covering wind and flood perils, are subject to a windstorm franchise of JPY200,000 (US$2,173). In contrast to deductibles as used in the U.S. market, the Japanese insurance market uses a franchise. For example, if the loss amount falls below the franchise, the policy holder pays the damages. However, if the loss is above the franchise, the insurer pays the entire loss, subject to the limit of coverage.

Superimposing the modeled wind field on the residential, commercial, and industrial exposure, insured losses due to wind damage from a repeat of Super Typhoon Vera would total between JPY1,355 and JPY1,655 billion (US$14.5 and US$18.0 billion[6]). This range of insured losses assumes some uncertainty in both the wind field footprint and the vulnerability of the property at risk. While damage would occur across a broad swath of Honshu, the highest losses would occur within the prefectures of Aichi, Mie, and Wakayama.

The magnitude of these potential losses comes as no surprise, as insured property loss estimates for a repeat of Super Typhoon Vera is well understood across the industry and is estimated from various sources to be between US$14 billion and US$15 billion (e.g., AXCO, 2009). Moreover, the Japanese Financial Services Agency (FSA) requires that insurance companies providing coverage in Japan must use the Super Typhoon Vera event for their solvency calculation. More specifically, since 2005, minimum catastrophe reserve requirements for an insurance company must be equivalent to expected claims payments from the return period of the 1959 storm, assumed to be a 1-in-70 year event.

Storm Surge Modeling in Ise Bay

As a significant proportion of the damage in the 1959 storm was due to storm surge flooding along the coastline of Ise Bay, an analysis of the expected impacts from a storm of similar size inundating the coastline in 2009 is warranted. Given the concentration of property at risk in the city of Nagoya and its harbor, at the center of one of the largest metropolitan regions of Japan, the destruction could be enormous. In estimating the impacts from storm surge in Ise Bay, the extent and depth of flooding must first be determined. Then, the value and construction type of all properties at risk within this flood extent is modeled, and the damage at each location can be calculated based on the expected flood vulnerability of the buildings and their contents. The total impact is then the sum of impacts across the affected region.

Flood Extent and Depth

For this analysis, a simulation developed by Japan's Ministry of Land, Infrastructure, Transport, and Tourism was utilized, which estimates the level of flooding in this region caused by a typhoon comparable in strength and similar in path to Vera. Known as the Super Typhoon Vera simulation, the path of the storm and its central pressure at landfall, as well as across Honshu, is shown in Figure 10. In this simulation, the minimum central pressure at landfall was set to 910 mb, which is somewhat lower than the central pressure of 929 mb at landfall during Typhoon Vera. This central pressure was chosen because it is equivalent to the lowest central pressure experienced in Japan in the historical record (i.e., Typhoon Muroto in 1934).

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[6] Based on a conversion rate of 92.025 Japanese Yen = 1 U.S. Dollar (as of September 21, 2009).

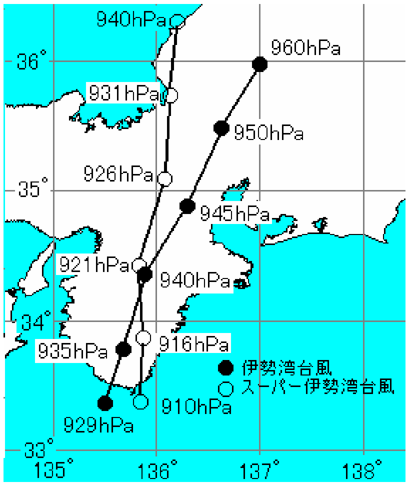


Figure 10: Tracks and central pressures for the simulated Super Typhoon Vera (white circle) and the historical storm in 1959 (black circle)

Figure 11 illustrates the extent and depth of storm surge flooding as a result of the simulated typhoon. Figure 11(a) shows the maximum inundation conditions in the case of flood defenses withstanding the storm surge and Figure 11(b) shows the inundation conditions where flood defenses collapse from the wave pressure. Across the impacted area, flood depths range from less than 1.6 ft (0.5 m) to over 16.4 ft (5.0 m). In this scenario, it is assumed that the flooding is due to storm surge with no accompanying inland river flooding. In addition, the mean high tide is assumed to be T.P.+1.22 m (T.P.+4.0 ft), which is slightly higher than the assumed high tide for defense height planning purposes (T.P.+1 m or T.P.+3.3 ft). At flood depths of more than 5 ft (1.5 m), one-story properties (e.g., wood frame residential structures) are a total loss.

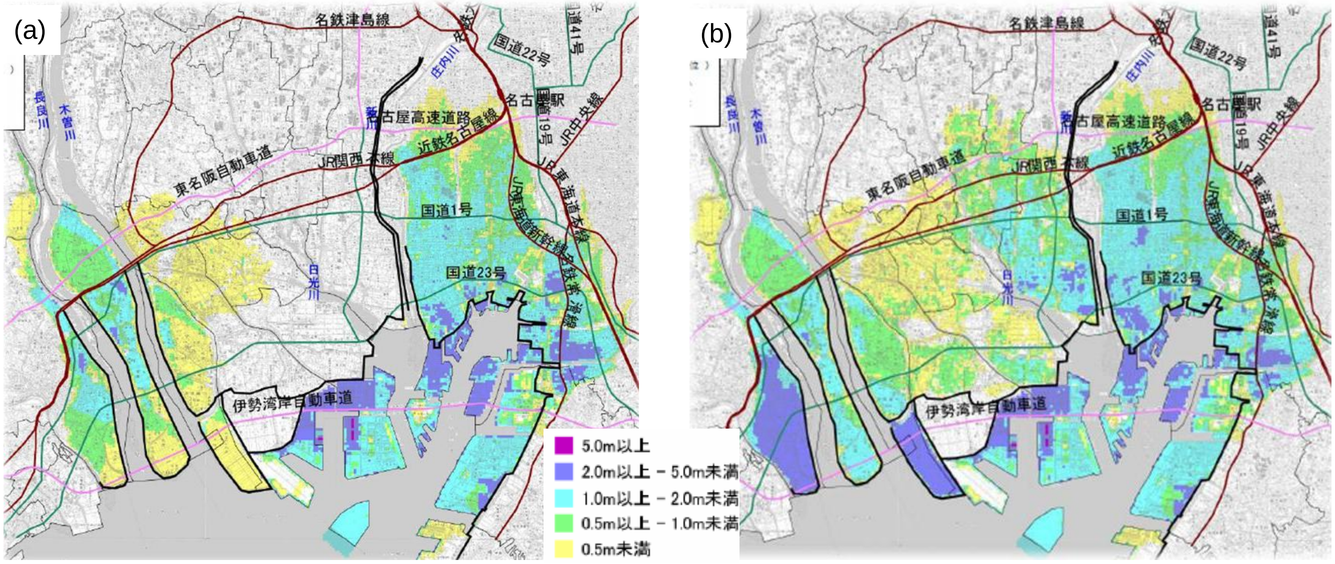
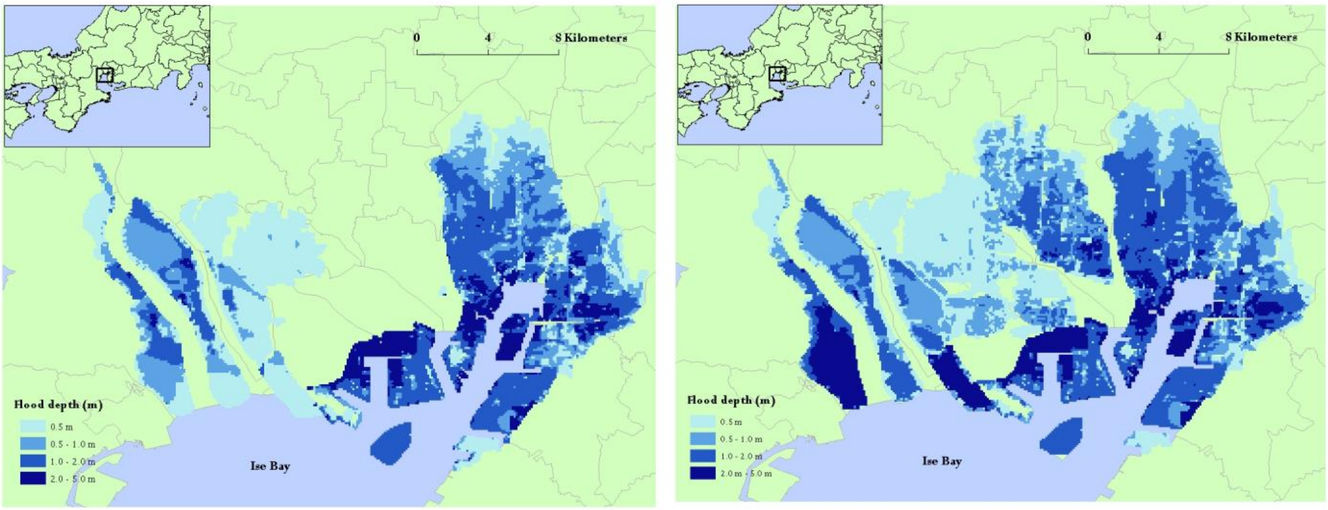


Figure 11: Maximum inundation depths (in meters) in Ise Bay, as estimated from the Super Typhoon Vera simulation: (a) flood depths with flood defenses and (b) flood depths with the collapse of defenses; flood defenses are shown (in black lines), as are transportation networks (in red, green, and pink lines)

The flood depth maps in Figure 11 were digitized and geographically referenced using landmarks such as river channels and administrative boundaries. By the end of the 1860s, the coastal areas around Ise Bay and Nagoya, formerly drainage land, had been reclaimed to increase farmland and agriculture. The shoreline seen today was formed at the beginning of the Meiji period (1868) and little has changed.

RMS assigned flood depths across the flood extent to 100-m by 100-m (330-ft by 330-ft) grid cells, based on the original digitized maps. The flood depths were refined using the 30-m (98.4 ft) resolution ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) digital elevation model (DEM), in order to ensure an accurate flood analysis, as well as mapping accuracy with regard to flood extent and depth. For example, as one of the flood depth ranges in the original map is large (6.6–16.4 ft or 2–5 m), the flood depths were refined, as the damage expected at a depth of 6.6 ft (2 m) is much less than the damage expected at a depth of 16.4 ft (5 m), especially to commercial properties or multi-family dwellings more than four stories in height. These digitized maps are illustrated below, where Figure 12(a) represents the extent and depth of flooding in the case of flood defenses holding and Figure 12(b) shows the extent and depth of flooding in the case of defense collapse.



(a)

(b)

Figure 12: Digitized maximum inundation depths (in meters) in Ise Bay, as estimated from the Super Typhoon Vera simulation: (a) flood depths with flood defenses at 100-m resolution and (b) flood depths with the collapse of defenses at 100-m resolution

Exposure

With these 100-m (330 ft) resolution flood depth maps, the property at risk from flooding is also digitized at the 100-m resolution grid in order to determine the extent of damage. ASTER imagery over the area, as well as other tools (e.g., Google Earth), were utilized to develop land use and land cover (LULC) classification data. With the LULC data, the concentration of various types of property at risk can be assigned to the 100-m grid cells.

Specifically, given the lines of business in the RMS® Japan Industry Exposure Database (IED) and the distribution of construction classes and building heights for each business class, the value of property in the Industry Exposure Database (IED) at the city/ward level is distributed to the same 100-m grid on which the flood depths were assigned. The concentration of residential and commercial/industrial property at risk within the flood extent, given the case of the collapse of flood defenses, is illustrated in Figure 13. As expected, more commercial and industrial properties are located along the coastline surrounding Nagoya Harbor.

RMS estimates that the value of property, including structures and their contents, at risk from flooding (i.e., within the flood extent) to be approximately JPY5.5 trillion (US$60 billion) in the case of the flood defenses withstanding the storm surge waves and to be approximately JPY7.0 trillion (US$76 billion) in the case of the flood defenses collapsing from the pressure of the waves. This includes concentrations of property in areas of central Nagoya. Of these estimates, in the case of flood defenses holding, approximately 60% of the value is attributable to the residential line of business, which includes single-family and multi-family dwellings, with the remaining value attributable to the commercial and industrial lines of business. In the case of the flood defense collapse, 55% of the value is attributable to residential property, with the remaining 45% of value at risk attributable to commercial and industrial lines.

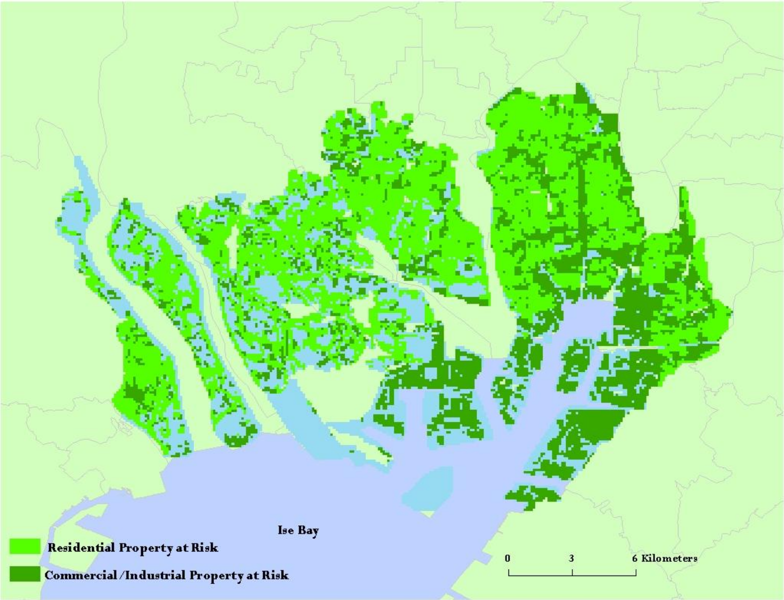


Figure 13: Property at risk from flooding in the case of the Super Typhoon Vera simulation, given the collapse of flood defenses; residential property (light green) and commercial/industrial property (dark green) are shown at the 100-m resolution overlaid on the extent of flooding (blue)

Building and Contents Vulnerability

The vulnerability of the property at risk is a function of the flood depth; as a result, the most important parameter in estimating property damage is a building's height. The methodology used in this analysis takes the expected flood depth and value of property at risk in each 100-m resolution grid cell and estimates the mean damage, based on a suite of vulnerability curves. Separate vulnerability functions are used for structure and contents damage for each line of business, taking into consideration the distribution of construction material (e.g., wood, reinforced concrete, etc.) and structure height (e.g., 1 story, 1–3 stories, 4–7 stories, etc.).

For example, the large majority of single-family dwellings are assumed to be one-story wood frame structures and thus more susceptible to damage in comparison to multi-family dwellings consisting of reinforced concretes structures up to seven stories tall. Taller buildings tend to have more restricted contents damage than shorter buildings, since part of the contents will be located on the higher floors that are not flooded. In addition, there is inherent uncertainty in the vulnerability of buildings and contents to the severity of the flooding, and in particular those situations in which the flooding could be considered to cause a total loss.

Potential Surge Loss

Based on the RMS analysis, the flood waters would overwhelm the region, severely damaging the residential, commercial, and industrial property at risk, as well as disrupting the transportation networks, harbor functions, and other infrastructure built in the region since the 1959 storm. However, if the flood defenses function as designed (i.e., do not collapse), the loss would be significantly reduced. More specifically, if the flood defenses withstand the storm surge waves, the property loss would be approximately 30% less than the property loss if flood defenses are breached or overwhelmed due to storm surge.

Residential property damage from storm surge would constitute fewer than 50% of the loss in the case of defenses withstanding the flood waters and close to 55% of the loss in the case of flood defense collapse, with the remaining losses sustained by the commercial and industrial lines of business. RMS estimates that the potential insured losses from the flood damage could add a further JPY184 billion to JPY552 billion (US$2 billion to US$6 billion) to the residential insured loss estimate for wind damage from this simulated typhoon event. This conclusion assumes some level of uncertainty in the scope of flood inundation, as well as the assumption that residential insurance policies for typhoon coverage pay out for both wind and flood damage. It is more difficult to conclude insured loss estimates to the industrial line of business, as flood coverage is an extension to basic coverage. It should also be emphasized that one cannot combine these estimates with the insured loss estimates from wind damage presented earlier in this report, as this estimate of flood loss is based on a Super Typhoon Vera scenario simulated by Japan's Ministry of Land, Infrastructure, Transport and Tourism. Insured wind losses presented in the wind field modeling section are based on a reconstruction of the 1959 windstorm footprint.

SUPER TYPHOON VERA IN PERSPECTIVE

A recurrence of Super Typhoon Vera would cause devastating consequences in Japan. However, in contrast to the 1959 storm, where insurance played a minimal role in recovering from the event, the majority of losses would be covered by the insurance industry. In the current Japanese property insurance marketplace, damage from storm surge is included as a standard extension to wind coverage for residential and commercial lines of business.

Moreover, in contrast to the 1959 storm, the extent of storm surge flooding in a recurrence of the event would be significantly reduced by the existing flood defenses and the warnings and emergency response to the event would be much better coordinated. In 1998, the Japan Meteorological Agency (JMA), which is responsible for communicating storm surge warnings, devised a numerical storm surge model to provide the basis for its warnings. The model provides 33-hour predictions of storm surges and sea levels for 290 points along the Japanese coastline (Higaki et al., 2008). In the event of a typhoon potentially making landfall along Japan's coastline, the model gives predictions of multiple storm surge scenarios with various meteorological conditions to consider the uncertainty in typhoon track forecasts.

The nature of natural hazard risk in 2009 also influences the impacts of a repeat of Super Typhoon Vera. The continuing issue of potentially higher sea levels due to climate change increases the threat of storm surge damage in Ise Bay, as well as other bays in Japan. The expected return period of the 1959 storm, assumed to be a 1-in-70 year loss event, may need to be assessed. The property along the coastline of Ise Bay is not only at risk from storm surge damage from typhoons, but from tsunami damage from an earthquake along the Tonankai segment of the Nankai Trough. While the height of the tsunami waves from an earthquake of expected magnitude is a minimal threat, the flood defenses could collapse due to significant ground shaking.

As this report shows, catastrophe models and their methodologies are useful tools in predicting the economic impacts of natural disasters. Although large efforts have been applied to flood defenses and early warning systems to help mitigate and reduce the impact of typhoons striking Japan, the potential for a large insured loss remains a serious and continuous threat. RMS remains committed to the Japanese insurance marketplace, providing sophisticated tools for the industry to price and manage catastrophe risk.

REFERENCES

AXCO (2009). *Insurance Market Report: Japan Non-Life (P&C)*. London: Axco Insurance Information Services.

Higaki, M., Hayashibara, H. and Nozaki, F. (2009). *Outline of the storm surge prediction model at the Japan Meteorological Agency.* Tokyo: Japan Meteorological Agency.

Ishizaki, H., Kawamura, S. and Huh, C. (1961). On the distribution of damaged houses by Isewan typhoon. *Annuals of Disaster Prevention Research Institute, Kyoto University*, 4, 95-104.

Ishizaki, H. (1965). The Distributions of Damaged Houses and Strong Winds by Typhoons. *Bulletin of the Disaster Prevention Research Institute*, 15(86).

JTWC (Joint Typhoon Warning Center), (1959). *1959 Annual Typhoon Report*. U.S. Navy: JTWC Annual Tropical Cyclone Reports. Retrieved from http://metocph.nmci.navy.mil/jtwc/atcr/1959atcr/pdf/1959_complete.pdf

JWF (Japan Water Forum), (2005). *Typhoon Isewan (Vera) and its Lessons*. Tokyo: Japan Water Forum. Retrieved from http://www.waterforum.jp/jpn/katrina/Typhoon_Isewan.pdf

Tagami, H., Kanno, T., Teranaka, K. and Kono, K. (1961). High tides countermeasures in land subsidence area. *IAHS Red Book Series,* I(88), 622-628.

Takeshi, M. (2008). *The history of the development of disaster prevention in Japan*. Retrieved on August 25, 2009, at http://www.id.emb-japan.go.jp/oda/en/whatisoda_04g1.htm

Tatano, H. (2008a). Flood risk in Japan: Status quo and management policies. In C. Scawthorn, and K. Kobayashi (Eds.) *Asian Catastrophe Insurance* (pp. 137-149). London: Risk Books.

Tatano, H. (2008b). *Features of Natural Disaster Risk*. Presented at the Disaster Prevention Research Institute, Kyoto University, April 16, 2008. Retrieved from http://imdr.dpri.kyoto-u.ac.jp/lecture/bousaikeizai/080416.pdf

Tsuchiya, Y. and Yasuda, T. (1980). High tide and life risk, refuge warning in relation to the Ise Bay Typhoon. *Journal of Natural Disaster Science*, 2(2), 27-60.

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