AON BENFIELD

2011 Thailand Floods Event Recap Report

Impact Forecasting — March 2012

Empower Results

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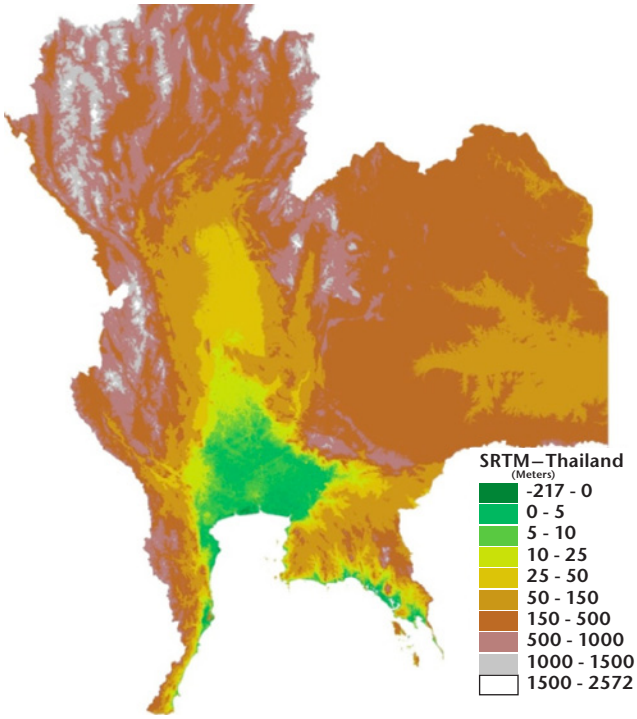
Executive Summary

2011 was a very notable year in Thailand as the country endured enormous damage in the wake of the worst flooding in at least five decades. Throughout the entire calendar year, more than 884 people were killed and millions of residents were either left homeless or displaced following significant flooding. The most extensive flooding—and the primary focus of this report—occurred between late July and early December across nearly every section of the country. In total, 65 of Thailand's 77 provinces were impacted during this timeframe and damage was widespread and severe in many locations. Economic losses were estimated by the World Bank at THB1.4 trillion (USD45.7 billion), which makes the floods one of the top five costliest natural disaster events in modern history.

Exhibit 1: Map of Thailand

Source: CIA World Factbook

Exhibit 2: Elevation Map of Northern and Central Thailand



Source: NASA's SRTM

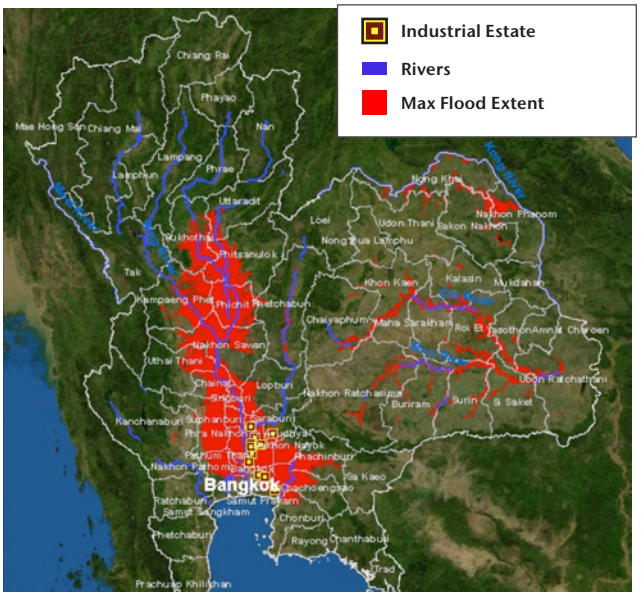
Some of the likely reasons for the floods included excessive rainfall, urbanization, high tides, insufficient drainage and flood protection systems, subsidence, the possible role of sudden release of waters from upstream dams and the general slope of land. Exhibit 2 illustrates the elevation of the Chao Phraya River Basin. Note that the map shows how the elevation within the Chao Phraya Basin gradually decreases as the river flows southward towards the Gulf of Thailand.

Exhibit 3 shows the maximum flood extent across central and northern Thailand on November 15, 2011.

Many of the primary sectors that form the backbone of the Thai economy (such as agriculture, manufacturing, tourism and personal property) were dealt a severe blow during the flooding of 2011. The loss of production throughout the duration of the floods led to a notable disruption of the global supply chain for major industries such as automobiles and electronics—effects which will take the first half of 2012 for many factories to return to normal production levels.

The insurance industry, which plays a vital role in the risk management of various sectors, suffered at least THB337.0 billion (USD10.8 billion) in losses—as published by Thailand's Office of Insurance Commission—and the industry has already undergone major changes as a result. Many insurers have started to seek a change in flood insurance policy coverage, modifying the current structure which sees flood insurance typically included with fire coverage.

Exhibit 3: Maximum Flood Extent as of November 15, 2011



Source: Thailand's GISTDA, Impact Forecasting

Due to the extensive nature of the floods, several international rating agencies began to reevaluate Thai insurers. Each of the rating agencies noted that the high level of insured losses would have a negative impact on both the life and non-life insurance sectors in Thailand.

Moving forward, reinsurers consider Thailand as being at risk for natural catastrophes, which could lead to significant changes in flood insurance policies—including increased pricing and decreased coverage.

In the wake of the floods, the Thai government enacted a broad response including a new natural disaster fund that would help insurers cover costs should another major natural disaster event of a similar magnitude strike again. The government also announced water management and flood projects to better prepare for flooding along the Chao Phraya River Basin.

During the latter half of 2011, Aon Benfield sent a reconnaissance team to conduct two damage surveys at multiple industrial estates. The team analyzed the floods' impact on affected facilities and also inspected embankments surrounding the estates.

In addition to the damage reconnaissance surveys, Impact Forecasting, the catastrophe model development center of excellence within Aon Benfield, has embarked on developing a riverine flood risk model to assist its clients during January 2013 renewals. The model will be released on Impact Forecasting's software platform ELEMENTS and will include residential, commercial and industrial lines of business. Impact Forecasting helps clients understand underlying risks from hurricanes, tornadoes, earthquakes, floods, wildfires and terrorist attacks on property, casualty and crop insurers and reinsurers. Impact Forecasting is the only catastrophe model development firm integrated into a reinsurance intermediary, providing our clients with unparalleled access to the broadest portfolio of integrated capital solutions and services.

Meteorological Background and Flood Overview

The flooding in Thailand during the second half of 2011 was enhanced by and likely the result of persistent monsoonal rains combining with the remnants of a series of tropical cyclones beginning in late July and lasting through the month of October. (Monsoon rains are defined as occurring due to a shift in wind direction from the ocean to land. In some cases, this pattern can cause significant rainfall.)

The presence of an active La Niña phase of the El Niño-Southern Oscillation (ENSO) also contributed to the excessive nature of the rainfall. The heaviest rains occurred across northern and central sections of Thailand, before swollen rivers and floodwaters began to shift southward towards the greater Bangkok metropolitan area. The following pages will help outline what is typical during a normal meteorological year in Thailand and will provide insights on what made the floods so devastating and how they unfolded.

What is Considered a Normal Meteorological Year in Thailand?

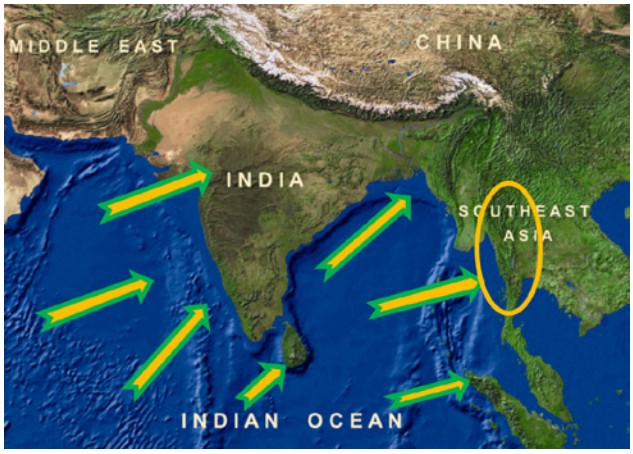
According to the Thai Meteorological Department (TMD), the country's climate endures three separate seasons: Rainy, Winter and Summer. The various regions of Thailand are typically prone to seasonal flash floods and river flooding even though dams, irrigation canals and flood detention basins have been built in recent years to mitigate flood damage.

Rainy Season

The Rainy Season (also known as the Southwest Monsoon Season) typically occurs between mid-May and mid-October. During this time, the Southwest Monsoon pattern prevails over central and northern sections of the country—spawning abundant amounts of rainfall—with the peak levels of precipitation normally received in August and September. The monsoon is supported by a stream of very warm, moist air approaching Thailand from the Indian Ocean. In addition to the southwest flow off of the Indian Ocean, an active Inter-Tropical Convergence Zone (ITCZ) and the arrival of tropical cyclones also provide enhanced moisture. (The ITCZ is typically noted on satellite imagery as a band of clouds near the equator that seasonally adjusts its location in a north/south direction based on the position of the sun.) During the month of May, the ITCZ will first arrive in southern Thailand before shifting northward into central and northern Thailand during August. As the season begins to wind down, the ITCZ again sinks southward prior to the arrival of the Northeast Monsoon.

It should be noted that along the West Coast of Thailand's southern region, tremendous rainfall occurs on the windward side of the local mountainous terrain.

Exhibit 4: Southwest Monsoon and Wind Direction



Source: Impact Forecasting

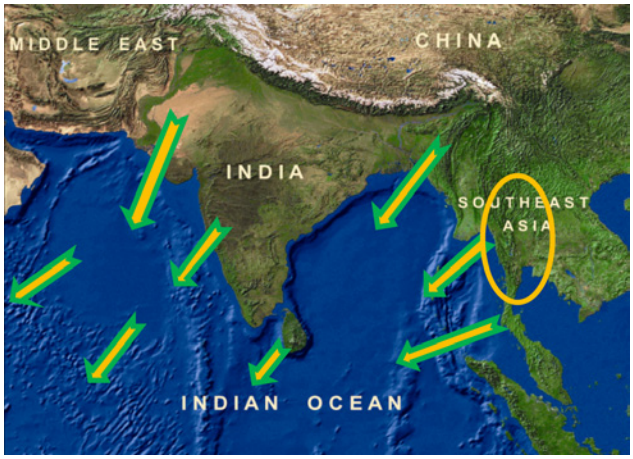
Winter Season

The Winter Season (also known as the Northeast Monsoon Season) typically occurs between mid-October and mid-February. During this time, the Northeast Monsoon pattern brings cool and dry air across northern and northeastern sections of the country due to the positioning of a strong ridge of high pressure over China's mainland. While this pattern brings dry and cool to the north, it also signals the start of a mild and rainy season for southern sections of the country—particularly along the east coast.

Summer Season

The Summer Season (also known as the Pre-Monsoon Season) typically occurs between mid-February and mid-May. This time is marked as a transitional period from the Northeast Monsoon to the Southwest Monsoon. Climatology suggests that the weather will become warmer, with April normally the hottest month in Thailand.

Exhibit 5: Northeast Monsoon and Wind Direction



Source: Impact Forecasting

Exhibit 6: Annual Rainfall Averages (in millimeters) for the Regions of Thailand

Region	Winter Season (mm)	Summer Season (mm)	Rainy Season (mm)	Annual # of Rainy Days
North	105.5	182.5	952.1	123
Northeast	71.9	214.2	1,085.8	117
Central	124.4	187.1	903.3	113
East	187.9	250.9	1,417.6	131
South				
—East Coast	759.3	249.6	707.3	148
—West Coast	445.9	383.7	1,895.7	176

Source: Thai Meteorological Department

Seasonal Rainfall Averages

Exhibit 6 above shows the 30-year average of rainfall totals for each region, broken down by season. Please note that the South region is split between East Coast and West Coast data, signifying the significant difference of rainfall seen on the windward and leeward sides of the mountainous terrain.

Active Start to 2011

Before the main flooding began between the months of July and December, the northern, central, eastern and southern regions of Thailand sustained significantly well above normal amounts of precipitation during the month of March. The presence of a trough in the north and an area of low pressure in the south (which were both prevalent throughout the month due to the positioning of separate ridges of high pressure in southern China and the Indian Ocean) were the reasons for the abundance of rain. According to the TMD, one-day rainfall records were established at 16 separate recording stations during the month.

Below are the regions that saw excessive rainfall totals and their percentages above normal solely during the month of March:

- North: 334%
- Central: 305%
- Eastern: 113%
- South (East Coast): 1,005%
- South (West Coast): 502%

Due to the abundance of rainfall, widespread flooding occurred across southern sections of the country in March and April. The Disaster Prevention and Mitigation Department declared eight provinces (Nakhon Si Thammarat, Phatthalung, Surat Thani, Trang, Chumphon, Songkhla, Krabi and Phang Nga) as disaster zones after the floods killed at least 61 people and saw upwards of 600,000 homes damaged from the worst flooding in a decade. Damage from the flooding and landslides was also extensive to businesses and the transportation and electrical infrastructures. The University of the Thai Chamber of Commerce estimated economic losses of at least THB27.2 billion (USD880.0 million).

It should be noted that the above normal rains in the north would essentially lay the groundwork for the substantial floods in the coming months as soils were oversaturated and river levels elevated.

In addition to Thailand, excessive rainfall was prevalent throughout much of Southeast Asia that also led to flood inundation in multiple countries during the second half of 2011. See Appendix A for a review.

Exhibit 7: Flooding in Nakhon Si Thammarat Province in early April 2011

Source: Alertnet

July — December Floods

The main Thailand floods of 2011, which primarily occurred between late July and early December, first became prevalent in northern sections of the country as a result of the start of the typical monsoon season. The arrival of the remnants of Tropical Storm Nock-ten in late July accelerated the severity of the rainfall (and floods) across the northern, northeastern and central portions of Thailand. As the calendar turned to August and September, a vigorous and on-going monsoon season (aided by the presence of La Niña) brought continued elevated rainfall totals to central and northern sections as flash floods, river flooding and landslides became more prevalent. An active tropical season in the Northwest Pacific Basin also added to the heightened floods and rainfall totals, with the remnants of four additional systems (Haima, Haitang, Nesat and Nalgae) reaching Thailand.

The timeframes in which the remnants of the five systems affected Thailand is noted, in addition to a map on the following page that provides the tracks of each:

- Haima (Red), June 24 – 26, 2011
- Nock-ten (Blue), July 30 – August 3 2011
- Haitang (Green), September 28, 2011
- Nesat (Yellow), September 30 – October 1, 2011
- Nalgae (Pink), October 5 – 6, 2011

The excessive rainfall that came from the tropical cyclones brought even more water throughout central and northern Thailand, in addition to rainfall from the seasonal monsoon. Exhibit 9 provides a sample of three tropical systems that impacted Thailand between June and August 2011, including the recorded rainfall and water runoff in four separate river basins (Ping, Wang, Yom and Nan). Please note that all four of these river basins drain into the main Chao Phraya River Basin.

Exhibit 8: Track Map of the Five Tropical Systems whose Remnants Brought Heavy Rainfall to Thailand. The blue shade shows the full flood extent.

Source: Aon Benfield Analytics / ImpactOnDemand

Exhibit 9: Water Runoff Volume in Ping, Vang, Yom and Nan River Basins from storms between June and August 2011

Storm	Duration	Average Rainfall by Basin (mm)				Runoff Volume by Basin (million cubic meters)			
		Ping	Wang	Yom	Nan	Ping	Wang	Yom	Nan
Haima	June 24-26, 2011	64.5	56.5	90.7	234.0	890.0	245.0	870.0	3,270.0
Nock-ten	July 30-31, 2011	97.1	117.7	126.2	46.9	1,000.0	370.0	900.0	1,100.0
Depression	August 18-20, 2011	37.6	24.0	45.0	56.2	260.0	65.0	325.0	590.0
					Totals	**2,150.0**	**680.0**	**2,095.0**	**4,960.0**
					Grant Total Runoff	**9,885.0**			

Source: Thailand's Royal Irrigation Department

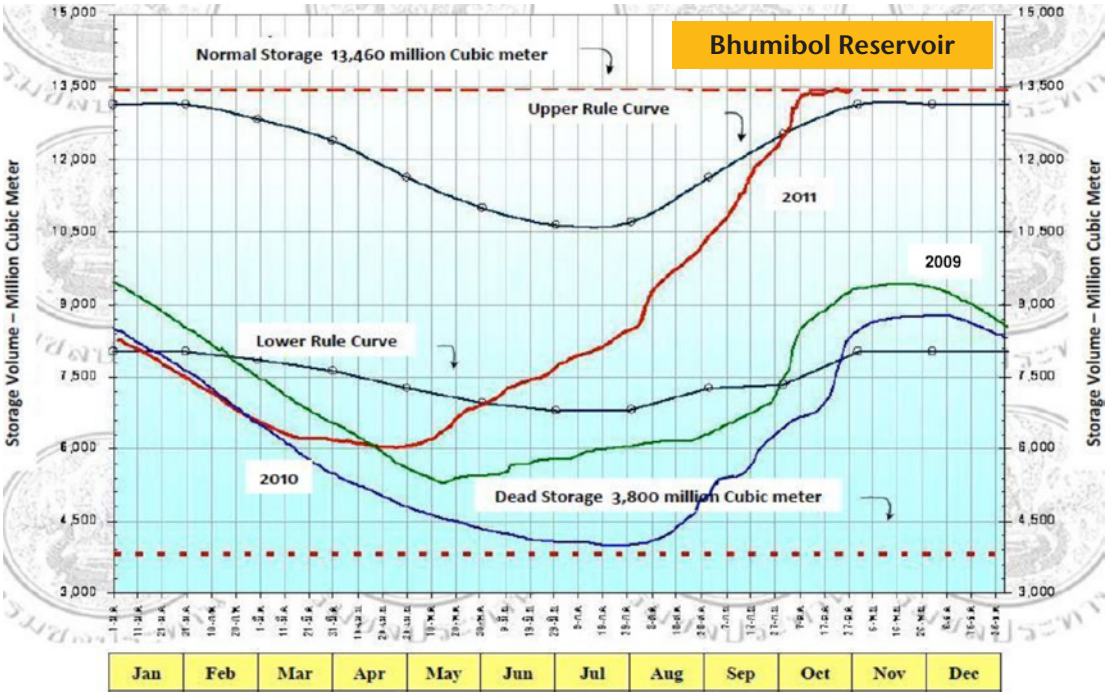
As the monsoonal and tropical cyclone-triggered rains continued in northern Thailand, and excess rainwater drained into the Chao Phraya River and its tributaries, the river swelled and breached its banks while flowing southward. The floods eventually covered an area from Chiang Mai Province in the north to Ayutthaya Province in the central plains (just north of Bangkok).

During this time period, the Bhumibol and Sirikit dams in the north began to discharge water as the dam reservoirs could not manage the level of water that was building up.

As the water flowed southward along the Chao Phraya River into Ayutthaya, Pathum Thani and Nonthaburi provinces, it broke floodgates which prompted the water to traverse through irrigation canals and into large areas of paddy fields.

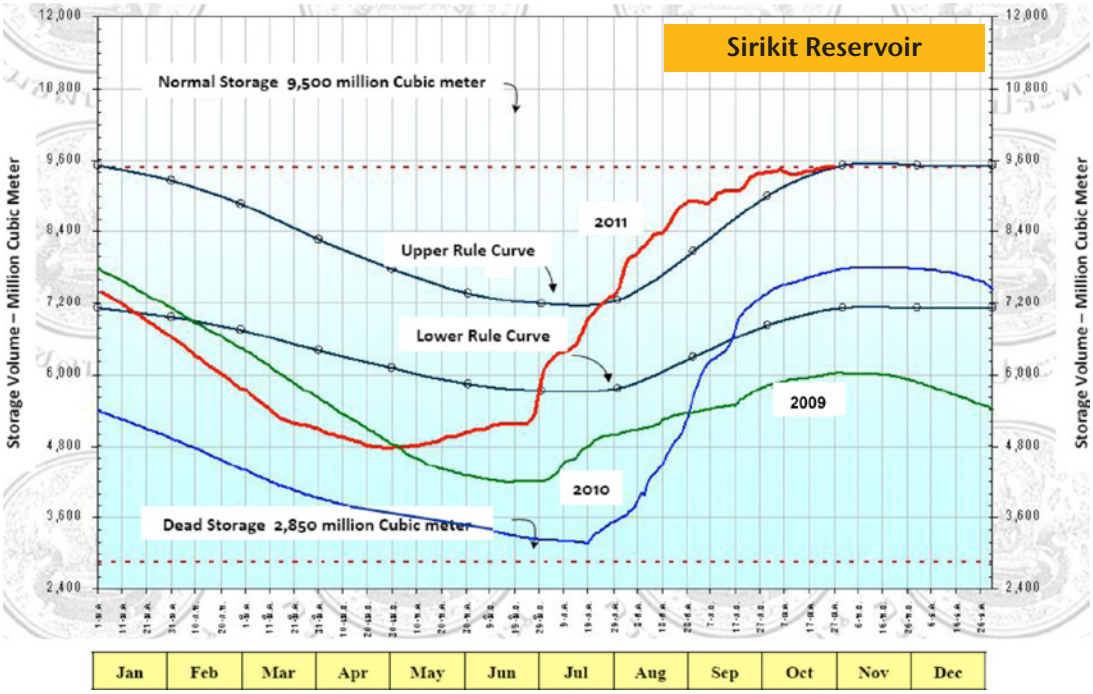
On the next page, Exhibits 10 and 11 show the progression of water storage in the Bhumibol and Sirikit dams for the entire year in 2011. The graphics also show the 2011 water levels in comparison to 2009 and 2010, as provided by Thailand's Royal Irrigation Department.

Exhibit 10: Water Storage Levels of the Bhumibol Reservoir Red=2011; Blue=2010; Green=2009)



Source: Thailand's Royal Irrigation Department

Exhibit 11: Water Storage Levels of the Sirikit Reservoir Red=2011; Blue=2010; Green=2009)



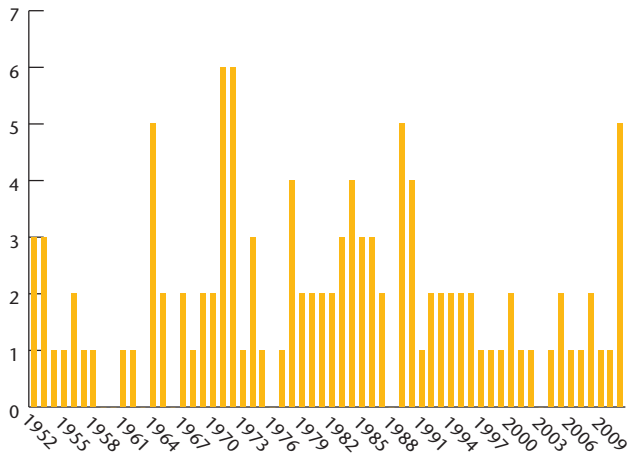
Source: Thailand's Royal Irrigation Department

In early and mid-October, the rain and floods were again reinforced by the arrival of the remnants of Typhoon Nalgae. As the month wore on, the floods reached their peak as rainfall totals approximately 40% above the annual average filled dams north of Bangkok to capacity, which prompted government officials to release more than 9 billion cubic meters (317 billion cubic feet) of water down a river basin the size of the state of Florida in the United States. During this time the floods in Ayutthaya Province reached their peak as water entered the city of Ayutthaya itself. The floods led to extensive flooding, including seven industrial estates after their protective barriers failed. This resulted in a significant number of major production factories sustaining substantial damage that led to a country-wide (and global) disruption of manufacturing supply chains.

As the flood waters continued to shift southward during October, the focus turned to Bangkok as efforts were made to prevent inundation in central sections of the city. At the height of the flooding in Bangkok, 470 locations in 32 northern, western and eastern sections of the city were impacted as water levels rose to a minimum depth of 80.0 centimeters (2.6 feet). The failure of several barriers led to inundation in the affected districts. In total, more than two million residents (20% of the city's population) were given mandatory evacuation notices as floodwaters also forced the closure of Don Mueang Airport and multiple main highways in and out of Bangkok. However, the flood prevention methods made to keep the heart of Bangkok dry were successful which kept a severe situation from becoming even greater.

During November and early December, the floods finally began to fully recede as the government used large pumping stations to drain an estimated 16 billion cubic meters (565 billion cubic feet) of water in areas from Ayutthaya Province southward to Bangkok. The water was drained into the Chao Praya River and from there into the Gulf of Thailand.

Exhibit 12: Number of Tropical Cyclones Affecting Northern and Central Thailand (1945-2011)



Source: IBTRACS/JTWC

To provide a historical context, there were several tropical cyclones during a single year in Thailand to affect the country, most notably in 1952, 1964, 1971, 1972 and 1989. However, there are no documented reports of serious flooding during these years that come close to the magnitude of what occurred in 2011. In addition to the excessive rainfall sustained from the heightened tropical cyclone activity and above normal monsoonal activity, the magnitude of the 2011 floods may also be correlated with the increase of construction in some areas during the last several years (and a corresponding decrease of agricultural land), inadequate drainage systems and the possible role of release of water from upstream dams. Exhibit 12 provides a glimpse of the number of tropical cyclones which have impacted northern and central Thailand between 1945 and 2011.

Exhibit 13: General Flooding

Source: U.S. Marines

The highest floods in the Chao Phraya River Basin in the past 30 years were due to an overabundance of water discharge were observed in 1983, 1995, 1996 and 2006. For further information about the Chao Phraya River and historical flood occurrences, see Appendix B.

November — December Floods

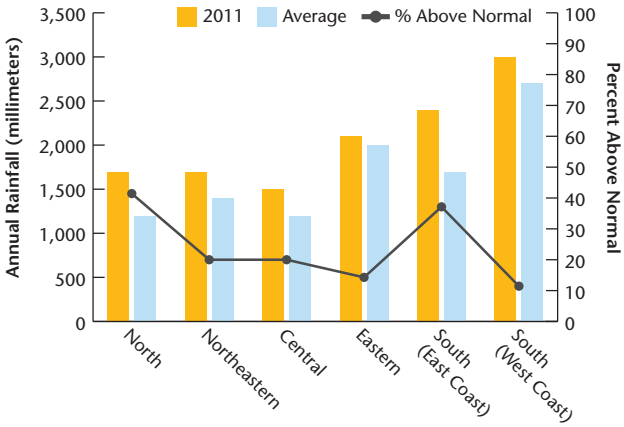
A third round of notable flooding during 2011 occurred again in southern Thailand between mid-November and the end of December. At least 10 people were killed and multiple provinces sustained additional damage to thousands of homes.

2011 Rainfall Totals

For the full year, every section of Thailand saw an elevated amount of rainfall when compared to the typical 30-year average. The combination of an active monsoon with the remnants of multiple tropical cyclones helped fuel the increase in precipitation during the calendar year in 2011.

Exhibit 14 shows the annual rainfall totals in 2011 for Thailand, broken down by region and also signifying the percent above normal.

Exhibit 14: Regions of Thailand — Total 2011 Rainfall as Compared to the 30-year Average



Source: Thai Meteorological Department

Damage Impacts

The impacts felt from the flooding between late July and early December were widespread across the vast majority of Thailand. In total, as many as 10 million people were affected in some way by the floods across 65 of the country's 77 provinces. The following sections will take a closer look at some of the damage and impacts caused by the extended flooding.

Personal Property Effects

Reports from the government suggested that as many as 1.5 million homes and other structures were impacted throughout the duration of the floods—with nearly four million total structures estimated to have sustained effects. According to the Thai Real Estate Information Center (REIC), as many as 300,000 homes were damaged in the greater Bangkok metropolitan region alone. When counting additional damage to all residential facilities in the region, the REIC noted that 700,000 total residential units were impacted. The World Bank reported that total economic losses to households were estimated at THB84.0 billion (USD2.7 billion).

Commercial Effects

The hardest-hit industries were electrical appliances and equipment, medical equipment, automobiles and food and beverage manufacturers. The Department of Industrial Works reported that more than 7,510 industrial and manufacturing plants were damaged by floods in 40 separate provinces. For a further look at preliminary information regarding the timing of the flood inundation in addition to an estimated aggregate total sum insured (TSI) in selected industrial estates, please see Appendices C and D.

Ayutthaya Province was one of the most heavily impacted areas, where at least 900 out of 2,150 factories were heavily damaged. In Ayutthaya province, all five industrial estates (Rojana, Saha Rattana Nakorn, Hi-Tech, Bang Pa-in and Factoryland) were inundated. Two additional industrial parks near Bangkok (Bang Chan and Lat Krabang) were also forced to temporarily suspend production due to inundation. Some of the notable companies who were forced to halt production in the industrial estates included: Toyota, Honda, Mazda, Nissan, Mitsubishi, Sony, Nikon,

Exhibit 15: Flood Inundation at the Rojana Industrial Park

Source: U.S. Marines

Sanyo Semiconductor, Canon, Western Digital, Hitachi, Hutchinson, Microsemi, ON Semiconductor and Matsushita. According to the chairman of the Japan Automobile Manufacturers Association, nine separate Japanese motor companies were forced to halt production at the height of the flooding and the production of approximately 6,000 vehicles were lost per day.

The extended shutdown of the industrial estates led to a substantial loss of production, with the supply of automobiles and electronics particularly seeing a sharp decrease in availability all around the world. The loss of production led to negative impacts to each company's bottom line.

Refer to Appendix C for an update on affected manufacturers.

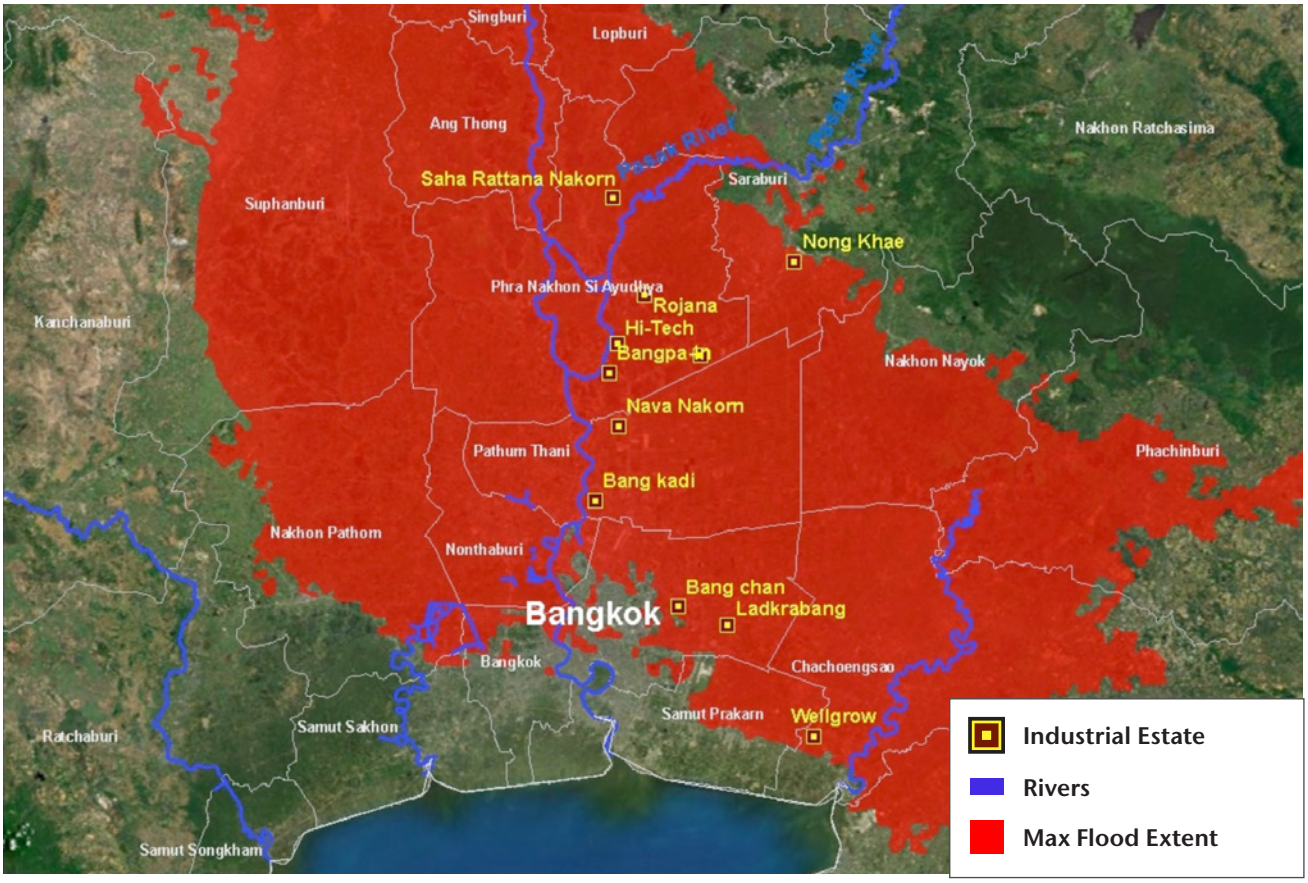
According to the Department of Industrial Works, damage costs to the industrial parks and estates were estimated at THB230.0 billion (USD7.4 billion)—including THB86.5 billion (USD2.8 billion) in damage to machinery and THB143.5 billion (USD4.6 billion) in damage to on-site raw materials, products that were currently in production and finished goods. The World Bank noted that the overall economic cost to manufacturing nationwide (including business interruption) was THB1.0 trillion (USD32.5 billion).

It should be noted that Ayutthaya Province accounts for 7% of Thailand's economy and generates at least 15% of the country's total manufacturing output. This region was just beginning to recover following the shutdown of factories after the deadly earthquake and tsunami event that struck Japan in March 2011. The Japan event led to a global chain reaction of industrial factory and manufacturing shutdowns.

Bangkok remains the economic hub of Thailand, which accounts for 41% of the country's economy. Any serious disruption to commerce or tourism in Bangkok would have led to impacts at an even larger scale than was already seen throughout the rest of the country.

The graphic below illustrates a closer look at some of the affected industrial estates just to the north and east of Bangkok.

Exhibit 16: Selected Industrial Estates Embedded within the Maximum Flood Extent on November 15, 2011



Source: GISTDA

Exhibit 17: Flooded Highway

Source: U.S. Marines

Infrastructure Effects

The agricultural and transportation infrastructures were both heavily impacted during the floods. The subsections below will provide a more detailed look at sustained effects.

Transportation Infrastructure

The transportation infrastructure sustained major damage during the floods, with a high number of roads and bridges having been submerged or washed away. The Department of Highways and the Department of Rural Roads reported that parts of 1,700 roads, highways and bridges were damaged or destroyed. The economic cost to roadways alone was listed at THB139.0 billion (USD4.5 billion).

Airports around Thailand were also hit, including in Bangkok. The city's secondary airport (Don Mueang) was forced to close in October 2011 after floodwater crept into the main terminal building and also over the facility's runways. The airport was re-opened to commercial flights in March 2012, after the eastern runway needed repairs. The president of Airports of Thailand reported that approximately THB150.0 million (USD4.8 million) was necessary to repair the runway.

Bangkok's main Suvarnabhumi International Airport was largely unaffected as a large dyke and water pump system surrounding the facility held firm.

Train services were also disrupted as rail tracks were left submerged or washed away on multiple routes.

Agricultural Infrastructure

More than 1.9 million hectares (4.7 million acres) of land—including 1.4 million hectares (3.3 million acres) of rice fields—were damaged. This represented 12.5% of all available cropland nationwide. The country's rice crop was particularly affected, where some estimates suggested that up to 25.0% of the crop sustaining damage. Despite the large loss of the rice crop, an overall nationwide bumper crop was anticipated and nationwide impacts were minimal. Combined with the fact that there was a global surplus of rice in 2011, there was not much of a ripple effect.

Thai government estimates stated that total economic losses to the farm sector from the floods was THB73.0 billion (USD2.4 billion).

Reconnaissance Trips to Thailand

During December 2011, a team from Aon Benfield's Singapore office visited some of the flood-affected industrial estates in Thailand.

Rangsit is a northern suburb of Bangkok. Exhibit 18 shows many cars were stranded on the side of an elevated tollway due to flooding. The area was sandbagged and there was a pump being used to reduce the water level. During the floods, there was quite a bit of traffic congestion as motorists were only able to use the tollway and not the main roads.

Most of the roads within the large industrial estate complexes were accessible—with the exception of a few—as floodwaters had receded. However, water marks were clearly visible on the buildings within the affected areas and deposits of mud and debris were noticed around the factories.

Exhibit 18: Parked Cars on Elevated Tollway

Source: Aon Benfield

Exhibit 19: Street View from Tollway

Source: Aon Benfield

Exhibit 20: Deposits of Mud around the Factories

Source: Aon Benfield

Exhibit 21: Watermarks Clearly Visible on Affected Buildings

Source: Aon Benfield

Clean-up projects were initiated at some factories and it was noted by the Aon Benfield team that there was an abundance of labor workers working to clean the facilities.

Exhibit 22: Standing Water in Navanakorn Industrial Estate

Source: Aon Benfield

Exhibit 23: Remnant Water in Navankorn Industrial Estate

Source: Aon Benfield

A follow-up visit occurred in December to other affected factories (along with the staff of a major regional client and loss adjusters). The following sections will provide some observations made during this reconnaissance trip to various industrial estates. Also included are some general comments observed during the trips. For additional photographs, please see Appendix E.

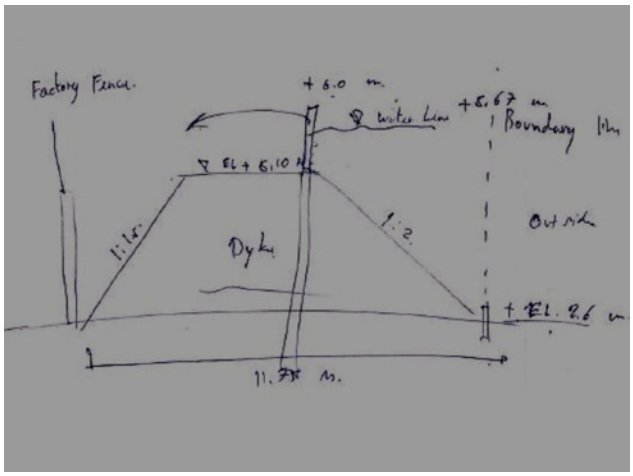
General Observations at Selected Industrial Estates

Rojana Industrial Estate

The estate was almost completely drained by December 2, 2011, and the team from Aon Benfield had an opportunity to speak with the project engineer regarding the earth dykes around the estate. Given that the floodwaters rose to 5.7 meters (18.6 feet) above mean sea level, the estate management company has considered raising the protection level of the embankment system to 6.0 meters (19.7 feet). There are two available options: 1) construct a retaining wall on top of the existing embankment, or 2) sheet piling through the embankment. The Japanese International Cooperation Agency (JICA) approves the dykes once they are constructed.

Of the 250 factories in Rojana, only 20 to 30 actually utilized power from Rojana Power Company as the rest utilized power from the national grid. During the floods, the provincial power supply was knocked offline. At the estate, flood warnings were issued two weeks in advance to the water's arrival though none of the factories were able to escape damage.

Exhibit 24: Hand Drawn Figure of Current Dyke with Proposed Wall at Rojana Industrial Estate



Source: Aon Benfield

Exhibit 25: Flood Prevention Pump Station

Source: Aon Benfield

Exhibit 26: Flood Prevention Pump Station

Source: Aon Benfield

Bang Pa-in Industrial Estate

Floodwaters receded from the facility around December 19, 2011 after factories in the estate endured up to 2.0 meters (6.6 feet) of water for up to five weeks.

Saha Rattana Nakorn Industrial Estate

The industrial estate was completely drained of water by December 4, 2011. Despite the presence of a large, on-site pumping station, it was not designed to handle the enormity of the floods experienced.

In fact, the pumping station itself became inundated and accompanying retention ponds were not sufficient in being able to handle the overwhelming amount of water experienced. The land surrounding the facility is relatively flat, as the estate is set against a rural backdrop.

Navanakorn Industrial Estate

Navanakorn was the oldest industrial estate visited by Aon Benfield, as it includes many older and smaller factories. Floodwaters arrived and breached embankments located behind the estate, and it took less than a day to reach its maximum depth. Waters were completely drained by December 6, 2011. All factories in the estate were affected, despite the fact that many had temporary defenses.

Hi-Tech Industrial Estate

The estate was drained of water by November 25, 2011, after an embankment up to 4.5 meters (14.8 feet) in height failed at several locations.

The Aon Benfield team noted that the embankment itself was earthen, appeared uneven, with grown vegetation around it (making it relatively inaccessible to any emergency repairs) and poorly formed. As noted, breaching was seen at several locations and it appeared that the estate did not drain as well as some of the others visited.

Exhibit 27: Grown Vegetation Near Embankment

Source: Aon Benfield

General Observations at Different Factories Visited

The main buildings at most of the toured factories were single-story with an elevated roof. They were primarily constructed from reinforced concrete on a reinforced concrete ground slab, and there was no significant structural damage to the buildings as the floodwaters arrived with a slow current. However, it was noted that most of the wooden partition walls inside the buildings needed replacement due to rotting and mold. This most likely was caused by the presence of longstanding water. Most of the factory interiors needed to be decontaminated and given an anti-mold treatment. Broken windows and doors also needed replacement.

Floodwaters entered the factories primarily over the perimeter walls after they were breached in some places. Temporary defenses like sandbags were put in at some places, but they were not sufficient to withstand the severity of the floods. The flood water was 'black water', which is heavily contaminated water known to damage a clean room environment inside factories. It was learned during the visit that the oxygen level in the water was low, and this led to a lower level of oxidation (and rusting). Lower portions of electrical panels, dryers, chillers and warehouse racks were the most affected by rusting.

Lab machinery, electronic components, precision parts, motors, microscopes and other specific instrumentation utilized in the factories was also damaged, in addition to larger machinery which could not be moved. A large portion of the machinery needed to be replaced.

In some cases, machinery parts can be restored due to a coating of oil on the machines, which prevented more serious damage. The availability of spare parts was a noted issue (because industries using similar machinery across different industrial estates needed similar spare parts at the same time), though there were a number of available technicians to make the repairs when the parts arrived. In some places, management decided to stop production prior to the arrival of water and moved selected machinery to higher floors. These decisions ended up saving this equipment from being affected. The flood waters also notably damaged air conditioners, which are located at a lower level. Transformers (which were not 'all-weather') were also damaged in some places where they are not situated at an elevation.

Most, if not all, of the product and stock was damaged due to the stagnant flood water. Even in cases where the stock and product was moved to a higher level, the standing water and high humidity damaged them. Post-flooding, test batches were being assessed to determine the impact of humidity on certain products.

Exhibit 28: Rusted Factory Parts

Source: Aon Benfield

Exhibit 29: Damaged Machinery Outside Factory

Source: Aon Benfield

Exhibit 30: Unaffected Transformer

Source: Aon Benfield

Common Elements at the Visited Industrial Estates

Most factory buildings were built either at the ground level or slightly elevated above the road level. Embankments were seen, but were at a lower level than the highest water mark observed and were unable to keep the floodwaters from entering the estates. The general condition of the embankments at the estates appeared poor as none were made of concrete and were discontinuous. The water either topped the walls or entered through breaches in the embankments. Most estates were planning the construction of higher embankments, and it may take two or three years to fully implement construction.

Exhibit 31: Bang Pa-in: Not a Continuous Embankment

Source: Aon Benfield

Exhibit 32: Rojana: Unconsolidated Soil Dyke

Source: Aon Benfield

Exhibit 33: Bangkadi: Loose Soil Dyke

Source: Aon Benfield

Exhibit 34: Saha Rattana Nakorn: Below High Water Mark

Source: Aon Benfield

It was noticed by the Aon Benfield team that nearly all factories within the affected estates sustained flood inundation and damage. Despite mitigation measures attempted by some facilities, the overwhelming amount of water led to widespread damage to machinery and product stock. In addition to the floodwater itself, high humidity levels led to molding in many factories.

As the clean-up process continues, the availability of spare parts and materials has become an issue. In addition, due to electrical switch boxes and transformers being damaged, in-house power supplies remain scarce. All national grid customers, however, have seen a return of electricity. Duration of the flood waters in the estates was between six and nine weeks, with some factories commencing clean-up towards the end of November 2011. Clean-up activities and loss assessors' fees will add to the costs. The widespread scale and duration of the floods will likely add up to a significant business interruption loss.

It will be quite some time before all of the factories are able to resume pre-flood production levels. Underinsurance appears to have been an issue in some cases, and several companies are looking to purchase new equipment as soon as possible to minimize business interruption losses.

There appears to have been two options which factory owners could have followed in the affected areas:

- Keep production running as long as possible before evacuating when the flood waters entered
- Stop production and try to mitigate potential losses by moving key equipment, product stock, contents and products to higher floors

Of the two options noted above, the first approach appeared to have been followed by some companies despite access to the estates having been cut off by floodwaters prior to overtopping embankments. The lack of employee presence due to the loss of road access would have forced a halt of production regardless. The overall sense was that most companies did not expect the floods to be nearly as extensive or last as long as they did. As for the second approach, some companies followed this line of thinking but saw extensive losses to equipment, product stock and products due to molding from excess humidity and stagnant water.

In the aftermath of the floods, insurers have hired forensic engineers to assess damage to equipment and machinery. This has accelerated recovery times by being able to avoid directly contacting equipment manufacturers to determine the possibility of repairs. There are reports that the loss adjuster fees have been quite high. Many international loss adjusters have been brought in for their experience with specialist equipment.

General Comments on Vulnerability

Vulnerability is highly sensitive to building type, product stock, contents and machinery. Furnished below are a few general observations regarding the vulnerability of different coverage types.

Buildings

It appeared that there was no significant structural damage to the affected buildings. However, non-structural impacts required the replacement of wooden partition walls, false ceilings and air conditioner compressors. Broken windows and damage to perimeter walls were also noted.

Many of the main production buildings were single story in height with a high roof, which restricted the ability of the operator to move machinery and product stock to a higher level. The building materials were mostly concrete, and no steel frames were observed in the main buildings.

Exhibit 35: Broken Perimeter Wall

Source: Aon Benfield

Exhibit 36: Wooden Partition Wall Needing Replacement

Source: Aon Benfield

Product Stock

Product stock was destroyed by humidity, mold and/or immersion. Even plastics were damaged by immersion in dirty water due to surface coating of contaminants. Product stock stored in upper portions of the warehouse was also rendered useless because of the mold (even more so in the case of sensitive products such as pharmaceuticals, food products, etc.).

Contents

Most of the contents were highly vulnerable to immersion and subsequent mold growth once the water receded. Contents like office furniture, computers and microscopes were rendered unsalvageable by mold, silt deposition and immersion.

Exhibit 37: Damaged Microscopes

Source: Aon Benfield

Exhibit 38: Damaged Furniture and Fixtures

Source: Aon Benfield

Machinery

Machinery was generally the most costly investment in many of the factories, though some of the stainless steel machinery that was damaged was repairable. Some factories adopted mitigation measures, such as applying oil-coating on machines, which prevented further damage. However, machinery with precision spare parts, like X-ray machines and semiconductor chip quality test equipment, were not able to be salvaged due to the longer duration of water inundation.

Exhibit 39: Damaged Machinery Placed Outside the Factory

Source: Aon Benfield

Exhibit 40: Damaged Machinery Placed Outside the Factory

Source: Aon Benfield

Economic Impacts

According to the World Bank, total economic losses from the July-December floods were estimated to be THB1.4 trillion (USD45.7 billion). The Thailand government also confirmed these economic losses. In the World Bank report, it was determined that a disproportionately large percentage of the losses (90%) were suffered by the private sector, as opposed to only 6% by the public sector. The other 4% includes combined miscellaneous losses. Exhibit 41 below provides a private sector breakdown of losses as estimated by the World Bank:

Exhibit 41: Breakdown of Economic Losses

Sector	Economic Losses (Billions THB)	Comments
Manufacturing	1,007	Most losses sustained at industrial factories
Tourism	95	Loss of tourism revenues over a 6-month span
Households/Personal Property	84	Includes structural and indoor content losses
Agriculture	40	Loss of agricultural production

Source: World Bank

The overall Thai economy sustained a much greater impact than was initially expected. According to the Fiscal Policy Office (FPO), the Gross Domestic Product (GDP) was expected to grow only by 1.1% for the calendar year 2011. This was well below the pre-flood projection of 4.5% growth and a revised 'worst-case' projection of an annual 1.7% growth as the floods were at its peak.

During the first three quarters of 2011, the Thai economy reported a 3.1% growth. However, the fourth quarter was very challenging as the floods had disrupted exports (particularly the farming and manufacturing sectors), which led to the economy shrinking. The GDP declined by 9% in the last quarter of 2011 compared to a year earlier, according to the National Economic and Social Development Board (NESDB).

Impacts on the Insurance Industry

According to the Office of Insurance Commission (OIC), insured losses from the July-December floods were expected to be in excess of THB337.0 billion (USD10.8 billion) as of December 21, 2011. It is likely that there will be further adjustments in the final loss figures as some of the losses are still being finalized. These exceptional losses in Thailand have increased awareness about the insurance coverage for unforeseeable events like floods, earthquakes and hail. This is in contrast to the current model of freely available flood insurance, where the massive damage incurred in 2011 should see premiums for this cover rise.

The projected premium income for the insurance industry in Thailand in 2011 was reduced from THB489.0 billion (USD15.8 billion) before the floods to THB472.0 billion (USD15.2 billion) after the floods. The reduction included life premiums accounting for approximately THB335.0 billion (USD10.8 billion)—a 13% year-over-year increase—and the non-life sector accounting for the other THB137.0 billion (USD4.4 billion).

Reinsurers' Responses

Reinsurers have suffered substantial losses from the flooding. However, general interest for business in Thailand continues among most of the reinsurers though floods created concerns about flood exposures amongst some reinsurers. Reinsurers have responded by limiting their exposure to flood risk through various measures ranging from imposing event limits on pro-rata treaties to total exclusion of Natural Catastrophe Cover, reducing their net shares of these treaties; by significantly raising the price of reinsurance cover; placing increased emphasis on Contingent Business Interruption (CBI) and by scrutinizing definitions of what constitutes a single event. A small number of reinsurers have chosen to exit the Thai market completely, whilst others have entered to take advantage of changes in terms and conditions. Some of these conditions could be permanent, as the increase in the minimum Capital Adequacy Ratio (CAR) from 125% to 140% takes effect from January 1, 2013.

Local Thai Insurance Industry

The floods were expected to bring about some significant changes in the local insurance industry in Thailand, with the general insurance segment experiencing most of the likely change.

In the past, flood coverage in Bangkok was offered practically free from the insured's perspective. It was routinely added onto fire insurance policies, with premiums covering 0.1 to 0.2% of the total sum insured (for properties such as homes and commercial buildings). Large Commercial and Industrial Risks are covered by All Risks policies, and these policies are driven by market rates.

In this particular class, the competition is very heavy, and often results in policy holders receiving flood (and other CAT perils) cover almost for free. As a result of the competition, there was a downward trend in the policy rates during the period between 2006 and 2010.

But the 2011 floods prompted a paradigm shift in the mindset of insurers. A majority now prefer flooding, earthquakes and storms to be excluded from fire insurance policies. Many insurance firms are letting their clients know that there is likely to be an alteration in the terms of renewal of household policies. The currently undecided new premium rates are predicted to be more than double the current rates, with several riders in the contracts.

New Risk-Based Capital (RBC) rules have taken effect from September 2011. Thailand's insurance regulator, the OIC, requires insurers to have a minimum capital adequacy ratio of 125%, which will increase to 140% in January 2013 under the new Risk Based Capital Framework. Policy sublimits for the coverage of natural catastrophe perils are expected to be implemented, with a minimum deductible to be born by the insured.

Aon Benfield's Response

In response to the unprecedented floods and the record losses, in addition to the damage reconnaissance surveys, Impact Forecasting (the catastrophe model development center of excellence within Aon Benfield) has embarked on developing a riverine flood risk model to assist its clients during January 2013 renewals. The model will be released on Impact Forecasting's software platform ELEMENTS and will include residential, commercial and industrial lines of business.

Observations from Rating Agencies

Standard & Poor's (S&P)

The latest article on the Thai floods was released by Standard and Poor's on February 29, 2012.

The article named *Thai Floods Dampen Asian Insurers' Earnings and Capitalization* discusses the current situation facing insurers after the Thai floods. The article commented that with announcements made by insurers and reinsurers in recent months, a better picture of Thai flood-related losses is showing how large the flood-related losses could be. S&P estimated that the current gross losses for insurers globally at about USD16.0 billion to USD18.0 billion. Ultimate losses are likely to exceed earlier estimates.

S&P commented that with higher-than-estimated flood losses, this could result in negative earnings and weaken capitalization more than they had expected. This could lead to downgrading of insurance companies on CreditWatch by one or more notches, or revising the outlook to negative. It does not expect the full extent of the flood losses to be known at least until the second quarter of 2012.

The outlook on the Thai non-life insurance market remains negative.

Earlier, on November 3, 2011, S&P published a report that discussed what impacts the Thailand floods were having on Thailand's non-life insurers in 2011. They commented that significant flood-related losses arising from the Thailand floods could potentially weaken the performance of Thailand's non-life insurers in 2011 and also revised the outlook on its non-life insurance sector from stable to negative. The sector is now considered susceptible to natural catastrophe risks, which is a change from their previous view.

The financial profile of some non-life insurers in Thailand was likely to deteriorate significantly in 2011 due to the potential decline in underwriting profits stemming from flood-related claims and investment earnings because of equity market-related losses. It was further added that the catastrophe models that insurance companies use are likely to have underestimated flood risks, given the lack of historical flood loss data of a similar scale. Therefore, the possibility that some insurers or reinsurers may not have adequate reinsurance or retrocession protection exists.

Going forward, S&P believes the floods will have a profound impact on the Thailand non-life insurance industry's catastrophe risks assessment and could alter the industry's risk profile.

A.M. Best

On November 23, 2011, A.M. Best published a special report analyzing the magnitude and size of the damages affecting insurers. Besides commenting on the size of the damages, they observed that the event ranked among the 10 costliest economic natural catastrophes in world history. It is also expected that the take-up rates for flood coverage and business interruption would increase among Thai companies. Meanwhile, the government is pressuring market participants to write coverage as a national economic priority so that manufacturing does not relocate abroad.

On February 9, 2012, A.M. Best published an update on the Thai floods. The article provided an update on overall flood losses, confirming the situation to be one of the costliest insured loss occurrences in recent years. The loss amount could increase further if the floods are classified as multiple events as event limits were not always specified in Thai insurance contracts. The article also covered the various implications resulting from the Thailand floods. Reinsurers will now consider Thailand as a risk for natural catastrophes, resulting in significant changes to flood insurance policies, including increased pricing and decreased coverage. Industry consolidation is also expected in 2012 resulting from the floods as weak insurers begin to seek new partners in the market.

Fitch Ratings

Fitch Ratings (Asia-Pacific) has expressed the opinion that the recent heavy losses will force local Thai insurers to pay out large claims and motivate them to secure their financial soundness by building capital. Some of the local insurers will likely realize that they are financially constrained. Fitch Ratings opined that the recapitalization is needed to pay out claims and that the RBC rules could lead to mergers and acquisitions in the insurance industry.

Government Response

National Disaster Fund

In the aftermath of the 2011 floods, the Thai government initiated a National Disaster Fund of THB50.0 billion (USD1.6 billion) to support the provision of natural disaster risk coverage to households, small firms and industries. This model was designed by a working committee of members from the Office of Insurance Commission (OIC), the General Insurance Association (GIA), the Thai Chamber of Commerce and the Federation of Thai Industries and was accepted by the Committee for Reconstruction and Future Development. This fund was to be mutually provided by 67 general insurance companies and the Thai government. The fund will be capable of covering losses of approximately THB500.0 billion (USD16.1 billion). The aim of the fund is to provide insurance with the lowest possible burden transferred to the clients. Close to 780,700 private homes, 229,300 small and medium sized enterprises and 15,600 large businesses were expected to carry natural disaster insurance in 2012. Insurance sales are expected to begin in April 2012.

The National Disaster Fund could permit insurers to continue with underwriting unpredictable natural disaster-related risks, such as floods, earthquakes, thunderstorms, cyclones and wildfires. According to the OIC, the government would revamp the infrastructure in order to counter any naturally occurring damages. The Natural Disaster Fund is expected to be in force for a minimum of three years, until reinsurance firms regain faith in Thailand. By December 30, 2011, the Thai cabinet had approved the establishment of the fund and the OIC proposed a framework for operations in January 2012.

Water Management and Flood Projects

The Thai cabinet countenanced the set-up of funds for flood prevention. Government bonds will be issued and a fund will be established in order to promote long-term investment for development of appropriate infrastructure for sustainable water management. Most of the funding would come from domestic sources, though some may come from overseas (including Japanese development funding sources). The Thai government designed a water management and flood prevention plan for areas along the Chao Phraya River Basin worth THB300.0 billion (USD9.7 billion), with an additional THB50.0 billion (USD1.6 billion) planned on infrastructure and 17 additional river basins.

The plan calls for dividing the Chao Phraya River Basin into a 'flood vulnerable' and a 'less vulnerable' area. The flood vulnerable area comprises of 80% agricultural land and some residential, commercial and industrial land. Some 18 million people live in this region. The other portion of the river basin, which houses approximately 7 million people, is less likely to sustain severe flooding.

The government plans to spend THB120.0 billion (USD3.9 billion) for the construction of floodways and flood diversion channels that would allow water flows up to 1.5 billion cubic meters (53 billion cubic feet) per second. There are also plans to tackle forest conservation, restoration and construction of dykes along the river basins of the Chao Phraya tributaries—in addition to construction of reservoirs along the tributaries. Money will also be used to enhance the current system of dykes, convert 320,000 hectares (790,000 acres) of farmland to be used for floodwater retention and enhance warning systems.

The cabinet has also endorsed a legal amendment to allow the Central Bank in Thailand to offer soft loans up to the amount of THB300.0 billion (USD9.7 billion) via state-run and other commercial banks to help alleviate financial difficulties for businesses and ordinary citizens who have been affected by the recent floods. The Bank of Thailand Act 2007 will be amended to allow this to be implemented. The cabinet has also consented to a plan that would financially aid flood-hit provinces by hiring workers to rejuvenate communities.

Flood Preparations

The Royal Irrigation Department (RID) prepared to discharge water from 400 dams and reservoirs to create space for replenishment. At the end of December 2011, the dams were operating at 90% of capacity and there were plans to release additional water to allow future inflow into the dams. The RID proposed 8,000 separate projects at a cost of THB1.7 trillion (USD55.0 billion) that would increase Thailand's water storage capacity.

According to the Industrial Estate Authority of Thailand (IEAT), plans are being drawn up for permanent dykes up to 6.5 meters (21.3 feet) in height to be built around the seven industrial estates that were forced to shut down during the 2011 floods. However, each estate is managed separately and is responsible for its own financing; hence, implementation of these plans may vary between the estates.

Return Period

The Danish Hydrological Institute (DHI) estimates that the return period of the floods to be above the 100-year threshold, though the estimate is not specific. The estimation is based on the observed peak levels of water at different stations in Chao Phraya River Basin. At the moment, there are no fully developed commercial vendor models available to assess potential insured losses from the flood risk in Thailand.

Exhibit 42: Peak Water Levels Recorded on the Chao Phraya River in meters above mean sea level

Station	Observed Peaks			Estimated Return Period (Years)					
	1983	1995	2011	2.0	5.0	10.0	25.0	50.0	100.0
Ayutthaya	4.7	5.1	5.9	3.4	4.1	3.7	5.1	5.4	5.6
Bank Sai	3.1	N/A	4.2	2.6	3.1	3.4	3.7	3.8	4.0
Pakret	2.2	2.6	3.2	2.2	2.6	2.7	2.9	3.0	3.1

Source: Danish Hydrological Institute

The floods have also raised awareness of non-quantified exposures among insurers and reinsurers. At this time, the flood aggregates in Thailand are mostly provided at provincial level by various insurance companies. The split between large industrial or commercial exposures by risk locations (i.e. specific industrial estate etc.) is generally not available.

Appendix A: Review of Other 2011 Floods in Southeast Asia

Major flooding during the summer and fall months was not solely confined to Thailand, as many other Southeast Asian countries sustained substantial flooding as well. Below is a look at four of the most affected countries:

Cambodia

Heavy rains, which began in early September 2011, led to substantial flooding across Cambodia over the course of multiple weeks and months. The Cambodian government reported that flash floods and flooding along the Mekong River had led to the deaths of at least 250 people as more than 1.2 million people were directly impacted in 19 separate cities and provinces across the country. At least 250,000 homes, schools and religious sanctuaries were damaged or destroyed, in addition to more than 3,000 kilometers (1,864 miles) of roads. The agricultural infrastructure saw at least 400,000 hectares (988,000 acres) of rice paddy fields submerged as well. Total economic losses were estimated at KHR660.0 billion (USD161.0 million).

Vietnam

The combination of monsoon rains and multiple tropical cyclones led to major floods throughout much of Vietnam during September, October and November. The most significant effects were felt in the Mekong River Delta, where at least 100 people were killed. The Central Committee for Storm and Flood Control reported that more than 175,000 homes were destroyed and 99,000 hectares (245,000 acres) of rice and other crops were submerged. At least 1,455 kilometers (904 miles) of dykes and 1,300 kilometers (808 miles) of roads were damaged as well. Total economic losses were estimated at VND2.9 trillion (USD135.0 million).

Laos

Laos also sustained two months of extensive flooding as high water levels in the Mekong River Delta occurred in response to an active monsoon season and the arrival of several tropical cyclones. The floods, which were prevalent between June and October, left at least 34 people dead and upwards of 140,000 homes destroyed. More than 64,400 hectares (160,000 acres) of rice paddy fields have been submerged. Total economic losses were estimated at LAK1.4 trillion (USD174.0 million).

Myanmar

Tropical Cyclone 02B came ashore in Bangladesh in late October, though its remnants led to extensive flooding across Myanmar. At least 215 people were killed as flash floods and river flooding in central and southern sections of the country damaged or destroyed more than 8,000 homes. The transportation and agricultural infrastructures were also heavily impacted. Total economic losses were listed at MMK11.0 million (USD1.7 million).

Appendix B: Review of Chao Phraya Basin

Before / After Comparison of Chao Phraya River in July and October 2011

Exhibit 43: Chao Phraya River in Ayutthaya Province — July 11, 2011

Source: NASA

Exhibit 44: Chao Phraya River in Ayutthaya Province — October 23, 2011

Source: NASA

Historical Flood Events in the Chao Phraya River Basin

The lower Chao Phraya River Basin has endured repeated floods throughout its history, which has prompted residents living along its banks to adapt their lifestyle to these recurring events. In terms of discharge, the worst floods in recent history (prior to 2011) were documented in 1831, 1942, 1983, 1995, 1996, 2002, and 2006. The combination of rapid urbanization, increased agricultural cultivation in the surrounding areas and a decrease in the level of flood retention has all contributed to the enhancement of these floods.

The Chao Phraya River and its tributaries comprise 162,800 square kilometers (62,850 square miles)—or approximately one-third—of Thailand's entire landmass. Of Chao Phraya's tributaries, the Wang River joins the Ping River and the Yom River joins the Nan River within the middle basin. All of these tributaries flow from Thailand's Northern Highland region. In the city of Nakhon Sawan, the Ping and Yom rivers join together and form the Chao Phraya River. Another tributary, the Pasak River, joins the Chao Phraya in the lower basin and the Tha Chin River diverges at the main stream. At the lower basin, the Chao Phraya flows through such locations as Chai Nat, Ayutthaya and Bangkok before entering the Gulf of Thailand. In the low alluvial plain, which begins below the Chainat Dam, many small canals split off from the main Chao Phraya River. These canals (also known as 'khlongs') are used for the irrigation of the region's rice paddies.

Some notable cities located along the Chao Phraya River include: Nakhon Sawan, Uthai Thani, Chainat, Singburi, Ang Thong, Ayutthaya, Pathum Thani, Nonthaburi, Bangkok, and Samut Prakarn.

Exhibit 45 analyzes historical floods and some of the natural and human factors in the Chao Phraya River Basin:

Exhibit 45: Historical Analysis

		1942	1983	1995
Human Intervention	Forest Cover[a]	166,000 km^2	106,000 km^2	92,000 km^2
	Area Denuded	N/A	60,000 km^2	74,000 km^2
	Reservoir Capacity	N/A	23 billion m^3	24 billion m^3
	Flood Protection	2,230 km^2	12,900 km^2	14,400 km^2
	Urban Area[b]	51 km^2	389 km^2	528 km^2
Natural Causes	Rainfall Upstream	Exceptionally heavy	Unusually heavy (Sept. to Nov.)	Unusually to exceptionally heavy
	Rainfall in Bangkok	Normal	Unusually heavy (Aug. to Nov.)	Normal to unusually heavy
	Tides	Normal Spring tide with seasonal effects	Normal spring tide with seasonal effects	Normal spring tide with seasonal effects

Source: Flood Management in Chao Phraya River Basin by Sripong, et al.

[a] Northern and Central regions of Thailand
[b] City of Bangkok only

Exhibit 46 provides a look at historical economic losses due to flooding along the Chao Phraya River Basin between 1978 and 1995. Please note that the totals below are rough estimates from various sources, and may differ from other published reports. The figures are losses from the time of occurrence and have not been adjusted for inflation or economic growth.

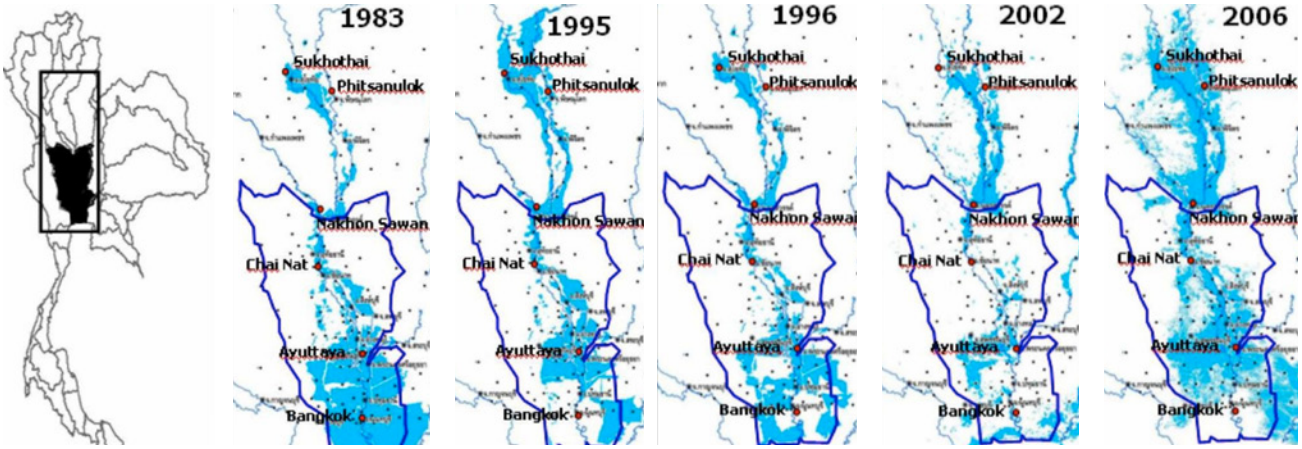
Exhibit 46: Flood management in Chao Phraya River Basin by Sripong, et al.

Year	Economic Cost (THB)	Economic Cost (USD)	Year	Economic Cost (THB)	Economic Cost (USD)
1978	21 million	692,000	1987	833 million	27.5 million
1979	3.2 million	105,000	1988	21 million	692,000
1980	1.55 billion	51 million	1989	3.2 million	105,000
1981	314 million	10.4 million	1990	1.55 billion	51 million
1982	224 million	7.4 million	1991	314 million	10.4 million
1983	1.1 billion	36.3 million	1992	224 million	7.4 million
1984	323 million	10.7 million	1993	2.18 billion	71.9 million
1985	350 million	11.5 million	1994	46 million	1.52 million
1986	628 million	20.7 million	1995	11.9 billion	392 million

Source: Various sources

The graphics below show flood extent areas during select events in the Lower Chao Phraya Basin.

Exhibit 47: Flood Extent Areas in Lower Chao Phraya Basin



Source: Integrated Flood Mitigation Management in the Lower Chao Phraya River Basin by Dr. Somkiat Prajamwong and Dr. Pomsak Suppataratam

Historical Flood Events in Bangkok

Exhibit 48 below provides a look at select previous flood events in the city of Bangkok. Please note that the economic losses listed solely represent the losses incurred within Bangkok's city limits. The losses are from the time of occurrence and have not been adjusted for inflation or economic growth.

Exhibit 48: Notable Floods in the City of Bangkok since 1785

Year	Flood Description	Economic Cost (THB)	Economic Cost (USD)
1785	4.25-meter (13.94-foot) flood height	N/A	N/A
1819	3.20-meter (10.50-foot) flood height	N/A	N/A
1831	Floodwaters reached the top of protective walls	N/A	N/A
1917	All roads underwater for at least one month's time	N/A	N/A
1942	1.50-meter (4.92-foot) flood height, which persisted for two months' time	N/A	N/A
1975	Floods caused by tropical depression	1.1 billion	36.2 million
1980	Four days of excessive rainfall in city prompts widespread flooding	700 million	23.1 million
1982	Heavy rainfall prompts flooding	1.1 billion	36.0 million
1983	Remnants of multiple tropical cyclones prompts 3-5 months of flooding in the city	6.6 billion	217.5 million
1995	Chao Phraya River measured at 2.27 meters (7.45 feet) above sea level	3.0 billion	98.8 million
1996	Water levels measured at 2.14 meters (7.02 feet); flood dike overtopped	1.5 billion	49.4 million

Source: Bangkok Metropolitan Administration

Appendix C: Flood Inundation Timing at Select Industrial Estates and Affected Manufacturers

The timing as to when floodwaters precisely entered various industrial estates continues to be investigated. Exhibit 49 below provides a preliminary and rough timeline on the dates in which floodwaters first entered selected industrial estates. The impact on specific individual risks will vary depending on the topography and floodwater defenses of each building within the industrial park. These dates should be verified on a case-by-case basis.

Exhibit 49: Estimated Timing of Initial Water Inundation at Select Industrial Estates

Province	Industrial Estate	Estimated Time of Water Inundation
Ayutthaya	Saha Rattana Nakorn	October 4, 2011
Ayutthaya	Rojana	October 10, 2011
Ayutthaya	Hi-Tech	October 13, 2011
Ayutthaya	Bang Pa-In	October 14, 2011
Pathum Thani	Navanakorn	October 17, 2011
Pathum Thani	Bangkadi	October 20, 2011
Ayutthaya	Factory Land (Wang Noi)	October 15, 2011

Source: Aon Benfield via reconnaissance trips to flood sites.

Manufacturer Updates

Toyota

The company announced in mid-December 2011 that the Thai floods led to lost production of 260,000 vehicles due to damaged auto part facilities. This represented a 3.4% decrease below their annual target. The production shutdown at the company's three Thai plants led to an annual earnings hit of USD1.55 billion and a 56% decrease in net revenue (USD2.3 billion). In late February 2012, the company stated that it would be increasing engine production in Thailand at a newly planned vehicle assembly factory. Toyota was affected by the floods more than any other carmaker.

Nissan

The company announced that 19,931 fewer vehicles had been produced as compared to 2010, representing a 13.5% reduction. The company's main plant at Samut Prakan was unaffected by the floods, but production was shut down until November 14, 2011 due to the lack of supply parts from other factories in Thailand. Normal levels of production resumed in early December.

Nissan reported that recovery costs related to the impact on supply chains from the Thai floods was JPY5.59 billion (USD67.6 million) in the three months ending December 31, 2011.

Honda

Extensive flooding at Honda's main manufacturing plant in Ayutthaya Province led to a global disruption in production due to a lack of auto parts. Honda was the only car manufacturer in Thailand to sustain damage to its primary four-wheel vehicle manufacturing plant. In addition to Thailand, production was halted by 50% at auto plants in the United States and Canada through the end of 2011. The company announced in November 2011 that due to a high volume of damaged equipment and machinery, a resumption of full production would not occur until April 2012.

Honda reported that sustained losses of JPY7.33 billion (USD88.3 million) due to lost inventories, and JPY7.65 billion (USD92.6 million) due to damaged property and equipment during the last three months of 2011. The company reported that in the three months ended December 31, 2011, it had recognized insurance recoveries of JPY11.8 billion (USD143.2 million).

Mazda

Production was suspended for more than one month's time due to the lack of necessary supplies, despite the company's primary factory located just southeast of Bangkok not having been damaged. Damage to the company's local supplier's facilities was the primary driver of the stoppage of production until the end of November 2011. Mazda reported that global retail volume was down 6.9% from the same period of the previous fiscal year.

For the first nine months ending December 31, 2011, Mazda recorded an operating loss of JPY54.3 billion (USD656.8 million). Out of the noted operating losses, the March 11, 2011 Japan earthquake accounted for JPY22 billion (USD266.1 million) and the Thai floods JPY4.2 billion (USD50.8 million). The JPY26.2 billion (USD316.9 million) was listed as a one-time loss due to external factors.

Mitsubishi Motors

The company's main Thai plant in Laem Chabang, southeast of Bangkok, was not damaged by flooding though production was suspended due to local parts suppliers having sustained damage to their own facilities. By the end of November 2011, production resumed to near normal levels.

Goodyear

Major flooding at the company's main aviation tire manufacturing facility in Bangkok led to a severe disruption in production through the end of November. Despite other facilities outside of Thailand ramping up aviation tire production, the shutdown in Bangkok led to a decrease in available supply of tires for the commercial airline industry in February and March 2012.

The company announced in February 2012 that losses resulting from the Thai floods (including business interruption and clean-up costs) were USD16 million.

Sony

The company sustained a widespread shutdown of production after two of Sony's three manufacturing facilities were damaged by the floods. The damage occurred at the company's production plants in Ayutthaya and Pathum Thani provinces (including the 502,000 square foot facility at Bangkadi Industrial Estate), which forced the postponement of launches of the NEX-7 and the Reflex Alpha 65 cameras. The shutdown also led to the loss of production for the company's television unit and other product sectors. The company was forced to temporarily shift production to other manufacturing facilities in Thailand, China and Japan.

Sony announced that in the three months ending December 31, 2011, it had sustained JPY8.86 billion (USD107.2 million) in losses due to repair, removal and cleaning of damaged facilities and an additional JPY4.62 billion (USD55.9 million) due to idle facility costs at manufacturing sites and other expenses. The company recorded insurance receivables of JPY4.87 billion (USD58.9 million), which were attributable to damaged assets and inventories. Business interruption or opportunity losses were not included in the insurance total.

Canon

The company saw a disruption of production to its printer division after the main factory in Pathum Thani sustained substantial flood damage. However, Canon's camera storage and distribution facilities were generally unaffected. The company's camera equipment production facilities are located outside of Thailand in Singapore and Japan.

Canon announced that for the fiscal year 2011, the Thai floods had an impact of JPY49.9 billion (USD603.6 million) on net sales.

Toshiba

The company sustained a significant disruption of production at ten separate manufacturing facilities in Pathum Thani Province. Nine of the damaged plants were located at Bangkadi Industrial Estate, with the tenth at Navanakorn Industrial Estate. Officials noted that Bangkadi is Toshiba's primary production center in Southeast Asia, where home appliances, semiconductors and lighting products are made. As of March 2012, the company had only partially resumed operations at the damaged facilities and was temporarily shifting some production to other countries in the region (such as the Philippines).

Western Digital

The company, which produces 60% of its hard drives in Thailand, saw a major disruption of production after some of its factories in Bang Pa-In and Navanakorn industrial estates were damaged by high floodwaters. Production slowly was restarted by the end of November 2011, though officials in March 2012 noted that it may not be until September 2012 for normal capacity production to resume. Western Digital sustained a 20% year-to-year quarterly decline after seeing a shipment reduction of 51% (or 24 million) fewer hard drives.

Western Digital reported that it had recorded USD199 million in losses relating to the Thai floods, including USD109 million to fixed asset impairments, USD39 million of recovery charges, USD28 million of write-downs of damaged inventory and USD23 million in wage continuation during the shutdown period of its facilities. The company is in the process of submitting insurance claims and, at this time, is unable to provide an estimate.

Nikon

The company reported significant damage to its primary production facility at Rojana Industrial Park in Ayutthaya Province. Nikon reported that the flood damage led to the stoppage of its DSLR camera lines. Production was suspended until November 30, 2011, when production partially resumed at partnering factories. Partial operations at Nikon's facility in Thailand resumed on January 3, 2012, with normal-scale production occurring at the end of March 2012.

Nikon estimated that impacts of business performance for the financial period ending March 31, 2012 would see a JPY65 billion (USD786.2 million) in reduction in net sales and a loss of JPY25 billion (USD302.4 million) in operational income due to lost sales. The company noted that it had sustained damage losses of JPY10.9 billion (USD131.8 million) to fixed assets and inventories. An insurance payment of JPY500 million (USD6.04 million) was received under damage insurance policies, and Nikon noted that additional insurance payments were pending (including from business interruption and other losses).

Hitachi

The company saw a major disruption of hard drive production, which was down to 17.2 million units shipped in the fourth quarter 2011 as opposed to the 31.9 million units shipped in the third quarter. (It should be noted that in March 2012, Hitachi Global Storage Technologies was sold to Western Digital.) At Hitachi Chemical's plant in Hi-Tech Industrial Estate, Ayutthaya Province, severe flood damage caused the shutdown of production of brake pad manufacturing. Partial production did not resume until the first quarter of 2012.

Hitachi announced that it had sustained an JPY14.6 billion (USD176.4 million) year-to-year quarterly loss due to the Thai floods and falling sales of its flat panel televisions.

Microsemi

The company saw the shutdown of operations at two subcontracted facilities in Thailand, which account for up to 5% of total quarterly revenues. Production was relocated to other factories as Microsemi announced that a full recovery would be seen by the end of the second fiscal quarter of 2012.

Microsemi announced that its first quarter 2012 gross margins had declined from fourth quarter 2011, primarily due to the Thai floods.

ON Semiconductor

The company sustained extensive damage to its facilities in Ayutthaya Province, and later announced that it was partially closing its operations at Bang Pa-In Industrial Facility by the end of the first quarter of 2012. ON Semiconductor noted that the recovery and reconstruction costs were too excessive to justify bringing back online. Production was shifted to other company-owned facilities that had excess equipment capacity and floor space.

ON Semiconductor announced that it had sustained a 14% decrease in quarterly revenue for the fourth quarter of 2011.

Appendix D: Estimated Aggregate TSI in Select Industrial Estates

The estimated aggregate TSI (Total Sum Insured) in selected industrial estates and preliminary information on flood depths in respective sites is found in Exhibit 50 below. Please note that the information provided in the table is only an approximation based on internal Aon Benfield sources and is not representative of the actual TSI in the respective locations. It does not include TSI from any property risks located outside of industrial estates within each province.

Exhibit 50: Estimated Aggregate TSI in Selected Industrial Estates

Province	Industrial Estate	Flood Depth (meters)	Estimated Aggregate TSI (THB)	Estimated Aggregate TSI (USD)
Ayutthaya	Saha Rattana Nakorn	2 to 4	10 billion	300 million
Ayutthaya	Rojana	2 to 3	150 billion	4.9 billion
Ayutthaya	Hi-Tech	2 to 3	20 billion	700 million
Ayutthaya	Bang Pa-In	2 to 3	15 billion	500 million
Ayutthaya	Factory Land	2 to 3	25 billion	800 million
Patumthan	Bangkadi	2 to 3	40 billion	1.3 billion
Patumthan	Navanakorn	2 to 3	30 billion	1.0 billion
Bangkok	Ladkrabang	N/A	50 billion	1.6 billion
		Totals	**340 billion**	**11.1 billion**

Source: Aon Benfield

Appendix E: Additional Photos from Aon Benfield On-Site Visits

Exhibit 51: Damaged Product Stock and Product

Source: Aon Benfield

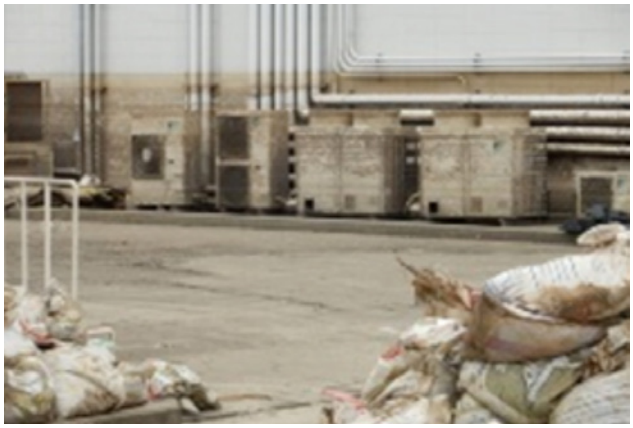
Exhibit 52: Heavy Mud Deposits around Factories

Source: Aon Benfield

Exhibit 53: Damaged Air Conditioning Units

Source: Aon Benfield

Exhibit 54: Damaged Air Conditioning Units



Source: Aon Benfield

Exhibit 55: Floodwaters at Historical Site in Ayutthaya City

Source: Aon Benfield

Exhibit 56: Large Pumps Used to Drain Water

Source: Aon Benfield

Exhibit 57: Highest Watermark Observed (>3.5 meters)

Source: Aon Benfield

Exhibit 58: Clean-up Activities at Factories

Source: Aon Benfield

Exhibit 59: Reconstruction Activities

Source: Aon Benfield

Exhibit 60: Choked Drainage at Industrial Estate

Source: Aon Benfield

Exhibit 61: Fallen Telephone Booth in Drainage Channel

Source: Aon Benfield

Exhibit 62: Accumulated Garbage Cleaned-up from Factory

Source: Aon Benfield

Source Information

Below are helpful sources used to compile information in this report:

- Bangkok Post
- The Nation
- Thai Meteorological Department (TMD)
- World Bank
- Thailand's Royal Irrigation Department (RID)
- NASA's Shuttle Radar Topography Mission (SRTM)
- Thailand's Geo-Informatics and Space Technology Development Agency (GISTDA)
- United States Marines
- Alertnet
- Thailand's Office of Insurance Commission (OIC)
- Danish Hydrological Institute (DHI)
- Bangkok Metropolitan Administration (BMA)
- Thai Real Estate Information Center (REIC)
- Thai Department of Industrial Works
- Thai Department of Highways
- Thai Department of Rural Roads
- United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP)

Event Updates use publicly available data from the internet and other sources. Impact Forecasting summarizes this publicly available information for the convenience of those individuals who have contacted Impact Forecasting and expressed an interest in natural catastrophes of various types. To find out more about Impact Forecasting or to sign up for the updates, visit Impact Forecasting's webpage at www.impactforecasting.com.

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