Addendum to the Environmental and Social Impact Assessment – Climate Risk and Vulnerability Assessment

Project Number: 51274-001
May 2018

THA: Bangkok Mass Rapid Transit (Pink and Yellow Lines)

Prepared by M. Scott-Brown for the Asian Development Bank. This is an updated version of the draft originally posted in October 2017 available on https://www.adb.org/projects/documents/tha-51274-001-eia

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List of Abbreviations

ADB	Asian Development Bank
ASI	Avoid-Shift-Improve Approach
BMA	Bangkok Metropolitan Administration
BMR	Bangkok Municipal Region
BMTA	Bangkok Mass Transit Authority
BOD	Biochemical Oxygen Demand
BRT	Bus Rapid Transport
BTS	Bangkok Mass Transit System Public Company Limited
CBD	Central Business District
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EHS	Environment, Health and Safety
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GRM	Grievance Redress Mechanism
LECZ	Low Elevation Coastal Zone
MRT	Metropolitan Rapid Transit
NO_2	Nitrogen Dioxide
NOx	Oxides of Nitrogen
OECD	Organization for Economic Cooperation and Development
OTP	Office of Traffic and Transport Policy and Planning
PM_{10}	Particulate Matter < 10 micron
$PM_{2.5}$	Particulate Matter <2.5 micron
PPP	Public Private Partnership
ROW	Right-of-Way
SO_2	Sulfur Dioxide
SPS	ADB Safeguard Policy Statement (2009)
SRT	State Railway of Thailand
TOD	Transport Oriented Development
USD	United States Dollar
WHO	World Health Organization

1. Introduction

Review of the Environmental and Social Impact Assessments (ESIAs) for both the Yellow and Pink Metro Lines shows that while there was an analysis of climate change impacts relating to reduced greenhouse gas emissions in the project economic analysis chapter (Chapter 9), there was no consideration of climate change impacts in the impact assessment chapter (Chapter 5). Nor was consideration given to the impacts of climate change and potential flooding on the operations of both Projects. The following section provides a conceptual analysis of climate change impacts of both projects and the impacts of climate change on the projects themselves. Recommendations are presented as to how climate change adaptation can be incorporated into management of Project operations.

2. Climate Change and the Project ESIAs

Both ESIAs present a case for greenhouse gas (GHG) reduction due to Pink and Yellow Line operations as vehicle operators switch to use of metros over the next 20 years. In both, results are presented for a distance-based fare and a 20-Baht flat fare. For the Pink line, calculations show that GHG reductions from 2018 – 2037 increase from 27-121 t CO_2e/hr for the distance-based fare and 43 – 144 t CO_2e/hr for the 20-Baht flat fare.[i] Similarly, calculations for the Yellow line present GHG reductions from 2019 – 2049 that go from 129.05 – 953.34 t CO_2e/hr for the distance based fare and 126.51-935.50 t CO_2e/hr for the 20-Baht flat fare.[ii]

The results in both EIAs show that a reduction in greenhouse gas emissions will result over the life of both projects. It should be noted that the calculations are markedly different between the two lines for the same time period and that further evaluation of this effect is needed.

There is no discussion in either EIA about climate change in the impact assessment chapter (Chapter 5). These will be presented in the following sections, considering impacts of the Projects on climate change and impacts of climate change on the Projects.

3. Trends in Bangkok

To set the context for analysis of climate change impacts, the following trends and figures are presented below:

- As of 2010, the Bangkok Metropolitan Region (BMR), or area of continuous urban (and suburban) development numbered nearly 15 million residents.[iii] The urban area covers approximately 900 square miles (2,330 square kilometers) and has a population density of 16,200 per square mile (6,200 per square kilometer). This is 1.5 times the density of the Paris urban area and more than 2.5 times that of Los Angeles.[iv]
- The city continues to urbanize – between 1998 and 2003, a 74% increase in urban development was experienced; housing stock has doubled.
- Bangkok city is not expected to grow further in size, but suburban districts will continue to do so. From 1978-2000, likely because of high housing prices and living costs in the inner city, the population density in the inner city decreased from 3.25 million people to 2.86 million people. Density in the suburban areas in the same time increased from 670,000 - 1.12 million persons.[v]

- Current motor vehicles use is estimated at 9,000,000 vehicles. In 2010, 55% of this total was cars, 39% motorcycle, 4% other and 2% truck and bus.[vi] The transport sector contributed to 50% of CO_2 emissions in 2007.[vii]
- In 2012, the average speed on main roads was 19 km/hr., down from 22 km/hr. in 2006.
- Road transport is still the preferred means of travel. In 2015, 40% of transport was by private vehicles, 15% by mass rapid transit, 31% by bus and other public transport and 14% by walking.
- Green gas emissions in Bangkok were estimated at 7.1 tons of carbon dioxide in 2005, equivalent to New York, but greater than London and less than Toronto. CO emissions in Bangkok declined by almost one half between 1992 and 2005.[viii]
- Total GHG emissions in 2011 amounted to 305.52 million tons of CO_2 equivalent ($MTCO_2eq$). The energy sector contributed to 72.97% of total GHG emissions, broken down further by electricity and heat generation (39%), transport (27%), manufacturing and construction (20%) and fugitive emissions (4%).[ix] [x]

4. Bangkok and Climate Change

Climate change and extreme weather events are affecting Bangkok and these effects will continue to increase in their intensity in the coming years. Between 1991-2013, the annual rainfall in Bangkok was 1710.6 mm; in the massive 2011 flood annual rainfall was 2257.5 mm.[xi] Bangkok is at high or extreme risk to flooding during the rainy season. Since 1942, nine floods have occurred in the BMR; the 2011 flood resulted in damages of USD$9.1 billion.[xii]

An analysis using AWARE for Projects was completed for both the Pink and Yellow Line Projects. The results showed an overall Medium Climate Risk rating for both projects. High risks are attributed to the potential for increased flooding and sea level rise and medium risks attributed to temperature increases, precipitation increase and availability of water.[xiii]

Extreme precipitation events and flood volumes are expected to increase in future. Susceptibility to flooding in Bangkok has been exacerbated due to the following:

- Bangkok is in an LECZ; the ground elevation of Bangkok is less than 2 m above sea level.
- Changes in land use and drainage of natural watercourses (swamps, wetlands, mangroves) have reduced the capacity to move water away from the urbanized area,
- Removal of mangroves has increased the propensity for coastal erosion and greater susceptibility to flooding from storm surges.
- Historically, groundwater extraction and changes in land use have increased subsidence in the metropolitan region, however efforts to control subsidence have produced results.
- Between 1978 to 2007 subsidence decreased from 10 cm/yr. to 1-2 cm/yr. This decrease is expected to continue in future.[xiv]
- Sea level rise is estimated at 25 mm/yr. but will likely increase in future. If sea level rise was 50 cm, 55% of Bangkok would be affected by floods and 72 % if sea levels rise 100 cm.[xv]

Temperatures in Bangkok are also on the rise. From 1961-2007, average maximum temperatures have risen about 1-degree C to 33.4°C while average minimum temperatures have risen about 2.5 degrees C to 25.5°C. The number of days over 35°C has risen to about 110 in 2007.[xvi]

5. <u>Impacts of the Project(s) on Climate Change</u>

As discussed in Section 2 above, the primary impact of the project on climate change will be positive, leading to an overall decrease in greenhouse gas emissions over the next 20-25 years. The extent of this positive impact will depend upon metro ridership and whether drivers will give up their cars to take mass rapid transport instead. This will rely on providing enough parking at the depot stations so that drivers entering the city from suburban areas can switch from their car to mass transit, with little inconvenience and little or no additional cost.

Transit times in mass transit must be far less than travel by car. Time efficiencies in the speed of metros versus spending two or more hours in gridlock will be key to attracting ridership. Increased efficiencies in intermodal transport from outlying metro stations to suburban areas and enhanced fare efficiencies will provide additional incentives to switch from private vehicle to mass transit.

6. <u>Impacts of Climate Change on the Project(s)</u>

A schematic of the relationships between climate change and the Yellow and Pink Line Projects is shown in Figure 1. The blue lines show a positive or increased effect between the two components, while the brown lines show a negative or decreased effect on the relationship between the two components.

Based on this conceptual model, the following scenarios are anticipated.

- **Temperature** – temperature increases will likely result in decreased ridership of the metro unless comfort levels are maintained. Increased temperatures could affect metro system operations to provide more air conditioning. Similarly, the effects of temperature on track and operating conditions should be evaluated.

- **Flooding** – increased flooding will not significantly affect metro operations as the system is elevated an average of 15 m over street level. Intermodal transport and ease of access to metro stations from street level however may be affected. Bangkok has an extensive flood control network in place consisting of a polder system, retention ponds, pumping stations, tunnels and drainage canals. This system will be upgraded in future through the installation of more diversion tunnels, an automated flood monitoring and response system and the construction of two east-west flood bypass systems to divert water away from the BMR. Flood control measures, both existing and planned, should result in minimal impacts to operations of overhead monorail and underground metro systems in Bangkok.

- **Precipitation** – increased rainfall events will affect flooding and have similar effects to what is described above.

- **Sea level rise** – sea level rise is expected to have the same effect on metro operations as flooding above.

- **Storm intensity** – storm intensity and storm surge will have the same anticipated effects on metro operations as sea level rise and flooding.

- **Groundwater extraction** – ground water extraction is expected to have little impact on metro operations. The EIA(s) address this concern.

- **Subsidence** – subsidence could affect metro operations regarding integrity of the support columns. This impact is considered minimal, given the 18-m depth to which these pilings are to be installed.

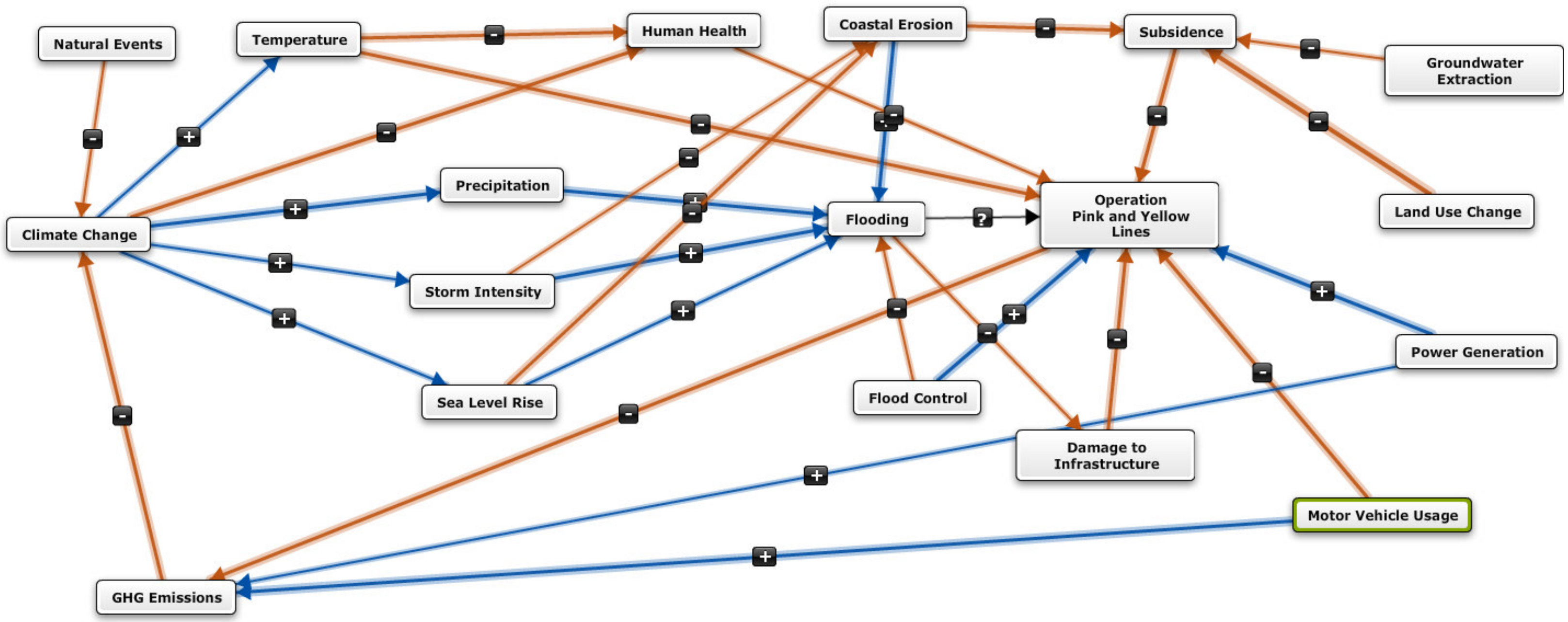
- **Flood control** – the continued installation and deployment of flood control structures and systems will have a positive effect on land use, metro operations and continued operations of Bangkok's inner city (see Figure 2).

- **Power generation** – the Thailand Power Development Plan 2015-2036 (PDP2015) still shows a strong reliance on fossils fuel for power generation in 2036 – 30-40% natural gas and 20-25% clean coal.[xvii] The impact of power generation for metro operations in terms of increased GHG emissions is unknown.

- **Motor vehicle usage** – the extent of future motor vehicle usage will affect levels of future GHG emissions is not fully clear. If there is a switch to more metro use, this will be positive. If vehicle usage continues the same trend, this could result in higher GHG emissions that may not be offset by reduced GHG emissions from metro operations. This requires ongoing monitoring and verification.

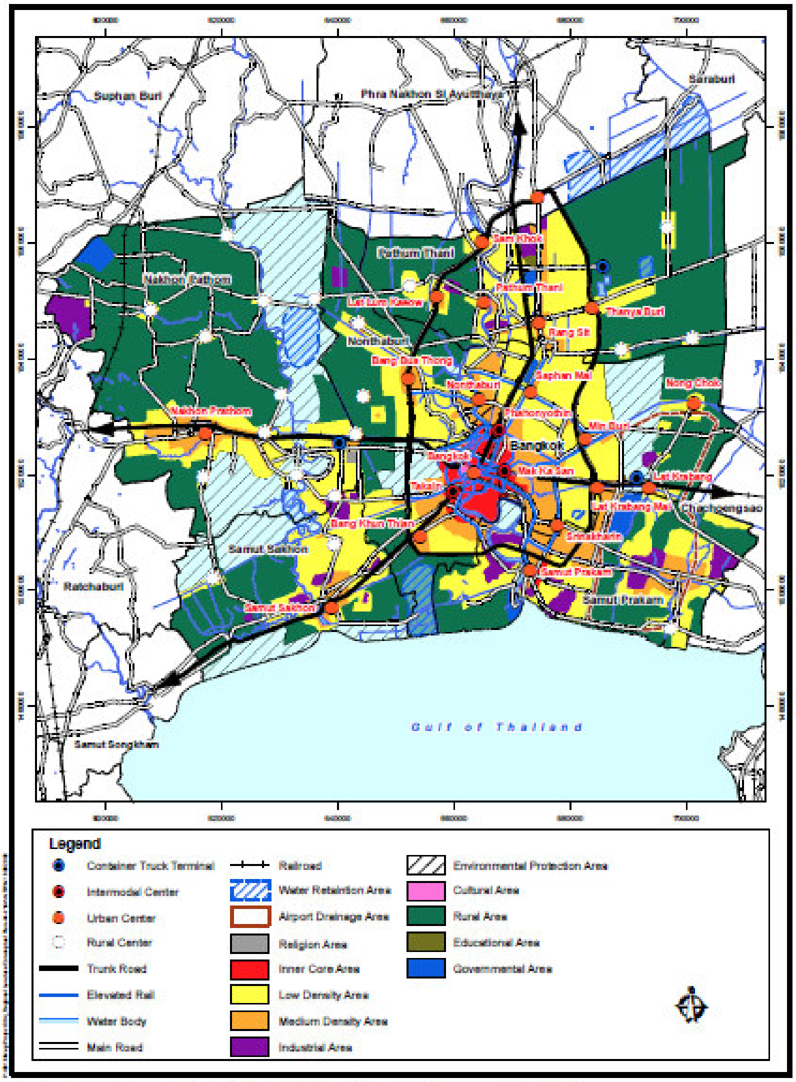
- **GHG emissions** – both EIAs state that the net effect of both projects on GHG emissions will be an overall reduction in emission levels. This needs to be further verified to understand when a switch in greater metro use occurs relative to continued private vehicle use.

Figure 1: Climate Change Relationships and Operations of the Pink and Yellow Metro Lines, Bangkok



Notes: the blue lines indicate a positive or increased relationship between each paired component, while the brown lines indicate a negative or decreased relationship between each paired component. A question mark denotes that the extent of the relationship between each component is not known.

Figure 2: Land Use Conceptual Plan of the Bangkok Municipal Region 2057



Source: Department of Public Works and Town & Country Planning (DPT), 2007

7. Conclusions

a) Both Project EIAs present a net reduction in GHG emissions resulting from operations of the Pink and Yellow Metro Lines. However, there is a significant difference in GHG reduction figures between the two lines which should be further analyzed.

b) It is not clear if the reduction in vehicle usage will occur to the extent specified in the EIA models. BMA authorities may choose to enable means to reduce vehicle usage in the inner city (e.g. tolls, restrictions, increased parking fees), both motorcycle and car, as has been done in other major urban centers. This will likely be more difficult to do than practical.

c) A more useful mechanism is to use incentives to attract drivers from entering the inner city such as more efficient intermodal transport from outlying metro stations to suburban centers, free parking at the metro depots, improved fare efficiencies of intermodal transport etc.

d) The Project EIAs do not examine the impacts of climate change on the Projects themselves. Increased flooding because of storm events, increased precipitation, coastal erosion etc. could impact metro operations, if the electrical supply infrastructure is affected. Also, passenger access to the metros could be restricted because of increased flooding. More days with higher temperature may have impacts on power consumption, metro operations and ridership.

e) With the implementation of proposed and future flood controls, flooding should not affect operations of the Pink and Yellow lines. Operational management plans should prepare for this possibility.

f) BTS and metro concessionaires should look to incorporate possible climate change impacts into their operational contingency plans.

Endnotes:

[i] P. 9-16 and 9-17. Amendment Report. Environmental Impact Assessment Report. The Pink Line MRT Project Khae Rai-Min Buri. Prepared by TEAM Consulting Engineering and Management Co. Ltd. October 2015.
[ii] P. 10-12 to 10-16. Chapter 10. Environmental Economics. The Report on Changes in Project Details in the EIA Reports on the Bangkok Mass Transit Yellow Line Project : Lat Phrao-Samrong Section. Prepared by AEC/HC/D2A/WE/ENRICH/PSG. 2016.
[iii] This includes the city of Bangkok and the adjacent provinces of Samat Prakan, Samut Sakhon, Pathum Thani, Nonthaburi and Nakhon Pathom.
[iv] https://www.lincolninst.edu/sites/default/files/pubfiles/making-room-for-a-planet-of-cities-full_0.pdf
[v] Bangkok Metropolitan Administration, Green Leaf Foundation and United Nations Environment Programme 2009
Bangkok Assessment Report on Climate Change 2009. Bangkok: BMA, GLF and UNEP
[vi] Private motorized transport, Bangkok, Thailand.Natcha Tulyasuwan. Case study prepared for global report on human settlements. 2013.Available from http://www.unhabitat.org/grhs/2013
[vii] OECD (2015), Green Growth in Bangkok, Thailand, OECD Green Growth Studies, OECD Publishing, Paris.
http://dx.doi.org/10.1787/9789264237087-en
[viii] See iv above.
[ix] Office of Natural Resources and Environmental Policy and Planning. Thailand's First Biennial Update Report. Under the United Nations Framework Convention on Climate Change. December 2015.
[x] Note the figure of CO_2 emissions is less than previous estimates perhaps due to better determination of the contribution of the power sector.
[xi] See vii above.
[xii] See xiii above.
[xiii] ADB. Aware for Projects. THA: Bangkok Mass Rapid Transit Project (Pink and Yellow Lines). Report generated 22 January 2018.
[xiv] World Bank. 2010. Climate risks and adaptation in Asian coastal megacities: a synthesis report.
[xv] See iv above.
[xvi] See iv above.
[xvii] Ministry of Energy. Thailand Power Development Plan 2015-2036 (PDP2015).

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01

Introduction

This report summarises results from a climate and geological risk screening exercise. The project information and location(s) are detailed immediately below.

The screening is based on the Aware™ geographic data set, compiled from the latest scientific information on current geological, climate and related hazards together with projected changes for the future where available. These data are combined with the project's sensitivities to hazard variables, returning information on the current and potential future risks that could influence its design and planning.

Project Information

PROJECT NAME:	Bangkok Mass Rapid Transit Project (Pink and Yellow Lines)
SUB PROJECT:	Pink Line
PROJECT NUMBER / REFERENCE:	51274-001
SECTOR:	Transport
SUB SECTOR:	Urban public transport
DESCRIPTION:	

02

Chosen Locations

1) Chaengwatthana

2) Depot/Park&Ride

3) Khae Rai Junction

4) Noparat Ratchathani

5) Pak Kret

6) Phranakhon Rajabhat University

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03

Project Climate Risk Ratings

Below you will find the overall climate risk level for the project together with a radar chart presenting the level of risk associated with each individual climate risk topic analysed in Aware^{TM}. Projects with a final “High risk” rating are always recommended for further more detailed climate risk analyses.

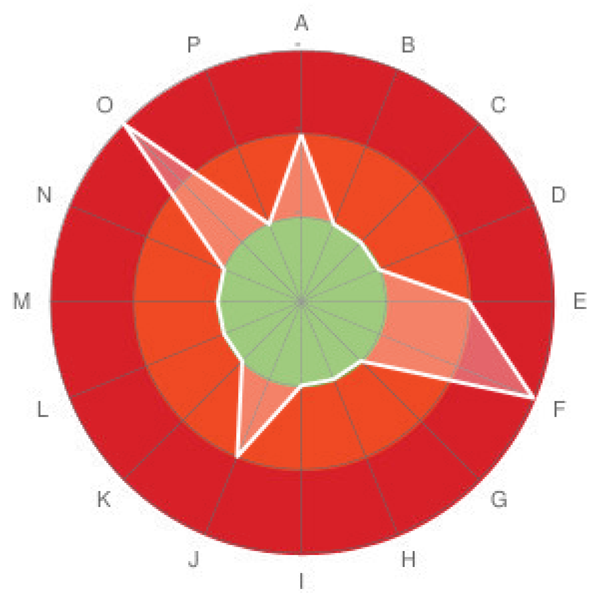
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher level of risk in relation to a risk topic. The green band (inner circle) suggests a lower level of risk in relation to a risk topic.

In the remaining sections of this report more detailed commentary is provided. Information is given on existing and possible future climate conditions and associated hazards. A number of questions are provided to help stimulate a conversation with project designers in order to determine how they would manage current and future climate change risks at the design stage. Links are provided to recent case studies, relevant data portals and other technical resources for further research.

Final project climate risk ratings

Medium Risk

Breakdown of climate risk topic ratings



A) Temperature increase
B) Wild fire
C) Permafrost
D) Sea ice
E) Precipitation increase
F) Flood
G) Snow loading
H) Landslide
I) Precipitation decrease
J) Water availability
K) Wind speed increase
L) Onshore Category 1 storms
M) Offshore Category 1 storms
N) Wind speed decrease
O) Sea level rise
P) Solar radiation change

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04
HIGH RISK

FLOOD

ACCLIMATISE COMMENTARY

• Our data suggest that the project is located in a region which has experienced recurring major flood events in the recent past. A high exposure in Aware means that between 1985 and 2016 there have been at least one significant, large-scale flood event in the region. This is based on post-processed data from the Dartmouth Flood Observatory at the University of Colorado.

• The risk and type of flooding is dependent on local geographical factors including:
- Proximity to the coast and inland water courses
- Local topography
- Land use characteristics, including land use in upstream catchment area
- Design and maintenance level of drainage infrastructure
- Vulnerability of exposed assets
• Up to date information on flood risk worldwide is available online, for example UNEP / UNISDR's Global Risk Data Platform and Dartmouth Flood Observatory's Global Active Archive of Large Flood Events.

1. What does this mean for the design and construction of my project?

• If floods are identified as a potential problem for the project, it is recommended that:
- More localized information is collected on past floods and their consequences in the exact project location, especially since flood hazard can change significantly over short distances; depending on the findings, a site-specific flood risk assessment (including flood modelling) might be required that provides a good understanding of the current and future flood risk level
- Information is collected on land use and building regulations, such as flood zonation ordinances
- The project siting, design and construction features ensure that site-specific flood risk management measures are undertaken. Such measures could include a combination of grey infrastructure (such as flood defence infrastructure) and green infrastructure (such as restoration of wetlands) to reduce flood risk, as well as measures to manage the residual flood risk (such as through flood early warning, flood preparedness planning, flood insurance etc.)

2. What does the science say could happen in the future and what does this mean for the design of my project?

• Climate change is projected to influence the frequency and intensity of flood events.
• Existing engineering designs may not take into consideration the impact of climate change on the risks from flooding. See "Critical thresholds" in the "Help & glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

3. As a starting point you may wish to consider the following questions:

Q1 Would the expected performance and maintenance of the project be impaired by flooding?
Q2 Is there a plan to integrate climate change into a flood risk assessment for the project?
Q3 Does the project siting consider flood risk to ensure the proposed project will not be impacted by flooding and will not increase risk of flooding?
Q4 Does the project design and construction features incorporate measures to manage flood risk, both in the immediate term and as risk of flooding changes as a consequence of climate change?
Q5 Will the project include emergency management plans which make provision for continued successful operation in the event of floods?

4. What next?

• See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
• Click here or here for the latest news and information relating to floods and climate change.

I have acknowledged the risks highlighted in this section.

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05
HIGH RISK

SEA LEVEL RISE

ACCLIMATISE COMMENTARY

You have indicated that the project is located in a Low Elevation Coastal Zone (LECZ), which could be affected by sea level rise.

1. What does this mean for the design of my project?

• There is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of inundation from the sea as well as potential future changes.

2. How could sea level rise affect the project even without future climate change?

• Low Elevation Coastal Zones (LECZs) are particularly prone to local tropical cyclones, mid-latitude storms and associated storm surges.
• Erosion of the coastline can exacerbate ‘coastal squeeze’, putting pressure on natural sea defences, such as salt marshes and mangroves as well as man-made structures.
• Up to date information on coastal storm and flood risk worldwide is available online, for example UNEP / UNISDR's Global Risk Data Platform.

3. What does the science say could happen by 2100?

• Some recent research suggests that global sea levels could be 0.75 to 1.9m higher by the end of the century.
• Local changes in ocean density/dynamics and land movements can also add to, or lessen, the effects of sea level rise at a given location.
• Sea level rise has the potential to accelerate the rate of coastal erosion. Changes in erosion regimes also impact the rate of sedimentation in other areas, particularly in estuarine and other tidal settings. This could provide problems with access to existing ports and jetties.
• In tropical regions, increasing ocean acidification and temperatures can lead to coral reef

bleaching and destruction. Such reefs can provide a natural barrier to coastal inundation and erosion.
• In addition, sea level rise could cause saline intrusion into aquifers, further depleting useable water resources.
• Local sea level rise in combination with storm surge and wave height poses a hazard to offshore fixed assets, such as oil and gas platforms.

If you want to know more about trends in sea level rise around the world, please refer to: NOAA's Sea Level Trends map.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here or here for the latest news and information relating to sea level and climate change.

I have acknowledged the risks highlighted in this section.

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06
MEDIUM RISK

TEMPERATURE INCREASE

Would an increase in temperature require modifications to the design of the project in order to successfully provide the expected services over its lifetime?

Chosen Answer

Cannot answer.

Not enough information is known about the sensitivity of the project design to increases in temperature.

ACCLIMATISE COMMENTARY

1. What does this mean for the design of my project?

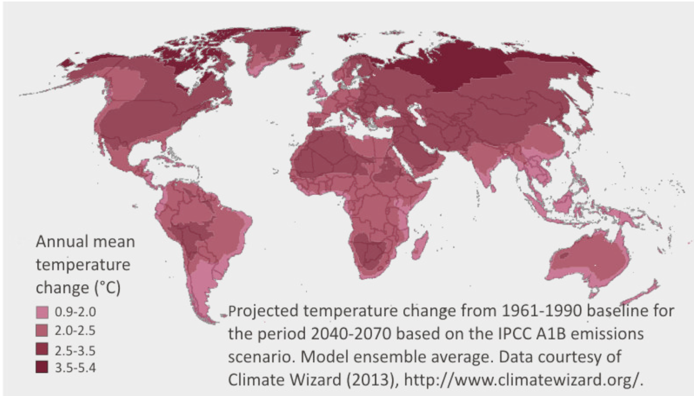
• Although you have stated that you could not answer whether the project is sensitive to increases in temperature it is recommended that you consider that an increase in mean seasonal and annual temperature could have implications for a number of hazards.
• There is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of high temperatures as well as potential future changes.

2. How could current high temperatures affect the project even without future climate change?

• Heatwaves put stress on buildings and other infrastructure, including roads and other transport links. In cities, the 'urban heat island' can increase the risk of heat related deaths.
• Warm weather can raise surface water temperatures of reservoirs used for industrial cooling. In addition, this could impact local eco-systems, improving the growing conditions for algae and potentially harmful micro-organisms in water courses.
• Heatwaves can have an impact on agricultural productivity and growing seasons.
• High temperatures can have implications for energy security. Peak energy demand due to demand for cooling can exceed incremental increases on base load in addition to the risk of line outages and blackouts.
• Human health can be affected by warmer periods. For example, urban air quality and disease transmission (e.g. malaria and dengue fever) can be impacted by higher air temperatures.
• Wildfire risk is elevated during prolonged warm periods that dry fuels, promoting easier ignition and faster spread.
• Permafrost and glacial melt regimes as impacted by warm periods.
• If our data suggests that there are existing hazards associated with high temperatures in the region, they will be highlighted elsewhere in the report. This may include existing wildfire risks as well as areas potentially impacted by permafrost and glacial melt.

3. What does the science say could happen by the 2050s?



• If you want to know more about projected changes in the project location across a range of GCMs and RCPs please refer to USGS's CMIP5 Global Climate Change Viewer for detailed maps.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here or here for the latest news and information relating to temperature and climate change.

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07
MEDIUM RISK

PRECIPITATION INCREASE

Would an increase in precipitation require modifications to the design of the project in order to successfully provide the expected services over its lifetime?

Chosen Answer

Cannot answer.

Not enough information is known about the sensitivity of the project design to increases in precipitation.

ACCLIMATISE COMMENTARY

1. What does this mean for the design of my project?

• There is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of heavy precipitation events as well as potential future changes.

2. How could current heavy precipitation affect the project even without future climate change?

• Seasonal runoff may lead to erosion and siltation of water courses, lakes and reservoirs.
• Flooding and precipitation induced landslide events.
• In colder regions, seasonal snow falls could lead to overloading structures and avalanche risk.
• If our data suggests that there are existing hazards associated with heavy precipitation in the region, they will be highlighted elsewhere in the report. This may include existing flood and landslide risks.

3. What does the science say could happen by the 2050s?

• If you want to know more about projected changes in the project location across a range of GCMs and RCPs please refer to USGS's CMIP5 Global Climate Change Viewer for detailed maps.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here or here for the latest news and information relating to water and climate change.

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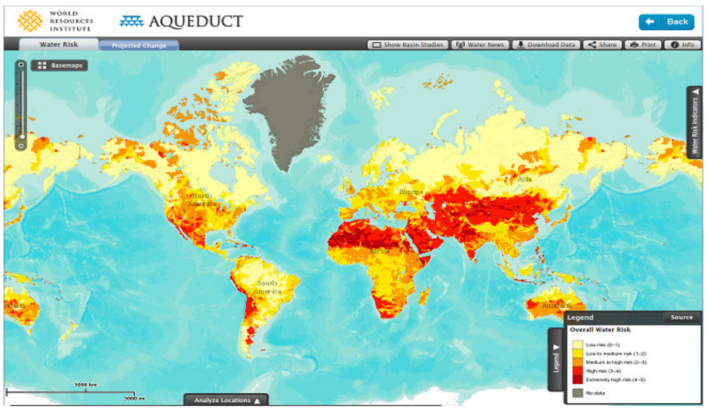
08

MEDIUM RISK

WATER AVAILABILITY

ACCLIMATISE COMMENTARY



• Our data suggest that the project is located in a region where there may be future water stress (2020s - 2050s). A high exposure in Aware means that either water stress is ‘extreme’ or high seasonal temperatures coincide with relatively low rainfall. Extreme water stress is defined as ‘less than 0.5 million litres available per person per year’ based on climate information as well as the effects of income, electricity production, water-use efficiency and other driving forces. This is post-processed data from Alcamo et al., 2007. Away from populated regions, high exposure also occurs where high seasonal temperatures (above 28 degrees Celsius average over 6 months) coincide with low rainfall (less than 100mm per month average over 6 months). This is based on post-processed data from the Global Precipitation Climatology Centre (GPCC), Climatic Research Unit (CRU) and a range of GCM projections.
• The situation may be exacerbated if there is increased competition for water with other users in the area and changes in local demographics.
• An associated reduction in water quality could also have a negative impact on the project.

1. What the science says could happen in the future and what does this mean for the design of my project?

• Climate change is projected to influence water availability. Regions that are already dry may suffer further if future precipitation is projected to decrease. Increased evaporation due to rising temperature will further impact on water availability. Seasonal availability of water may also change whereby there may be a shift in the timing of its availability.
• Existing engineering designs may not take into consideration the impact of climate change on the risks from water availability and design standards may not be met. See "Critical thresholds" in the "Help & glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.
• If water availability is identified as a potential problem for the project, it is recommended that a more localised and in-depth assessment is carried out. This information can then be used to inform the project design process if necessary.
• If you want to know more about projected changes in water availability in the project location, please refer to: the World Resources Institute's Aqueduct.

2. As a starting point you may wish to consider the following questions:

Q1 How would a lack of water impact the expected performance of the project?
Q2 Would a reduction in water supply have consequences for the expected maintenance of the project?
Q3 Will there be a water shortage continuity strategy in place for the project?
Q4 Will it be necessary to carry out water availability risk assessments in any of the project locations? If so, these assessments should take into account climate change?
Q5 Will there be an investment in water efficient technology or practices to help minimise the quantities of water required for its operational processes?

3. What next?

• See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
• Click here or here for the latest news and information relating to water and climate change.

I have acknowledged the risks highlighted in this section.

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09

LOW RISK

PRECIPITATION DECREASE

Would a decrease in precipitation require modifications to the design of the project in order to successfully provide the expected services over its lifetime?

Chosen Answer

No - modifications are not required.

The design of the project would be unaffected by decreases in precipitation.

ACCLIMATISE COMMENTARY

1. What does this mean for the design of my project?

• Even though you have suggested that designs would not be affected by a decrease in precipitation, it is worth considering existing precipitation related hazards in the region where the project is planned.

2. How could reduced precipitation affect the project even without future climate change?

• Decreased seasonal runoff may exacerbate pressures on water availability, accessibility and quality.
• Variability of river runoff may be affected such that extremely low runoff events (i.e. drought) may occur much more frequently.
• Pollutants from industry that would be adequately diluted could now could become more concentrated.
• Increased risk of drought conditions could lead to accelerated land degradation, expanding desertification and more dust storms.
• If our data suggests that there are existing hazards associated with decreased precipitation in the region, they will be highlighted elsewhere in the report. This may include water availability and wildfire.

3. What does the science say could happen by the 2050s?

• Climate model projections do not agree that annual average precipitation will decrease in the project location which could indicate a relatively high degree of uncertainty (see the section "Model agreement and uncertainty" in "Help and glossary" at the end of this report). On the other hand, this could also mean precipitation patterns are not expected to change or may even increase (see elsewhere in the report for more details of projections related to precipitation increase).
• If you want to know more about projected changes in the project location across a range of GCMs and RCPs please refer to USGS's CMIP5 Global Climate Change Viewer for detailed maps.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here or here for the latest news and information relating to water and climate change.

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The sections above will provide details on all high and medium climate hazard risks from Aware[TM] where these are suggested by the climate sensitivities of the project and / or the underlying data. Selected Low risks may also be detailed. Local conditions, however, can be highly variable, so if you have any concerns related to risks not detailed in this report, it is recommended that you investigate these further using more site-specific information or through discussions with the project designers.

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Project Geological Hazard Risk Ratings

Below you will find the overall geological hazard risk level for the project together with a radar chart presenting the level of risk associated with each individual geological risk topic analysed in Aware^{TM}. Projects with a final “High risk” rating are always recommended for further more detailed geological risk analyses.

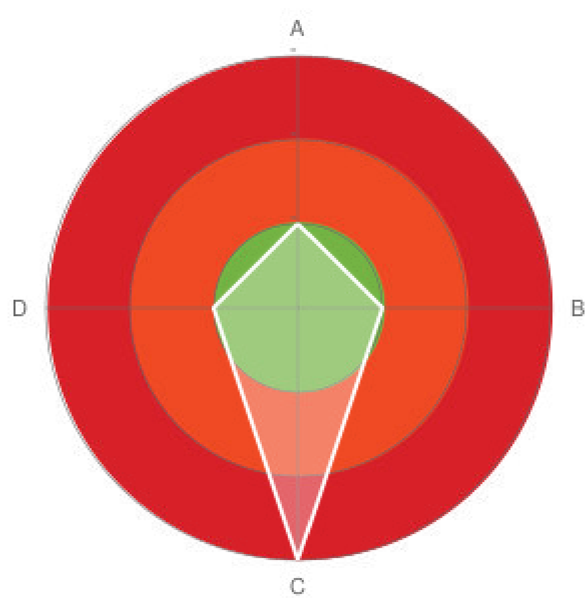
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher level of risk in relation to a risk topic. The green band (inner circle) suggests a lower level of risk in relation to a risk topic.

In the remaining sections of this report more detailed commentary is provided. Information is given on existing geological conditions and associated hazards. A number of questions are provided to help stimulate a conversation with project designers in order to determine how they would manage geological risks at the design stage. Links are provided to recent case studies, relevant data portals and other technical resources for further research.

Final project geological hazard risk ratings

Medium Risk

Breakdown of geological hazard risk topic ratings



A) Earthquake

B) Seismic landslide

C) Tsunami

D) Volcano

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HIGH RISK

TSUNAMI

ACCLIMATISE COMMENTARY

• Our data suggest that the project is located in a region where there is a tsunami run up hazard associated with a 500yr return period event. This is based on post-processed data from the International Centre for Numerical Methods in Engineering (CIMNE) and INGENIAR Ltda (GAR15).
• The risk and scale of tsunami flooding is dependent on the size of the tsunami event and local geographical factors including proximity to the coast and local topography.
• Up to date information on tsunami risk worldwide is available online, for example UNEP / UNISDR's Global Risk Data Platform, NCEI's Global Historical Tsunami Database and NOAA's Pacific Tsunami Warning Center.

1. What does this mean for the design and construction of my project?

• If tsunami risk is identified as a potential problem for the project, it is recommended that:
- More localised information is collected on past tsunamis and local site condition
- Information is collected on local land use and building regulations, such as tsunami zonation ordinance
- The project siting, design and construction features ensure tsunami risk reduction considerations. It is recommended that consideration be given to site selection, in particular whether it is feasible for the project to be located on higher ground
- Where the proposed infrastructure will act as a critical facility, such as power supply, communication networks etc., a more detailed tsunami risk assessment is undertaken to inform the project siting, design and construction process

2. What the science says could happen in the future and what does this mean for the design and construction of my project?

• Although rising sea level is unlikely to have a noticeable additional effect on flooding from the larger, more destructive scale of tsunamis, it may exacerbate the extent of flooding that may be expected from smaller scale events.

• Existing engineering design and construction may not take into consideration the impact of climate change on otherwise manageable flood risk from small scale tsunamis. See "Critical thresholds" in the "Help & glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

3. As a starting point you may wish to consider the following questions:

Q1 Would the expected performance and maintenance of the project be impaired by tsunami related flooding?
Q2 Does the project team have a good understanding of the tsunami risk in the area, including past tsunamis, local site conditions, local land use and building regulations?
Q3 If the proposed infrastructure will act as a critical facility, is there a plan to assess tsunami risk to project location, design, construction and operation?
Q4 Does the project design and construction features incorporate measures to reduce tsunami risk, both in the immediate term and as the extent of related seawater inundation changes as a consequence of climate change?
Q5 Will the project have access to tsunami early warning systems and implement emergency evacuation procedures both during project implementation and over the life of supported infrastructure?

4. What next?

• See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on disaster risk reduction.

I have acknowledged the risks highlighted in this section.

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The sections above will provide details on all high geological hazard risks from Aware™ where these are suggested by the underlying data. Local conditions, however, can be highly variable, so if you have any concerns related to risks not detailed in this report, it is recommended that you investigate these further using more site-specific information or through discussions with the project.

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HELP AND GLOSSARY:

Model agreement and uncertainty:

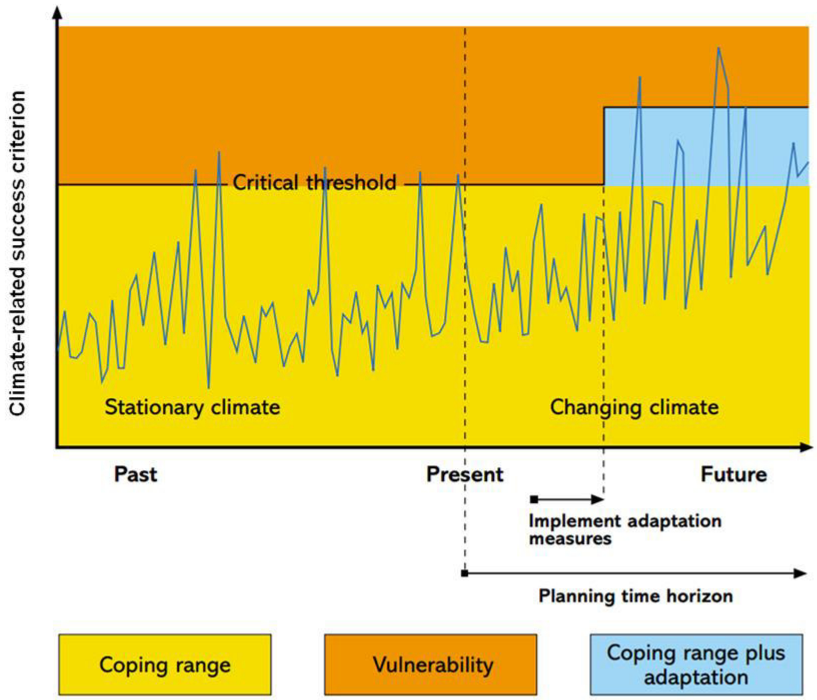
Although climate models are constantly being improved, they are not good enough to predict future climate conditions with a degree of confidence which would allow precise adaptation decisions to be made. Outputs from different climate models often differ, presenting a range of possible climate futures to consider, and ultimately a wide range of possible actions to take. In Aware, climate projections make use of GCM ensemble percentiles to determine: for temperature increase, whether 75% of CMIP5 GCM ensemble agree on a magnitude of change; for precipitation increase and decrease, whether 75% of CMIP5 GCM ensemble agree on the direction of change.

Even with improvements in climate modelling, uncertainties will remain. It is likely that not all the climate statistics of relevance to the design, planning and operations of a project's assets and infrastructure will be available from climate model outputs. The outputs are typically provided as long-term averages, e.g. changes in average monthly mean temperature or precipitation. However, decisions on asset integrity and safety may be based on short-term statistics or extreme values, such as the maximum expected 10 minute wind speed, or the 1-in-10 year rainfall event. In such cases, project designers or engineers should be working to identify climate-related thresholds for the project (see "Critical thresholds" section below) and evaluate whether existing climate trends are threatening to exceed them on an unacceptably frequent basis. Climate models can then be used to make sensible assumptions on potential changes to climate variables of relevance to the project or to obtain estimates of upper and lower bounds for the future which can be used to test the robustness of adaptation options.

The key objective in the face of uncertainty is therefore to define and implement design changes (adaptation options) which both provide a benefit in the current climate as well as resilience to the range of potential changes in future climate.

Critical thresholds:

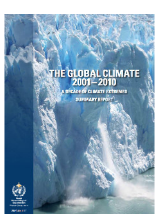
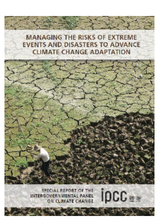
A key issue to consider when assessing and prioritising climate change risks is the critical thresholds or sensitivities for the operational, environmental and social performance of a project. Critical thresholds are the boundaries between ‘tolerable’ and ‘intolerable’ levels of risk. In the diagram below, it can be seen how acceptable breaches in a critical threshold in today’s climate may become more frequent and unacceptable in a future climate.

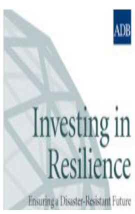
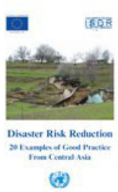


The relationship between a critical threshold and a climate change related success criterion for a project. [Source: Willows, R.I. and Connell, R.K. (Eds.) (2003). *Climate adaptation: Risk, uncertainty and decision-making*. UKCIP Technical Report, UKCIP, Oxford].

Climate change scenarios can be used to see if these thresholds are more likely to be exceeded in the future. The simplest example is the height of a flood defence. When water heights are above this threshold, the site will flood. The flood defence height is the horizontal line labelled 'critical threshold'. Looking at the climate trend (in this case it would be sea level or the height of a river) – shown by the blue jagged line – it can be seen that the blue line has a gradual upward trend because of climate change. This means that the critical threshold is crossed more often in the future – because sea levels are rising and winter river flows may be getting larger. So, to cope with this change, adaptation is needed – in this case, one adaptation measure is to increase the height of the flood defence.

Further reading and resources:

	Report detailing changes in global climate: The Global Climate 2001 - 2010
	IPCC report on climate-related disasters and opportunities for managing risks: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)
	IPCC report on impacts, adaptation and vulnerability: Climate Change 2014: Impacts, Adaptation, and Vulnerability

	
	IFC report on climate-related risks material to financial institutions: Climate Risk and Financial Institutions. Challenges and Opportunities.
	Nationally Determined Contributions (NDCs) submitted under the COP21 Paris Agreement: NDC Registry.
	ADB report on investment in disaster resilience: Investing in Resilience: Ensuring a Disaster-Resistant Future.
	UNISDR's report on disaster risk success stories: Disaster risk reduction: 20 examples of good practices from Central Asia.
	UNISDR's review and analysis of data and information on disaster risk patterns and trends: Global Assessment Report on Disaster Risk Reduction.
	CRED's International Disasters Database: EM-DAT.
	DesInventar Project's historical disaster impact catalogues: DesInventar.

	National progress reports to UNISDR on DRM commitments: HFA National Progress Reports.
	National documents DRM policy and strategy documents and studies: Disaster risk reduction in the world.
	National-level factsheets based on the Global Assessment Report: Country Profiles.
	GEM NEXUS Building and population inventory : GED4GEM database.
	GAR analysis tool of exposure including population, capital stock and economic indicators: Risk Data Platform CAPRAViewer.

Aware data resolution:

The proprietary Aware data set operates at a resolution of 0.5 x 0.5 decimal degrees (approximately 50 km x 50 km at the equator). These proprietary data represent millions of global data points, compiled from environmental data and the latest scientific information on current climate / weather related hazards together with potential changes in the future. Future risk outcomes are based on projections data from the near- to mid-term time horizons (2020s or 2050s, depending on the hazard and its data availability).

Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (Meehl et al., 2007) and 5 (CMIP5) multi-model dataset (Taylor et al., 2012), were resampled to a 0.5 degree grid.

[Taylor, K.E., R.J. Stouffer, G.A. Meehl (2012) "An Overview of CMIP5 and the experiment design." Bulletin of the American Meteorological Society, 93, 485-498.

[Meehl, G. A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J. F. B. Mitchell, R. J. Stouffer, and K. E. Taylor: The WCRP CMIP3 multi-model dataset: A new era in climate change research, Bulletin of the American Meteorological Society, 88, 1383-1394, 2007]

Aware data application:

In some instances Risk Topic ratings are only based on Aware data, including:
• Flood
• Permafrost
• Landslides – precipitation induced
• Earthquake
• Landslides – seismic induced
• Volcano
• Tsunami

Country level risk ratings:

These are generated from the data points within a country's borders. For single locations, site-specific data are used, and for multiple locations or countries, composite data across the portfolio of locations are used.

Glossary of terms used in report

"Climate model projections agree": for temperature, defined as 75% of CMIP5 GCM ensemble members agreeing that annual average temperature increase will reach 2°C; for precipitation increase or decrease, defined as 75% of CMIP5 GCM ensemble members agreeing on the direction of annual average precipitation change.

"Climate model projections do not agree": for temperature, defined as only 25% of CMIP5 GCM ensemble members agreeing that annual average temperature increase will reach 2°C; for precipitation increase or decrease, defined as only 25% of CMIP5 GCM ensemble members agreeing on the direction of annual average precipitation change.

The overall climate risk score for the project (high, medium or low) is based on a count of high risk topic scores. A project scores overall high climate risk if greater than or equal to 3 individual risk topics score high. A project scores overall medium climate risk if between 1 and 2 individual risk topics score high. A project scores overall low climate risk if none of the individual risk topics score high.

The overall geological risk score for the project (high, medium or low) is based on a count of high risk topic scores. A project scores overall high geological risk if greater than or equal to 2 individual risk topics score high. A project scores overall medium geological risk if 1 individual risk topic scores high. A project scores overall low geological risk if none of the individual risk topics score high.

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Report generated by: Cecilia de Castro, Asian Development Bank | Date created: 30.01.2018 02:16

01 Introduction

This report summarises results from a climate and geological risk screening exercise. The project information and location(s) are detailed immediately below.

The screening is based on the Aware™ geographic data set, compiled from the latest scientific information on current geological, climate and related hazards together with projected changes for the future where available. These data are combined with the project's sensitivities to hazard variables, returning information on the current and potential future risks that could influence its design and planning.

Project Information

PROJECT NAME:	THA: Bangkok Mass Rapid Transit Project (Pink and Yellow Lines)
SUB PROJECT:	Yellow Line
PROJECT NUMBER / REFERENCE:	51274-001
SECTOR:	Transport
SUB SECTOR:	Urban public transport
DESCRIPTION:	

02 Chosen Locations

1) Station 1 - Ratchada Road

2) Station 11 Srinagarinda-Phatthanakan Rd

3) Station 17 Srinagarinda-Bang Na Rd

4) Station 21 Theparak Rd-Si Thepa Intersection

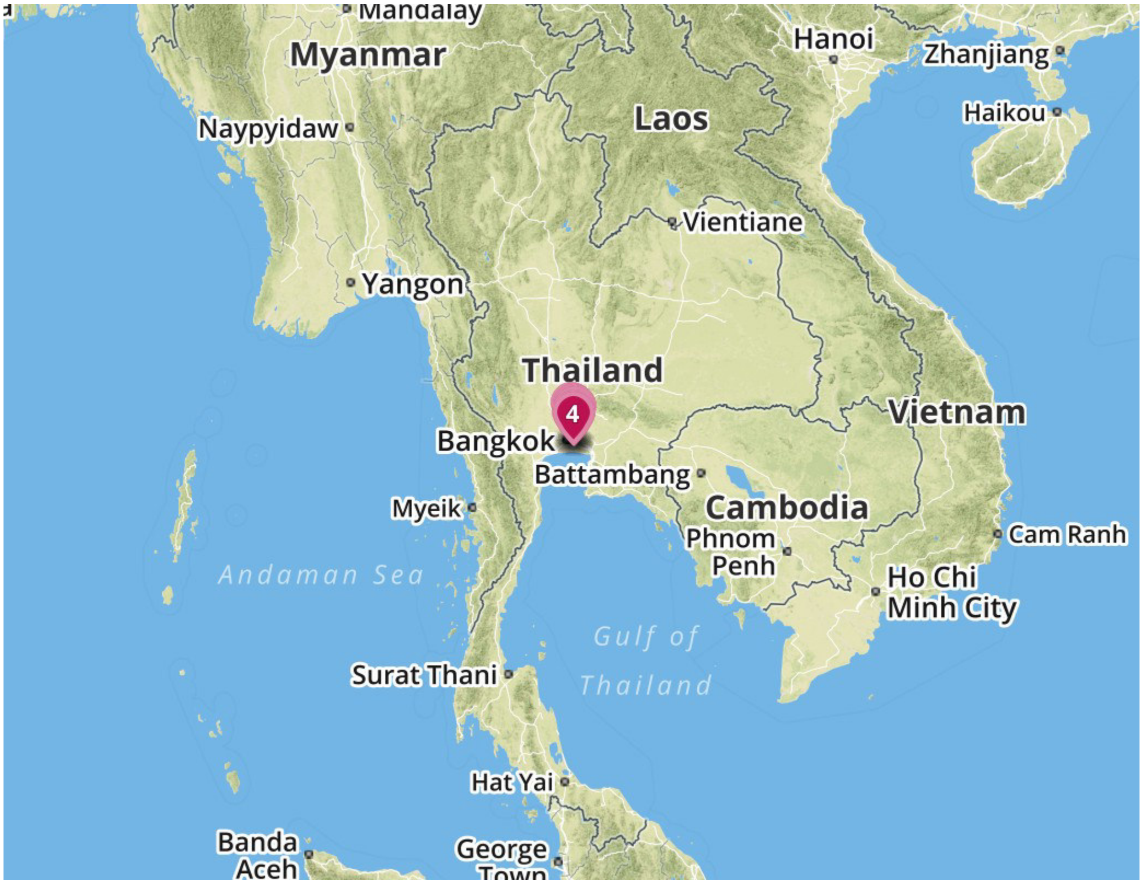
5) Station 23 Samrong

6) Station 4 - Lat Phrao Road

7) Station 8 - Bang Kapi-Tawanna

8) STation 9 - Ramkhamhaeng Road

9) Statiuon 20 - Srinagarinda-Sri Darn



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03

Project Climate Risk Ratings

Below you will find the overall climate risk level for the project together with a radar chart presenting the level of risk associated with each individual climate risk topic analysed in Aware^{TM}. Projects with a final "High risk" rating are always recommended for further more detailed climate risk analyses.

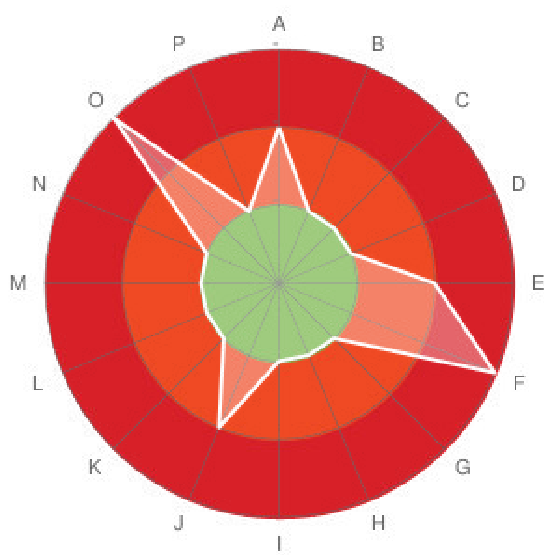
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher level of risk in relation to a risk topic. The green band (inner circle) suggests a lower level of risk in relation to a risk topic.

In the remaining sections of this report more detailed commentary is provided. Information is given on existing and possible future climate conditions and associated hazards. A number of questions are provided to help stimulate a conversation with project designers in order to determine how they would manage current and future climate change risks at the design stage. Links are provided to recent case studies, relevant data portals and other technical resources for further research.

Final project climate risk ratings

Medium Risk

Breakdown of climate risk topic ratings



A) Temperature increase
B) Wild fire
C) Permafrost
D) Sea ice
E) Precipitation increase
F) Flood
G) Snow loading
H) Landslide
I) Precipitation decrease
J) Water availability
K) Wind speed increase
L) Onshore Category 1 storms
M) Offshore Category 1 storms
N) Wind speed decrease
O) Sea level rise
P) Solar radiation change

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04

HIGH RISK

FLOOD

ACCLIMATISE COMMENTARY

• Our data suggest that the project is located in a region which has experienced recurring major flood events in the recent past. A high exposure in Aware means that between 1985 and 2016 there have been at least one significant, large-scale flood event in the region. This is based on post-processed data from the Dartmouth Flood Observatory at the University of Colorado.

• The risk and type of flooding is dependent on local geographical factors including:
- Proximity to the coast and inland water courses
- Local topography
- Land use characteristics, including land use in upstream catchment area
- Design and maintenance level of drainage infrastructure
- Vulnerability of exposed assets
• Up to date information on flood risk worldwide is available online, for example UNEP / UNISDR's Global Risk Data Platform and Dartmouth Flood Observatory's Global Active Archive of Large Flood Events.

1. What does this mean for the design and construction of my project?

• If floods are identified as a potential problem for the project, it is recommended that:
- More localized information is collected on past floods and their consequences in the exact project location, especially since flood hazard can change significantly over short distances; depending on the findings, a site-specific flood risk assessment (including flood modelling) might be required that provides a good understanding of the current and future flood risk level
- Information is collected on land use and building regulations, such as flood zonation ordinances
- The project siting, design and construction features ensure that site-specific flood risk management measures are undertaken. Such measures could include a combination of grey infrastructure (such as flood defence infrastructure) and green infrastructure (such as restoration of wetlands) to reduce flood risk, as well as measures to manage the residual flood risk (such as through flood early warning, flood preparedness planning, flood insurance etc.)

2. What does the science say could happen in the future and what does this mean for the design of my project?

• Climate change is projected to influence the frequency and intensity of flood events.
• Existing engineering designs may not take into consideration the impact of climate change on the risks from

flooding. See "Critical thresholds" in the "Help & glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

3. As a starting point you may wish to consider the following questions:

Q1 Would the expected performance and maintenance of the project be impaired by flooding?
Q2 Is there a plan to integrate climate change into a flood risk assessment for the project?
Q3 Does the project siting consider flood risk to ensure the proposed project will not be impacted by flooding and will not increase risk of flooding?
Q4 Does the project design and construction features incorporate measures to manage flood risk, both in the immediate term and as risk of flooding changes as a consequence of climate change?
Q5 Will the project include emergency management plans which make provision for continued successful operation in the event of floods?

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here for the latest news and information relating to floods and climate change.

I have acknowledged the risks highlighted in this section.

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05
HIGH RISK

SEA LEVEL RISE

ACCLIMATISE COMMENTARY

You have indicated that the project is located in a Low Elevation Coastal Zone (LECZ), which could be affected by sea level rise.

1. What does this mean for the design of my project?

• There is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of inundation from the sea as well as potential future changes.

2. How could sea level rise affect the project even without future climate change?

• Low Elevation Coastal Zones (LECZs) are particularly prone to local tropical cyclones, mid-latitude storms and associated storm surges.
• Erosion of the coastline can exacerbate ‘coastal squeeze’, putting pressure on natural sea defences, such as salt marshes and mangroves as well as man-made structures.
• Up to date information on coastal storm and flood risk worldwide is available online, for example UNEP / UNISDR's Global Risk Data Platform.

3. What does the science say could happen by 2100?

• Some recent research suggests that global sea levels could be 0.75 to 1.9m higher by the end of the century.
• Local changes in ocean density/dynamics and land movements can also add to, or lessen, the effects of sea level rise at a given location.
• Sea level rise has the potential to accelerate the rate of coastal erosion. Changes in erosion regimes also impact the rate of sedimentation in other areas, particularly in estuarine and other tidal settings. This could provide problems with access to existing ports and jetties.
• In tropical regions, increasing ocean acidification and temperatures can lead to coral reef bleaching and destruction. Such reefs can provide a natural barrier to coastal inundation and erosion.
• In addition, sea level rise could cause saline intrusion into aquifers, further depleting useable water resources.
• Local sea level rise in combination with storm surge and wave height poses a hazard to offshore fixed assets, such as oil and gas platforms.

If you want to know more about trends in sea level rise around the world, please refer to: NOAA's Sea Level Trends map.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here for the latest news and information relating to sea level and climate change.

I have acknowledged the risks highlighted in this section.

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06
MEDIUM RISK

TEMPERATURE INCREASE

Would an increase in temperature require modifications to the design of the project in order to successfully provide the expected services over its lifetime?

Chosen Answer

Cannot answer.

Not enough information is known about the sensitivity of the project design to increases in temperature.

ACCLIMATISE COMMENTARY

1. What does this mean for the design of my project?

• Although you have stated that you could not answer whether the project is sensitive to increases in temperature it is recommended that you consider that an increase in mean seasonal and annual temperature could have implications for a number of hazards.
• There is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

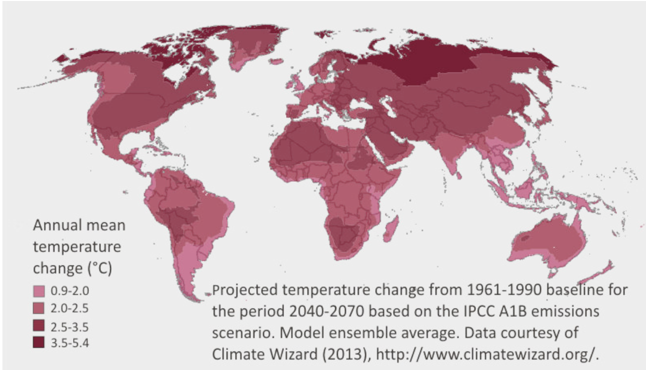
• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of high temperatures as well as potential future changes.

2. How could current high temperatures affect the project even without future climate change?

• Heatwaves put stress on buildings and other infrastructure, including roads and other transport links. In cities, the ‘urban heat island’ can increase the risk of heat related deaths.
• Warm weather can raise surface water temperatures of reservoirs used for industrial cooling. In addition, this could impact local eco-systems, improving the growing conditions for algae and potentially harmful micro-organisms in water courses.
• Heatwaves can have an impact on agricultural productivity and growing seasons.
• High temperatures can have implications for energy security. Peak energy demand due to demand for cooling can exceed incremental increases on base load in addition to the risk of line outages and blackouts.
• Human health can be affected by warmer periods. For example, urban air quality and disease transmission (e.g. malaria and dengue fever) can be impacted by higher air temperatures.
• Wildfire risk is elevated during prolonged warm periods that dry fuels, promoting easier ignition and faster spread.
• Permafrost and glacial melt regimes as impacted by warm periods.
• If our data suggests that there are existing hazards associated with high temperatures in the region, they will be highlighted elsewhere in the report. This may include existing wildfire risks as well as areas potentially impacted by permafrost and glacial melt.

3. What does the science say could happen by the 2050s?

• If you want to know more about projected changes in the project location across a range of GCMs and RCPs please refer to USGS's CMIP5 Global Climate Change Viewer for detailed maps.



4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here for the latest news and information relating to temperature and climate change.

I have acknowledged the risks highlighted in this section.

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07

MEDIUM RISK

PRECIPITATION INCREASE

Would an increase in precipitation require modifications to the design of the project in order to successfully provide the expected services over its lifetime?

Chosen Answer

Cannot answer.

Not enough information is known about the sensitivity of the project design to increases in precipitation.

ACCLIMATISE COMMENTARY

1. What does this mean for the design of my project?

• There is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of heavy precipitation events as well as potential future changes.

2. How could current heavy precipitation affect the project even without future climate change?

• Seasonal runoff may lead to erosion and siltation of water courses, lakes and reservoirs.
• Flooding and precipitation induced landslide events.
• In colder regions, seasonal snow falls could lead to overloading structures and avalanche risk.
• If our data suggests that there are existing hazards associated with heavy precipitation in the region, they will be highlighted elsewhere in the report. This may include existing flood and landslide risks.

3. What does the science say could happen by the 2050s?

• If you want to know more about projected changes in the project location across a range of GCMs and RCPs please refer to USGS's CMIP5 Global Climate Change Viewer for detailed maps.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here for the latest news and information relating to water and climate change.

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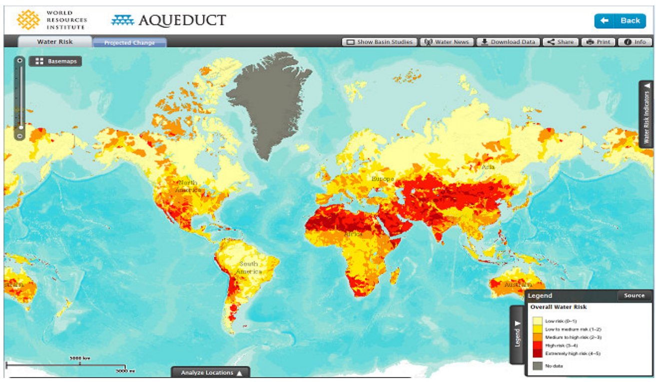
08

MEDIUM RISK

WATER AVAILABILITY

ACCLIMATISE COMMENTARY



• Our data suggest that the project is located in a region where there may be future water stress (2020s - 2050s). A high exposure in Aware means that either water stress is ‘extreme’ or high seasonal temperatures coincide with relatively low rainfall. Extreme water stress is defined as ‘less than 0.5 million litres available per person per year’ based on climate information as well as the effects of income, electricity production, water-use efficiency and other driving forces. This is post-processed data from Alcamo et al., 2007. Away from populated regions, high exposure also occurs where high seasonal temperatures (above 28 degrees Celsius average over 6 months) coincide with low rainfall (less than 100mm per month average over 6 months). This is based on post-processed data from the Global Precipitation Climatology Centre (GPCC), Climatic Research Unit (CRU) and a range of GCM projections.
• The situation may be exacerbated if there is increased competition for water with other users in the area and changes in local demographics.
• An associated reduction in water quality could also have a negative impact on the project.

1. What the science says could happen in the future and what does this mean for the design of my project?

• Climate change is projected to influence water availability. Regions that are already dry may suffer further if future precipitation is projected to decrease. Increased evaporation due to rising temperature will further impact on water availability. Seasonal availability of water may also change whereby there may be a shift in the timing of its availability.
• Existing engineering designs may not take into consideration the impact of climate change on the risks from water availability and design standards may not be met. See "Critical thresholds" in the "Help & glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.
• If water availability is identified as a potential problem for the project, it is recommended that a more localised and in-depth assessment is carried out. This information can then be used to inform the project design process if necessary.
• If you want to know more about projected changes in water availability in the project location, please refer to: the World Resources Institute's Aqueduct.

2. As a starting point you may wish to consider the following questions:

Q1 How would a lack of water impact the expected performance of the project?
Q2 Would a reduction in water supply have consequences for the expected maintenance of the project?

Q3 Will there be a water shortage continuity strategy in place for the project?
Q4 Will it be necessary to carry out water availability risk assessments in any of the project locations? If so, these assessments should take into account climate change?
Q5 Will there be an investment in water efficient technology or practices to help minimise the quantities of water required for its operational processes?

3. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here for the latest news and information relating to water and climate change.

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LOW RISK

PRECIPITATION DECREASE

Would a decrease in precipitation require modifications to the design of the project in order to successfully provide the expected services over its lifetime?

Chosen Answer

No - modifications are not required.

The design of the project would be unaffected by decreases in precipitation.

ACCLIMATISE COMMENTARY

1. What does this mean for the design of my project?

• Even though you have suggested that designs would not be affected by a decrease in precipitation, it is worth considering existing precipitation related hazards in the region where the project is planned.

2. How could reduced precipitation affect the project even without future climate change?

• Decreased seasonal runoff may exacerbate pressures on water availability, accessibility and quality.
• Variability of river runoff may be affected such that extremely low runoff events (i.e. drought) may occur much more frequently.
• Pollutants from industry that would be adequately diluted could now could become more concentrated.
• Increased risk of drought conditions could lead to accelerated land degradation, expanding desertification and more dust storms.
• If our data suggests that there are existing hazards associated with decreased precipitation in the region, they will be highlighted elsewhere in the report. This may include water availability and wildfire.

3. What does the science say could happen by the 2050s?

• Climate model projections do not agree that annual average precipitation will decrease in the project location which could indicate a relatively high degree of uncertainty (see the section "Model agreement and uncertainty" in "Help and glossary" at the end of this report). On the other hand, this could also mean precipitation patterns are not expected to change or may even increase (see elsewhere in the report for more details of projections related to precipitation increase).
• If you want to know more about projected changes in the project location across a range of GCMs and RCPs please refer to USGS's CMIP5 Global Climate Change Viewer for detailed maps.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here for the latest news and information relating to water and climate change.

I have acknowledged the risks highlighted in this section.

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The sections above will provide details on all high and medium climate hazard risks from Aware^{TM} where these are suggested by the climate sensitivities of the project and / or the underlying data. Selected Low risks may also be detailed. Local conditions, however, can be highly variable, so if you have any concerns related to risks not detailed in this report, it is recommended that you investigate these further using more site-specific information or through discussions with the project designers.

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Project Geological Hazard Risk Ratings

Below you will find the overall geological hazard risk level for the project together with a radar chart presenting the level of risk associated with each individual geological risk topic analysed in Aware^{TM}. Projects with a final "High risk" rating are always recommended for further more detailed geological risk analyses.

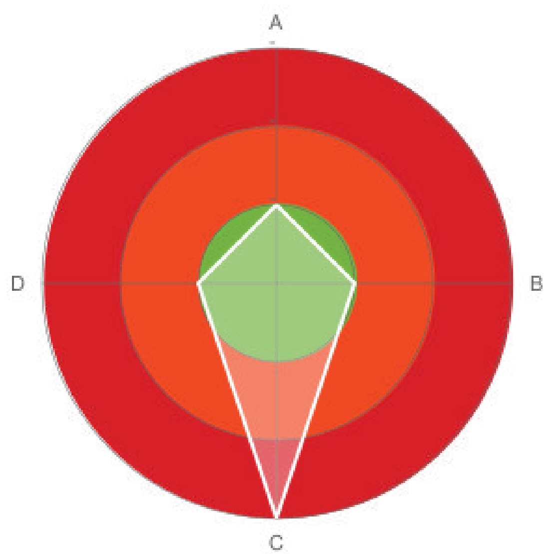
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher level of risk in relation to a risk topic. The green band (inner circle) suggests a lower level of risk in relation to a risk topic.

In the remaining sections of this report more detailed commentary is provided. Information is given on existing geological conditions and associated hazards. A number of questions are provided to help stimulate a conversation with project designers in order to determine how they would manage geological risks at the design stage. Links are provided to recent case studies, relevant data portals and other technical resources for further research.

Final project geological hazard risk ratings

Medium Risk

Breakdown of geological hazard risk topic ratings



A) Earthquake

B) Seismic landslide

C) Tsunami

D) Volcano

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HIGH RISK

TSUNAMI

ACCLIMATISE COMMENTARY

• Our data suggest that the project is located in a region where there is a tsunami run up hazard associated with a 500yr return period event. This is based on post-processed data from the International Centre for Numerical Methods in Engineering (CIMNE) and INGENIAR Ltda (GAR15).
• The risk and scale of tsunami flooding is dependent on the size of the tsunami event and local geographical factors including proximity to the coast and local topography.
• Up to date information on tsunami risk worldwide is available online, for example UNEP / UNISDR's Global Risk Data Platform, NCEI's Global Historical Tsunami Database and NOAA's Pacific Tsunami Warning Center.

1. What does this mean for the design and construction of my project?

• If tsunami risk is identified as a potential problem for the project, it is recommended that:
- More localised information is collected on past tsunamis and local site condition
- Information is collected on local land use and building regulations, such as tsunami zonation ordinance
- The project siting, design and construction features ensure tsunami risk reduction considerations. It is recommended that consideration be given to site selection, in particular whether it is feasible for the project to be located on higher ground
- Where the proposed infrastructure will act as a critical facility, such as power supply, communication networks etc., a more detailed tsunami risk assessment is undertaken to inform the project siting, design and construction process

2. What the science says could happen in the future and what does this mean for the design and construction of my project?

• Although rising sea level is unlikely to have a noticeable additional effect on flooding from the larger, more destructive scale of tsunamis, it may exacerbate the extent of flooding that may be expected from smaller scale events.
• Existing engineering design and construction may not take into consideration the impact of climate change on otherwise manageable flood risk from small scale tsunamis. See "Critical thresholds" in the "Help & glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

3. As a starting point you may wish to consider the following questions:

Q1 Would the expected performance and maintenance of the project be impaired by tsunami related flooding?
Q2 Does the project team have a good understanding of the tsunami risk in the area, including past tsunamis, local site conditions, local land use and building regulations?
Q3 If the proposed infrastructure will act as a critical facility, is there a plan to assess tsunami risk to project location, design, construction and operation?
Q4 Does the project design and construction features incorporate measures to reduce tsunami risk, both in the immediate term and as the extent of related seawater inundation changes as a consequence of climate change?
Q5 Will the project have access to tsunami early warning systems and implement emergency evacuation procedures both during project implementation and over the life of supported infrastructure?

4. What next?

• See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on disaster risk reduction.

I have acknowledged the risks highlighted in this section.

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The sections above will provide details on all high geological hazard risks from Aware™ where these are suggested by the underlying data. Local conditions, however, can be highly variable, so if you have any concerns related to risks not detailed in this report, it is recommended that you investigate these further using more site-specific information or through discussions with the project.

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HELP AND GLOSSARY:

Model agreement and uncertainty:

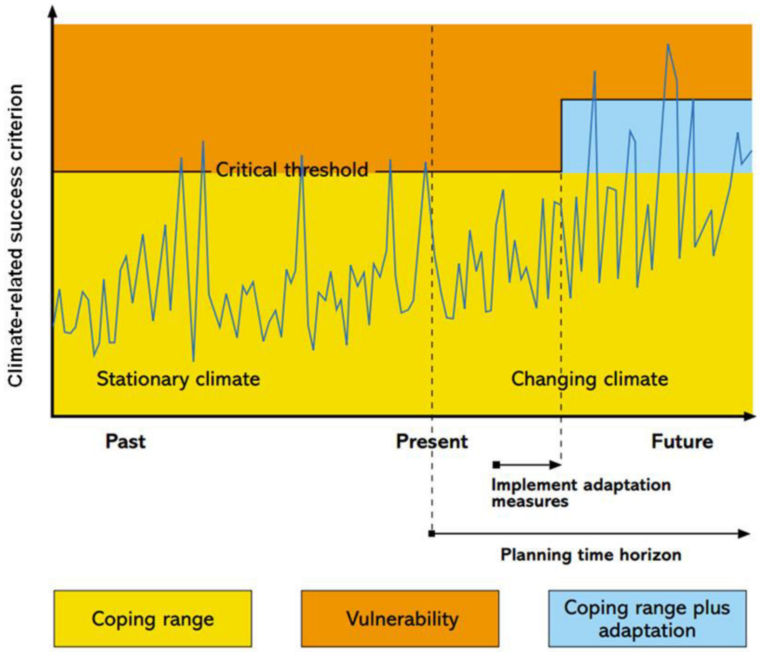
Although climate models are constantly being improved, they are not good enough to predict future climate conditions with a degree of confidence which would allow precise adaptation decisions to be made. Outputs from different climate models often differ, presenting a range of possible climate futures to consider, and ultimately a wide range of possible actions to take. In Aware, climate projections make use of GCM ensemble percentiles to determine: for temperature increase, whether 75% of CMIP5 GCM ensemble agree on a magnitude of change; for precipitation increase and decrease, whether 75% of CMIP5 GCM ensemble agree on the direction of change.

Even with improvements in climate modelling, uncertainties will remain. It is likely that not all the climate statistics of relevance to the design, planning and operations of a project's assets and infrastructure will be available from climate model outputs. The outputs are typically provided as long-term averages, e.g. changes in average monthly mean temperature or precipitation. However, decisions on asset integrity and safety may be based on short-term statistics or extreme values, such as the maximum expected 10 minute wind speed, or the 1-in-10 year rainfall event. In such cases, project designers or engineers should be working to identify climate-related thresholds for the project (see "Critical thresholds" section below) and evaluate whether existing climate trends are threatening to exceed them on an unacceptably frequent basis. Climate models can then be used to make sensible assumptions on potential changes to climate variables of relevance to the project or to obtain estimates of upper and lower bounds for the future which can be used to test the robustness of adaptation options.

The key objective in the face of uncertainty is therefore to define and implement design changes (adaptation options) which both provide a benefit in the current climate as well as resilience to the range of potential changes in future climate.

Critical thresholds:

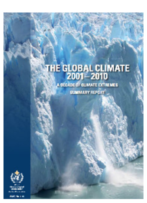
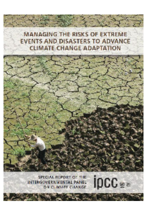
A key issue to consider when assessing and prioritising climate change risks is the critical thresholds or sensitivities for the operational, environmental and social performance of a project. Critical thresholds are the boundaries between ‘tolerable’ and ‘intolerable’ levels of risk. In the diagram below, it can be seen how acceptable breaches in a critical threshold in today’s climate may become more frequent and unacceptable in a future climate.

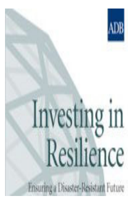


The relationship between a critical threshold and a climate change related success criterion for a project. [Source: Willows, R.I. and Connell, R.K. (Eds.) (2003). *Climate adaptation: Risk, uncertainty and decision-making*. UKCIP Technical Report, UKCIP, Oxford].

Climate change scenarios can be used to see if these thresholds are more likely to be exceeded in the future. The simplest example is the height of a flood defence. When water heights are above this threshold, the site will flood. The flood defence height is the horizontal line labelled 'critical threshold'. Looking at the climate trend (in this case it would be sea level or the height of a river) – shown by the blue jagged line – it can be seen that the blue line has a gradual upward trend because of climate change. This means that the critical threshold is crossed more often in the future – because sea levels are rising and winter river flows may be getting larger. So, to cope with this change, adaptation is needed – in this case, one adaptation measure is to increase the height of the flood defence.

Further reading and resources:

	Report detailing changes in global climate: The Global Climate 2001 - 2010
	IPCC report on climate-related disasters and opportunities for managing risks: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)
	IPCC report on impacts, adaptation and vulnerability: Climate Change 2014: Impacts, Adaptation, and Vulnerability

	IFC report on climate-related risks material to financial institutions: Climate Risk and Financial Institutions. Challenges and Opportunities.
	Nationally Determined Contributions (NDCs) submitted under the COP21 Paris Agreement: NDC Registry.
	ADB report on investment in disaster resilience: Investing in Resilience: Ensuring a Disaster-Resistant Future.
	UNISDR's report on disaster risk success stories: Disaster risk reduction: 20 examples of good practices from Central Asia.
	UNISDR's review and analysis of data and information on disaster risk patterns and trends: Global Assessment Report on Disaster Risk Reduction.
	CRED's International Disasters Database: EM-DAT.
	DesInventar Project's historical disaster impact catalogues: DesInventar.
	National progress reports to UNISDR on DRM commitments: HFA National Progress Reports.
	National documents DRM policy and strategy documents and studies: Disaster risk reduction in the world.
	National-level factsheets based on the Global Assessment Report: Country Profiles.

	GEM NEXUS Building and population inventory : GED4GEM database.
	GAR analysis tool of exposure including population, capital stock and economic indicators: Risk Data Platform CAPRAViewer.

Aware data resolution:

The proprietary Aware data set operates at a resolution of 0.5 x 0.5 decimal degrees (approximately 50 km x 50 km at the equator). These proprietary data represent millions of global data points, compiled from environmental data and the latest scientific information on current climate / weather related hazards together with potential changes in the future. Future risk outcomes are based on projections data from the near- to mid-term time horizons (2020s or 2050s, depending on the hazard and its data availability).

Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (Meehl et al., 2007) and 5 (CMIP5) multi-model dataset (Taylor et al., 2012), were resampled to a 0.5 degree grid.

[Taylor, K.E., R.J. Stouffer, G.A. Meehl (2012) "An Overview of CMIP5 and the experiment design." Bulletin of the American Meteorological Society, 93, 485-498.

[Meehl, G. A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J. F. B. Mitchell, R. J. Stouffer, and K. E. Taylor: The WCRP CMIP3 multi-model dataset: A new era in climate change research, Bulletin of the American Meteorological Society, 88, 1383-1394, 2007]

Aware data application:

In some instances Risk Topic ratings are only based on Aware data, including:
• Flood
• Permafrost
• Landslides – precipitation induced
• Earthquake
• Landslides – seismic induced
• Volcano
• Tsunami

Country level risk ratings:

These are generated from the data points within a country's borders. For single locations, site-specific data are used, and for multiple locations or countries, composite data across the portfolio of locations are used.

Glossary of terms used in report

"Climate model projections agree": for temperature, defined as 75% of CMIP5 GCM ensemble members agreeing that annual average temperature increase will reach 2°C; for precipitation increase or decrease, defined as 75% of CMIP5 GCM ensemble members agreeing on the direction of annual average precipitation change.

"Climate model projections do not agree": for temperature, defined as only 25% of CMIP5 GCM ensemble members agreeing that annual average temperature increase will reach 2°C; for precipitation increase or decrease, defined as only 25% of CMIP5 GCM ensemble members agreeing on the direction of annual average precipitation change.

The overall climate risk score for the project (high, medium or low) is based on a count of high risk topic scores. A project scores overall high climate risk if greater than or equal to 3 individual risk topics score high.

A project scores overall medium climate risk if between 1 and 2 individual risk topics score high. A project scores overall low climate risk if none of the individual risk topics score high.

The overall geological risk score for the project (high, medium or low) is based on a count of high risk topic scores. A project scores overall high geological risk if greater than or equal to 2 individual risk topics score high. A project scores overall medium geological risk if 1 individual risk topic scores high. A project scores overall low geological risk if none of the individual risk topics score high.

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