PROJECT CLIMATE RISK ASSESSMENT AND MANAGEMENT

I. Basic Project Information

Project Title: Jiangxi Ji'an Sustainable Urban Transport Project
Project Budget: ADB financing US$120 million, Total cost of Project US$289.60 million, Proposed Global Environment Facility financing of US$2.5 million
Location: People's Republic of China, Jiangxi Province
Sector: Transport (Urban public transport, Urban roads and traffic management, Transport policies and institutional development) and Water and other urban infrastructure and services.
Theme: Inclusive growth and environmental sustainability
Brief Description: The project proposes: (i) a 6.9-kilometer (km) bus rapid transit (BRT) system and public transport hub, (ii) river rehabilitation and "greenway" development, (iii) traffic management system and 19.3 km of urban roads, and (iv) institutional strengthening and capacity building. Additional financing from the Global Environment Facility is being sought for environmental improvement presented in Supplemental Linked Document 17 of the RRP. The proposed project will contribute to inclusive growth and environmentally sustainable development in Jiangxi Ji'an by improving the efficiency and sustainability of urban transport. The urban roads and river rehabilitation will be the project components most vulnerable to climate change effects projected for Jiangxi province.

II. Summary of Climate Risk Screening and Assessment

A. Sensitivity of project component(s) to climate/weather conditions and sea level The project area is low-lying and located in the middle reaches of the Gan River which is historically subject to flooding, particularly during the rainy season between May and July. Screening and assessment was carried out to determine the vulnerability of project financed infrastructure to future climate change impacts.	
Project component 1. Yudai River rehabilitation - flood protection design standards. 2. Urban roads - bridge, pavement and stormwater drainage design standards. 3. Urban roads - maintenance frequency for roads and stormwater drainage infrastructure **4.** Urban roads – continuity of services	*Sensitivity to climate/weather conditions and sea level* 1. Intensity and frequency of heavy rainfall events 2. Increased risk of flood 3. Winter and summer temperature extremes
B. Climate Risk Screening Initial climate risk screening was carried out using AWARE for Projects and the project was identified as being at high risk from increased precipitation, risk of flood, snow loading[1] and onshore Category 1 storms;[2] medium risk from decreased precipitation, wind speed increase and solar radiation change; and low risk from temperature increase. An EARD study of climate change risk in Jiangxi determined that the province is at high risk from severe storms, floods and droughts (2031–2060). The risk screening indicated that there is potential for an increase in incidences where current design standards will not be sufficient and a more detailed assessment of climate change risks was recommended to determine the extent to which the project design, operation and maintenance standards take into consideration future climate change impacts.	
Risk Topic	*Description of the Risk*

[1] The project is located in a region where snow is commonly observed and future precipitation may also increase (2050s). The impact of increasing precipitation at higher latitudes could represent an increased risk of snow.

[2] A Category 1 storm is characterised by sustained winds in excess of 199km/hour (33 metres/second).

1. Intensity and frequency of heavy rainfall events 2. Winter and summer temperature extremes 3. Severe storms (tropical cyclone) 4. Snow loading	1. Maximum flood height may increase requiring a change in design criteria 2. Increased drainage capacity may be required. 3. Structural integrity of pavement, subsurface and bridge expansion joints may be affected by waterlogging 4. Improved emergency response mechanisms to ensure continuity of operations and services may be needed.

Climate Risk Classification

High (AWARE climate risk screening report is included in Annex 1)

C. Climate risk assessment

A detailed climate risk and vulnerability assessment (CRVA) was funded ($35,000) through the ADB Climate Change Fund, see Annex 2 for Terms of Reference. The application was approved by RSES on 19 June 2014. The detailed CRVA report is included in Annex 3.

The CRVA made use of 40 of the IPCC Fifth Assessment Report General Circulation Models (GCMs) and a pattern scaling method was adopted to build a model ensemble to project climate change impacts for the project area. Baseline spatial climatology for the project areas was derived from the WorldCLIM Database which has a spatial resolution of 1 kilometre and baseline site-specific climate conditions from hydrometeorological station data from the project area. The CRVA presents projections based on a range of future greenhouse gas scenarios. The median scenario climate change projections are based on the IPCC Fifth Assessment Report Representative Concentration Pathway (RCP) 6.0. The low scenario climate change projections are based on RCP4.5 and the high scenario climate change projections are based on RCP8.5 (see Appendix 1 of the detailed report for a full explanation of RCPs). A statistical relationship between heavy rainfall and flood was developed to support the assessment.

The CRVA projections indicate that, based on the median climate change scenario, there could be an average increase in rainfall of 1.5 to 4.5% by 2050 and 3 to 9% by 2100. The 1:50 year annual maximum rainfall event intensity could increase by 8% by 2050 and 16% by 2100. This increase in average rainfall, intensity and frequency is likely to result in a more severe flood risk for the project area.

Annual average temperature is projected to increase by 1.3ºC by 2050 and 2.5 ºC by 2100. The minimum temperatures, both average and extreme low are expected to increase. The CRVA did not identify significant risks from snow loading, onshore Category 1 storms, decreased precipitation, wind speed increase and solar radiation change. In fact, a reduced frost period and reduced snow fall are projected reducing the significance of those risk factors in the future.

The CRVA reviewed the key design standards adopted for the project:

(i) 1:2[1] year rainfall event intensity was adopted for the design of the stormwater drainage for the urban roads. It was determined that the 1:2 year rainfall event intensity may increase from 88.92mm to 92.40mm by 2050.

(ii) 1:20[2] and 1:50[3] year 24 hour rainfall intensity standards were adopted for urban floodwater drainage system design.

[1] 1:2 has a 50% probability of occurrence in any given year.
[2] 1:20 has a 5% probability of occurrence in any given year.
[3] 1:50 has a 2% probability of occurrence in any given year.

(iii) The road design criteria is a 1:50 year flood level, however, the actual height is 59masl (metres above sea level) along most sections owing to local topography so flooding of the road network is unlikely even under a high emissions scenario climate change projection as the current 1:200 year flood water level is 55.42masl.

(iv) 1:50 year flood water level was adopted for Yudai River flood protection design. The largest flow height observed in Ji'an over a 30 year period was in 2010 when was a flood water height of 53.14masl was recorded. By 2050, an increase of 0.45m is projected and by 2100, an increase of 0.85m. The flood protection works have been designed based on a historical 1:50 year flood event (54.41m) plus a 0.5m safety factor.

(v) In addition the Ji'an Government plan to enhance the Gan River dykes for flood protection to the current 1:100 year flood height of 54.93 m and in the future for a 1:200 year flood height.

III. Climate Risk Management Response within the Project

The CRVA made the following recommendations for the detailed design:

1. Current design criteria for stormwater drainage for urban roads and urban floodwater drainage may not be adequate by 2050. For drainage components that would be difficult to replace or repair it is recommended that the high emissions scenario climate change projections are adopted as the basis for design. A drainage capacity increase of between 6 to 10% is estimated to cost CNY10 Million (~US$1.6 Million). More drainage capacity may be required beyond 2050.

2. The road drainage network is designed to drain into the Gan River. During periods when flood of the Gan River coincides with heavy rainfall in the urban area, stormwater cannot drain to the Gan River which may result in waterlogging of the urban area. It is recommended that a flood water pumping station may be considered.

3. The current design criteria for the flood protection works already incorporate a factor of safety of 0.5m so it is considered that this design standard is adequate for low and middle emission scenario climate change projections of 0.5 m flood height increase. This design standard may be inadequate in the event of a high climate change scenario and/or after 2050 when projections indicate a flood height increase of 0.85m. However, given the key infrastructure components of the project will be designed with sufficient height (59 masl), risk from future climate change impacts will likely be limited to the landscape and greenspace components along the Yudai River.

4. The Ji'an Government proposes to enhance the flood protection capacity of the Gan River dykes, which will effectively alleviate the risk of Gan River flood on the project. The Gan River watershed includes reservoirs and dams that have significant flood storage capacity, and the Wan'an Reservoir has further potential to adjust the flood height at Ji'an when it operated at its full capacity. In addition, the effectiveness of these hydraulic facilities for flood management is heavily dependent on accurate and real-time hydro-meteorological information. The Ji'an Government has included the development of a comprehensive hydro-meteorological prediction system in the current Twelfth Five Year Development Plan. It is recommended that this system is linked to an early warning system and integrated climate and disaster risk management action plan to ensure that critical transport infrastructure is protected and continuity of services maintained during a severe weather event.

The Government has agreed to take account of these recommendations in the detailed design and will confirm if/which measures are adopted and if there is an incremental cost for adaptation measures.

01

Introduction

This report summarises results from a climate risk screening exercise. The project information and location(s) are detailed in Section 02 of this report.

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

Project Information

PROJECT NAME:	Jiangxi Ji'an Sustainable Urban Transport Project
SUB PROJECT:	Urban Roads
REFERENCE:	45022
SECTOR:	Urban flood protection
SUB SECTOR:	Fluvial defences
DESCRIPTION:	

02

Chosen Locations

1) China

03 Project Risk Ratings

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

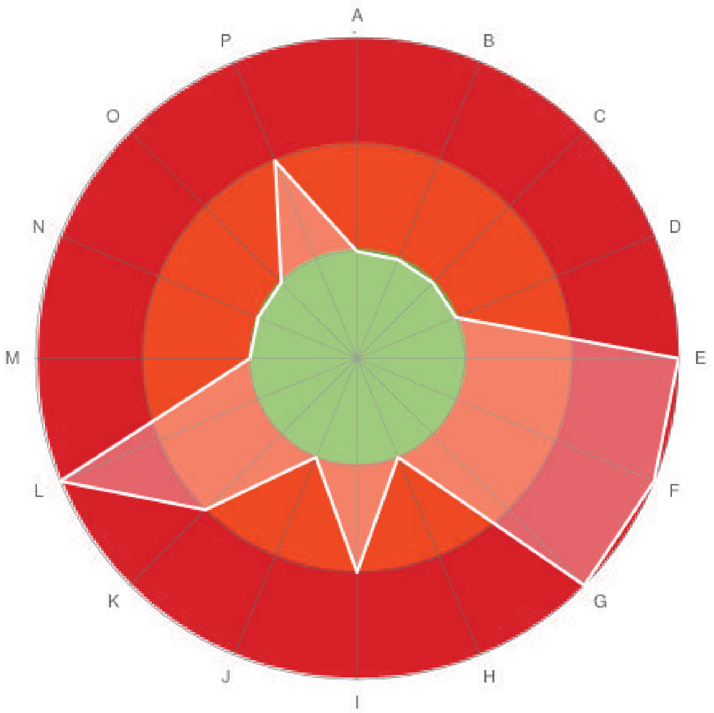
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher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

High Risk

Breakdown of 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

04
HIGH
RISK

PRECIPITATION INCREASE

ACCLIMATISE COMMENTARY

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

• The project is considered to have high sensitivity to increased precipitation and 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?

• Climate model projections agree that seasonal precipitation will increase in the project location. This indicates a relatively low degree of uncertainty that precipitation will increase in the region.
• If you want to know more about projected changes in the project location across a range of GCMs and emissions scenarios please refer to The Nature Conservancy's Climate Wizard for detailed maps and Environment Canada's Canadian Climate Change Scenarios Network for scatter plots of expected changes.

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.

☐ I have acknowledged the risks highlighted in this section.

05

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 2010 there have been more than 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
• Urban drainage infrastructure
• Up to date information on flood risk worldwide is available online, for example UNEP / UNISDR's Global Risk Data Platform.

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 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.
• If flooding 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.

2. 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 Will the project include continuity plans which make provision for continued successful operation in the event of floods?

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 floods and climate change.

☐ I have acknowledged the risks highlighted in this section.

06

HIGH RISK

SNOW LOADING

ACCLIMATISE COMMENTARY

Our data suggest that the project is located in a region where snow is commonly observed and future precipitation may also increase (2050s). This is based on snow extent data for the northern (1967 – 2005) and southern hemispheres (1987 – 2002) from the US National Snow and Ice Data Centre (NSIDC) in addition to precipitation projections from 16 GCMs. Up to date information on snow conditions worldwide is available online from the NSIDC.

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

• The impact of increasing precipitation at higher latitudes could represent an increased risk of snow loading which could impact on the structural integrity of buildings and other infrastructure.
• Existing design standards may not take into consideration the impact of climate change on snow loading risk. 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 increased snow loading could be a 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.

2. 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 heavy snow falls?
Q2 Are there any plans to integrate climate change into a snow loading risk assessment for the project?
Q3 Will the project include continuity plans which make provision for continued successful operation in the event of disruption from heavy snow?

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 snow and climate change.

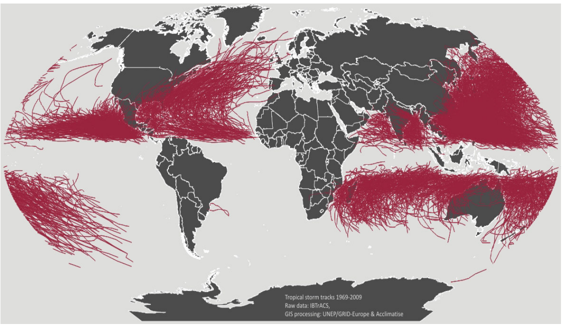
☐ I have acknowledged the risks highlighted in this section.

07

HIGH RISK

ONSHORE CATEGORY 1 STORMS

ACCLIMATISE COMMENTARY



• Our data suggest that the project is located in a region which has experienced Category 1 storms in the recent past. A high exposure in Aware means that between 1968 and 2009 there have been at least one Category 1 storm in the region. This is based on post-processed data from UNEP/ GRID-Europe.
• On the Saffir-Simpson Hurricane Scale a category 1 storm is characterised by sustained winds in excess of 119 km/hr (33 m/s).
• Even this least intense storm can still produce plenty of damage and be life threatening.
• These regions may also susceptible to lower intensity but more frequent tropical storms as well as less frequent higher-intensity storms.
• Up to date information on storm risk worldwide is widely available online, for example UNEP / UNISDR's Global Risk Data Platform.

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 the frequency and intensity of tropical storms.
• Existing engineering designs may not take into consideration the impact of climate change on the risks from tropical or extra tropical storms. 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 coastal surges and high winds are 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.

2. 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 hazards associated with tropical storms e.g. storm surges and strong winds?
Q2 Are there any plans to integrate climate change factors into a storm risk assessment for the project?
Q3 Will the project include continuity plans which make provision for continued successful operation in the event of storm damage?

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 storms and climate change.

☐ I have acknowledged the risks highlighted in this section.

08

MEDIUM RISK

PRECIPITATION DECREASE

ACCLIMATISE COMMENTARY

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

• The project is considered to have medium sensitivity to decreased precipitation and 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 decreased precipitation events as well as potential future changes.

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 seasonal 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 emissions scenarios please refer to The Nature Conservancy's Climate Wizard for detailed maps and Environment Canada's Canadian Climate Change Scenarios Network for scatter plots of expected changes.

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.

I have acknowledged the risks highlighted in this section.

09
MEDIUM RISK

WIND SPEED INCREASE

ACCLIMATISE COMMENTARY

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

• The project is considered to have medium sensitivity to wind and 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 increasing wind speed as well as potential future changes.

2. How could stronger winds affect the project even without future climate change?

• The design and operation of certain infrastructure (e.g. wind turbines) is determined by the prevailing climatic wind conditions.
• Given the energy in the wind is the cube of wind speed, a small change in the wind climate can have substantial consequences for the wind energy available.
• Similarly, small changes could have dramatic consequences for wind related hazards e.g. wind storm damage.
• If our data suggests that there is an existing risk of tropical storms in the region, it will be highlighted elsewhere in the report.

3. What does the science say could happen in the future?

• Climate change could alter the geographic distribution and/or the seasonal variability of wind resource.
• Climate model projections remain uncertain and it appears unlikely that mean wind speeds will change by more than the current inter-annual variability.
• Changes in extreme wind speeds associated with extra-tropical and tropical storm are similarly uncertain. However, there have been studies that suggest fewer but more intense events. Stronger storms bring with them an increases risk of coastal storm surge, coastal erosion, wind damage and flooding.
• Given future uncertainty it is advisable to carefully assess past wind speed in the region, bearing in mind that it could change in the future. The UNEP Solar and Wind Energy Resource Assessment SWERA provides a useful global overview of wind information.

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 wind and climate change.

I have acknowledged the risks highlighted in this section.

10
MEDIUM RISK

SOLAR RADIATION CHANGE

ACCLIMATISE COMMENTARY

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

• The project is considered to have medium sensitivity to changes in solar radiation and there is a potential for incidences where current design standards will not be sufficient or met. 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 fluctuating solar radiation as well as potential future changes.

2. How could changes in solar radiation affect the project even without future climate change?

Medium (yearly, seasonal) or longer term variations in solar radiation at the Earth's surface can affect for example:
• Agricultural yields. In some cases, the rate of photosynthesis (and therefore growing season) is proportional to the surface solar radiation.
• Solar power potential.
• The rate of degeneration of building materials.

3. What does the science say could happen in the future?

• Future projections of regional 'dimming' or 'brightening' are difficult to predict. This is due largely to the uncertainty surrounding cloud formation under climate change conditions.
• Given future uncertainty it is advisable to carefully assess past variations in solar radiation in the region, bearing in mind that it could change in the future. The UNEP Solar and Wind Energy Resource Assessment SWERA provides a useful global overview of solar radiation information.

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 solar radiation and climate change.

☐ I have acknowledged the risks highlighted in this section.

aware
Aware for Projects

11
LOW
RISK

TEMPERATURE INCREASE

ACCLIMATISE COMMENTARY

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

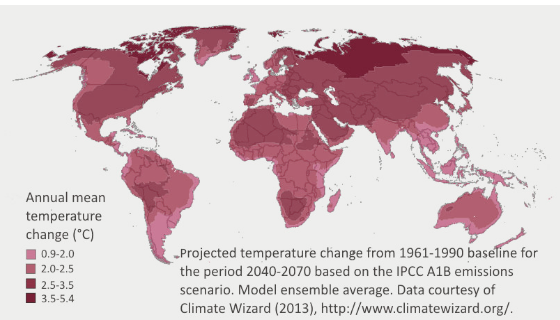
• Even though the project has been identified as having a low sensitivity to temperature, it is worth considering existing temperature related hazards in the region where the project is planned.
• There is a potential for an increase in incidences where current design standards will not be sufficient. 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?



Projected temperature change from 1961-1990 baseline for the period 2040-2070 based on the IPCC A1B emissions scenario. Model ensemble average. Data courtesy of Climate Wizard (2013), http://www.climatewizard.org/.

• Climate model projections agree that seasonal temperatures will increase by over 2 ˚C in the project location. This indicates a relatively low degree of uncertainty that temperatures will increase in the region.
• If you want to know more about projected changes in the project location across a range of GCMs and emissions scenarios please refer to The Nature Conservancy's Climate Wizard for detailed maps and Environment Canada’s Canadian Climate Change Scenarios Network for scatter plots of expected changes.

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.

I have acknowledged the risks highlighted in this section.

12

The sections above detail all High and Medium risks from Aware^{TM}. Selected Low risks are also 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.

HELP AND GLOSSARY:

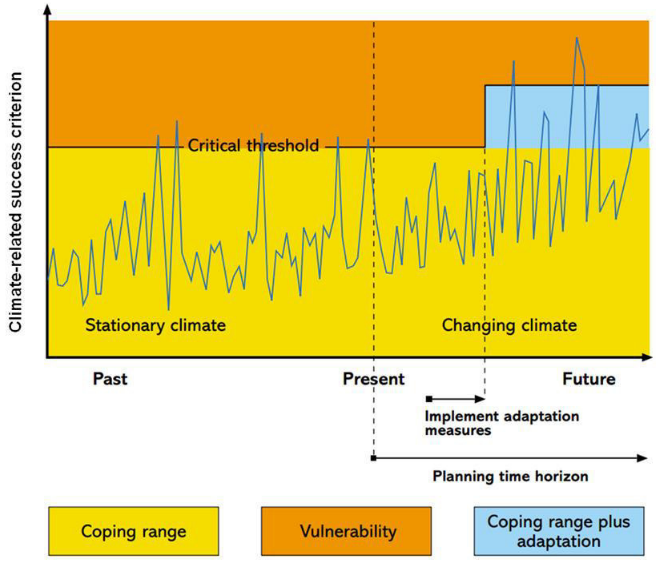
Model agreement and uncertainty:

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 are described as having potentially higher degree of uncertainty when less than 14 out of 16 GCMs agree on the direction and / or a pre-defined magnitude 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:

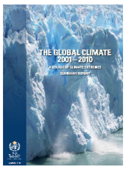
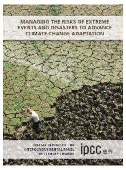
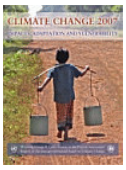


The relationship between a critical threshold and a climate change related success criterion for a project. [Source: Willows, R.I. and Connell, R.K. (Eds.) (2003). *Climate adaptation: Risk, uncertainty and decision-making*. UKCIP Technical Report, UKCIP, Oxford].

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 above, 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.

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:

	Report detailing changes in global climate: The Global Climate 2001 - 2010 (PDF)
	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: Working Group II Report "Impacts, Adaptation and Vulnerability"
	IFC report on climate-related risks material to financial institutions: Climate Risk and Financial Institutions. Challenges and Opportunities.

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 (CMIP3) multi-model dataset (Meehl et al., 2007), were downscaled to a 0.5 degree grid.

[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

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": defined as more than 14 out of 16 GCMs agreeing on the magnitude (e.g. temperature warming of 2 °C) and / or direction of change (e.g. seasonal precipitation).
"Climate model projections do not agree": defined as 14 or fewer out of 16 GCMs agreeing on the magnitude (e.g. temperature warming of 2 °C) and / or direction of change (e.g. seasonal precipitation).
"Significant proportion": defined as at least 25% of locations when multiple locations are selected.
"Large proportion": defined as at least 75% of locations when multiple locations are selected.

The above thresholds are used as a means of providing a project-wide risk score where a project may be spread across multiple locations. This requires more than one individual location to be at risk to begin signifying whether there is a risk at the overall project level. However, it is always recommended that individual locations are analysed separately for more accurate, site-specific risk screening. The overall risk score for the project (high, medium or low) is based on a count of high risk topic scores. A project scores overall high risk if greater than or equal to 3 individual risk topics score high. A project scores overall medium risk if between 1 and 2 individual risk topics score high. A project scores overall low risk if none of the individual risk topics score high.

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Annex 2: Terms of Reference for Climate Change Specialist

Climate Change Specialist (international consultant, 2.0 person-months). The Climate Change Specialist will assess climate change risks and vulnerability of the project components and options for managing identified risks.

Scope of Work. The following tasks will be carried out:

(i) In consultation with the key members of the PPTA team and relevant project documentation, identify project components that are sensitive to climate/weather conditions;

(ii) In consultation with the ADB/PPTA/design team develop a detailed work plan for carrying out a climate risk and vulnerability assessment, including: key study sites/areas, and future timeframe (e.g. 20, 30 or 50 years); climatic/hydrological variables/parameters to be analysed; inventory of data required for the study, and data acquisition plan; methods and techniques for climate scenario analyses; methods for impact assessments; methods for identifying risk management/adaptation options; and a plan for interacting with the PPTA team (including objectives, timeline, relevant team members); and key outputs with milestones.

(iii) The timing of the study should take into account the overall timeline of the detailed design (scheduled to commence in June 2014) when results from the study will need to be communicated and considered by the design team;

(iv) Carry out the climate risk and vulnerability assessment, including the development of climate scenarios, assessment of potential risks of climate sensitive project components to projected climate change, and the identification of possible adaptation interventions during design and operation to manage such risks;

(v) Discuss possible adaptation interventions with ADB project leader prior to wider discussion. Conduct a workshop on the findings of the study with key project partners and stakeholders to agree the adaptation options to be taken forward.

(vi) Prepare a detailed technical report on the study, including the overall methodology, data used, assumptions made, key findings and their implications for the project preparation[1], caveats/limitations of the study and their implication for the project preparation;

Deliverables. The climate change specialist is expected to provide the following deliverables:

(vii) A technical note outlining the sensitivities of project components to climate conditions;

(viii) A technical report on the study, including: an executive summary, key findings and their implications for the design, construction and maintenance of project components; methodological framework; data, scenarios and assumptions underlying the study; key findings including projected climate change in the project sites/areas, potential impacts of projected climate change on project components; possible adaptation interventions to address impacts/risks to ensure climate resilient design, construction, operation and maintenance of project components; and wider implications of climate change and associated impacts for road network development, caveats and limitations of the study

(ix) A set of presentational material, with detailed notes, to be derived from the Technical Report described in (iii) above

[1] Including plans for the design, construction and maintenance of project components

Qualifications and experience. The Climate Change Specialist will be a climate scientist with at least 10 years of experiences working in the fields of climate change scenario analysis, climate change impact, vulnerability and adaptation in Asia. He/she will also need to a track record of advising on adaptation options and communicating climate science with multidisciplinary teams and a wide range of audiences.

Technical Assistance Consultant's Report

Contract No. 115574-S82959

TA-7965 PRC: Jiangxi Ji'an Sustainable Urban Transport Project

Climate Change Impact Assessment on Jiangxi Ji'an Sustainable Urban Transport Project in People's Republic of China

October 2014

Prepared by Wei Ye

Asian Development Bank

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Abbreviations

ADB	Asian Development Bank
AR5	The Fifth Assessment Report (Intergovernmental Panel on Climate Change)
DMC	developing member country (ADB)
GCM	general circulation model
GEV	general extreme value function
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
JSTDP	Ji’an Sustainable Transport Development Project
PMO	Project Management Office
PPTA	Project Preparatory Technical Assistance
PRC	People’s Republic of China
RCP	Representative Concentration Pathway
SUCDRI	Shanghai Urban Construction Development and Research Institute
V&A	Vulnerability and Adaptation

Executive Summary

The objective of this study is to assess the vulnerability of the Ji'an Sustainable Transport Development Project (JSTDP) to the impact of projected climate change and to identify adaptive measures to reduce the vulnerability. The JSTDP is to be implemented in the Jizhou District, which is the urban centre of Ji'an city. It includes a 6.94 Km bus rapid transit (BRT) corridor; five urban roads totalling 19.33 Km in length; and the rehabilitation of an 8.02 km section of the Yudai River.

Geographically, Jizhou is characterised by low and flat plains on the west side of the Gan River. It has been under consistent flood thread from the Gan River and the rivers across its urban area. The flood of Jianxi is mainly triggered by torrential rain during the rainy season; hence the heavy rainfall event is the highest risk to the climate sensitive component of the JSTDP. Based on the IPCC AR5 General Circulation Model (GCM) outputs and historical observation from the area; quantitative climate projections for the key climate variables were generated. A statistical relationship between heavy rainfall and flood was developed to support the vulnerability and adaptation (V&A) assessment.

The climate scenario analysis has revealed that average rainfall is likely to increase gradually in the future, which may become noticeable by 2050 particularly for the rainy season. The climate change impact is even more manifested as a result of changes in the intensity and frequency of heavy rainfall events. The median projections from the GCM ensemble indicated that, for the 1:50 year annual maximum 10 day rainfall event, its intensity is likely to increase by 8% and 16% in 2050 and 2100 respectively. The increase in both average rainfall and, in particular, the heavy rainfall intensity and frequency implies a more severe flood risk for the project area. Taking these adverse impacts into project design consideration may prevent costly infrastructure maintenance and repairs and minimise the disruption of transportation due to climate disaster in the future.

1. Introduction

Climate change will pose various threats to a transport system. In order to achieve a sustainable development, it is important to make climate adaptation adjustments to engineering specifications, alignments, and master planning; incorporate associated environmental measures; and adjust maintenance and contract scheduling for transport projects (ADB 2010). An effective climate-proofing of a transport system requires project specific climate change impact vulnerability assessment and identifying, evaluating and implementing feasible adaptation measures to strengthen project resilience to future climate change impact. This report presents the climate change impact V&A assessment for the Ji'an Sustainable Transport Development Project (JSTDP) in Jiangxi Province, the People's Republic of China (PRC).

1.1 Background of the project area

Jiangxi Province is located in the middle of the PRC with an area of 166900 km^2, and Ji'an is its second largest city in terms of area. Topographically, most areas of Jiangxi are mountains and high hills, which constitute 54% of its total area. Mountains surround the province from the east, south and west forming a water basin with a shape almost coinciding with the province administration boundary. The Poyang Lake in the northern border of Jiangxi is the bottom of the basin and also the outlet of the five major rivers of the province. The Gan River is the longest river of Jiangxi, and is one of the major tributaries of the Yangtze River. It is 823 Km long and its network covers almost from the southern border of the province to the Poyang Lake in the north. The upper reach of the Gan River is characterised by high mountains, whereas the middle and low reaches are relatively low in altitude with small hills and plains.

Jiangxi has subtropical humid climate and is characterised by mild temperature. The average annual temperature is between 16-20°C and the average annual rainfall is 1650 mm. The rainfall has distinctive seasonality with the 3 month rainfall of rainy season from April to June accounting for almost half of the annual total. Due to its unique geography and abundant rainfall; the province, particularly the area along the Gan River, has been under consistent threat of flood during the rainy season. Since 1950, Jiangxi had more than 2000 floods, with a death toll of 2023 and total direct economic damage of over US$ 1 billon (Fan et al., 2012).

Ji'an Citys is located in the middle reach of the Gan River between latitude 25°58′32''N to 27°57'50''N and longitude 113°46′E to 115°56′E.The city extends 218 Km from north to south and 208 Km from east to west, with an area of 25300 Km^2, the second largest prefectural city of Jiangxi. The city population is approximately 5 million. The Luoxiao Mountains in the west of the city is one of the torrential rainfall centres of Jiangxi. Jizhou district is the urban centre of Ji'an located on the relative low-lying Ji-Tai plain in the middle of Ji'an (Figure 1). Jizhou is bisected by the Gan River. The section length of the Gan River in Jizhou is 20 Km. The river width varies from 600-800 metres during the dry season to 1500-2500 metres during flooding. The catchment area of the Gan River above Ji'an is 56223 Km^2.

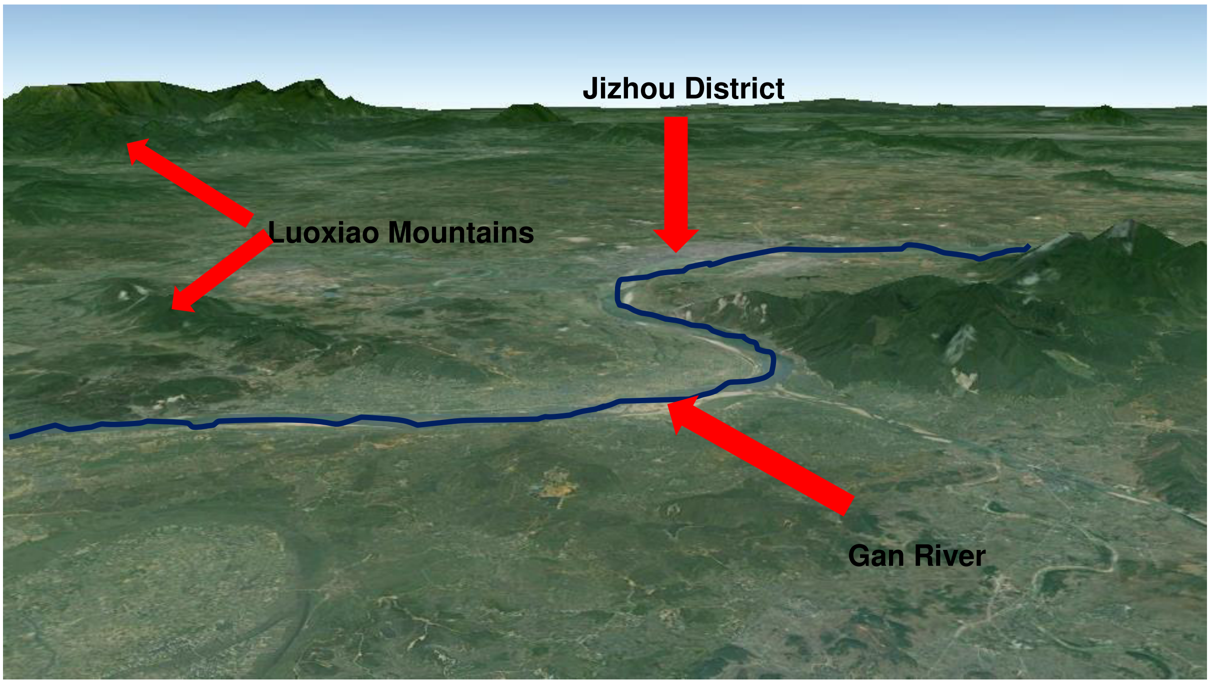

Figure 1: Topography of Ji'an and location of Jizhou, the project area.

Ji'an is the most important city in the middle of Jiangxi. Due to the fast economic development; its urban area needs to expand with new road networks, improved and safer public transport services, improved non-motorized transport and more efficient multimodal interchange of transport to alleviate existing problems caused by overcrowded urban population. Hence, the Ji'an Municipal Government has proposed the new Western City Development of Jizhou District, with a planned new city area of 52 Km^2 and a projected population of 276000 by 2020 and an ultimate population of 300000. Currently the Jizhou District has a land area of 425 Km^2 and a population of 343200. The JSTDP is located in the new city development area and includes the following four components (Figure 2):

- The development of a 6.94 Km bus rapid transit (BRT) corridor along Jinggangshan Road with 15 stations, as well as the improvement of the station square at the existing Ji'an Railway Station;
- Rehabilitation of 8.02 Km of Yudai River (5.3 Km) and its tributary (2.72 Km);
- Construction of five urban roads totalling 19.33 Km in the Western City Development Area and traffic management improvement through the provision of coordinated signal system, central control system and traffic information collection system; and
- Capacity building and institutional strengthening.

With the exception of the capacity building and institutional strengthening, the other three components require designing and planning before construction. Transport system design requires careful consideration of local climate conditions to prevent any disastrous damage to the system from climate hazard. Climate change has the potential to alter the climate condition; hence this study is focused on the climate change impact on the sensitive project components to the climate and the implication for the design process for the Yudai River rehabilitation and five new road development components.

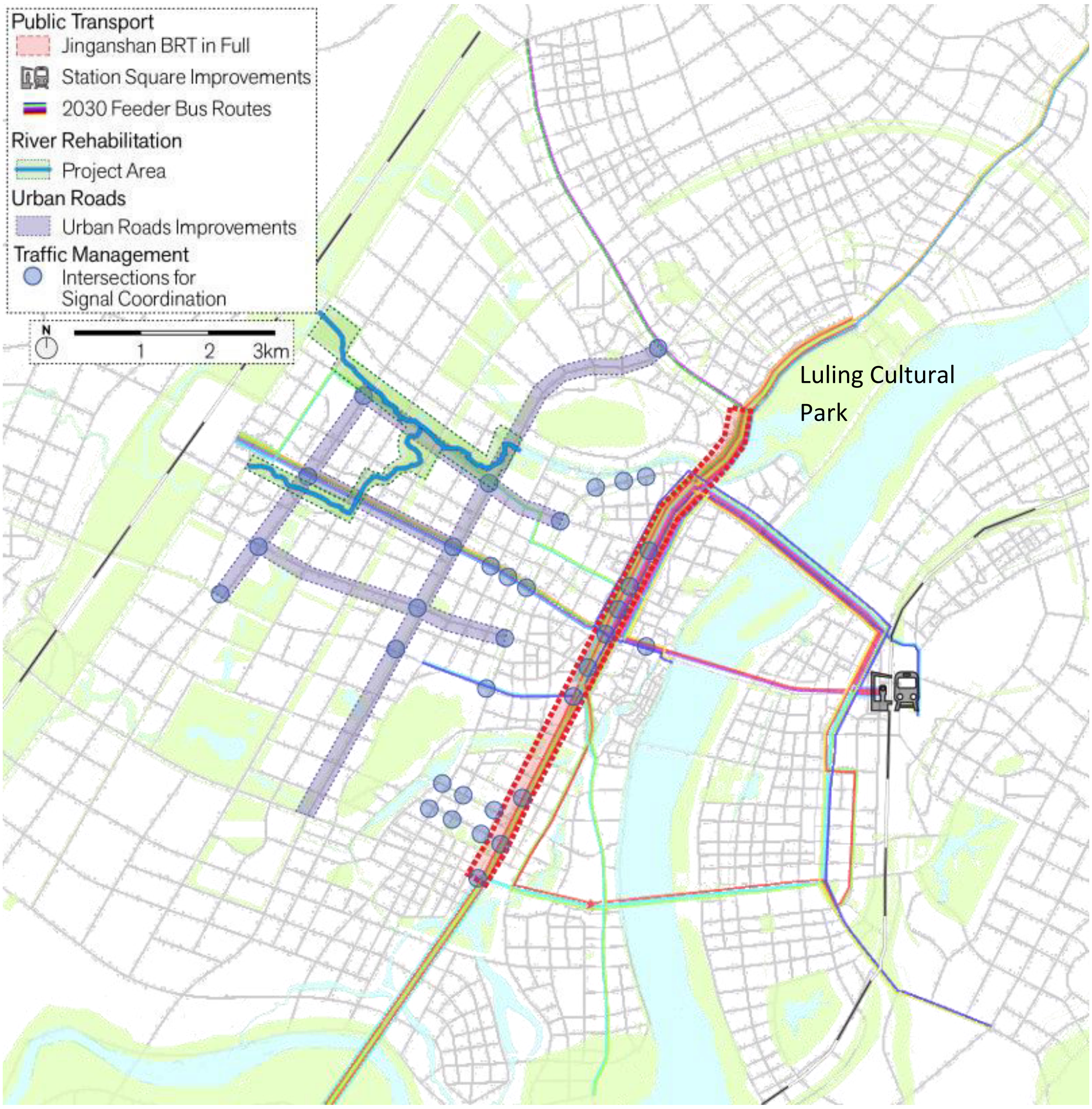

Figure 2: Location of the project components *(source: ADB)*

1.2 Potential risks of climate change to the project

Transport is vulnerable to climate variability and change. Although most climate factors can influence a transport system, for systems located at inland regions the major road damages are sourced from temperature and precipitation. The influence of these two factors on a transport system is to a large degree manifested by their extremes and aftermath. In terms of temperature, the high temperature caused extreme heat places stress on road infrastructure; softens the asphalt causing traffic rutting and potentially resulting in cracking. Extreme heat can also stress the steel in bridges through thermal expansion and movement of bridge joints. Extremely low temperature can cause fatigue and thermal cracking of the pavement. A wide range of temperatures (the difference between the maximum and the minimum temperature) will make asphalt binders difficult to span accordingly. In terms of precipitation, a torrential rain can lead to urban waterlogging if the drainage system has inadequate capacity. Flood resulted from torrential or heavy rainfall can cause severe water damage to roads, including collapse of the slope bed; damage to the subgrade, road surface, and key infrastructure components such as bridges; and damage due to landslide and debris flow etc.

The latest climate science points to an increasingly rapid pace of climate change over the forthcoming decades. Such change will likely alter the long term climatic averages and, in particular, the frequency and severity of extreme weather events. Hence the heat extremes and extreme rainfall, as well as floods are likely to become more intense and more frequent during this century.

The Ji-Tai plain has relative low altitude, and is historically threatened by river flooding from the Gan River. In addition, the JSTDP is built on low-lying farmland along the Yudai River in the western side of Jizhou, hence is under the risk of waterlogging from torrential rain. As most urban flooding in Ji'an is caused by rainfall; within the context of this study, potential changes in rainfall, including changes in its variability, is of critical importance to the long term sustainability of the JSTDP. As indicated in the EIA report (ADB, 2014) detailed design of project components sensitive to the flood, and the flood control capacity of the Yudai River, will need to take account of potential changes to accommodate the climate change impact consequences. The temperature of Ji'an is characterised as mild sub-tropical climatology. The change in temperature is not expected to have major impact on the project. Nevertheless, the climate change impact on temperature related factors is also analysed in this study.

1.3 Purpose and scope of this study

This study aims to provide an assessment of potential risks posed by climate change to the design of the climate sensitive components of the JSTDP, and identify options to manage such risks by proposing and analysing a range of adaptive measures.

Climate risk assessment will consider changes in temperature and rainfall based on outputs from the latest climate modelling experiments. Consideration of climate risk management options will include both "hard" measures entailing possible adjustment in design specifications, as well as "soft" options of ecological, governance or an institutional learning nature.

The overall objective of the climate change V&A assessment is to minimize the road damage and disruption in road use due to climate change impact. A scoping exercise was carried out to identify the vulnerability of the project to climate change impact. For the JSTDP, the temperature and rainfall sensitive project components includes road subgrade, pavement, bridge structures, slope protection and drainage system. The current design criteria are based on historical data and do not take account of changes in key hydro-met parameters under a changing climate.

Because the focus of this study is on the project vulnerability to changes in temperature and rainfall and its extremes, the required information to support this climate change impact assessment is historical observed temperature and rainfall at appropriate spatial and temporal scale, as well as the future climate change projections based on the latest scientific findings. Section 2 below will describe the methodology underlying the climate risk assessments. Details on the baseline and scenario datasets used for climate impacts assessment are provided in Section 3. Section 4 presents the impacts of climate change for the various components of the proposed project and their implications for the design, construction and operation of the project. Two future timeslice, i.e., 2050 and 2100, were used to illustrate the impact consequences. Possible adaptation options to manage climate risks within the context of the project, as well as a preliminary assessment of them, are discussed in Section 5. The report concludes with a set of recommendations on the design, construction and operation of the proposed project.

2. Methodology

A risk is the product of the interaction between hazards, exposure and vulnerability. In this study, hazard is used to denote the threat from climate factors of temperature and rainfall, their extremes and aftermath. Exposure is refer to the presence of infrastructure and other assets related to a transport system that could be adversely affected when hazard happens and which, thereby, are subject to potential future harm, loss, or damage. For this project, the exposure is also related to the closeness of a low lying flood prone area to a major river (the Gan River). Vulnerability is defined generally as the susceptibility to be adversely affected. The vulnerability can be either physical or socio-economic. For example for this project, the vulnerability may come from the inadequate capacity of the project for future flood protection, or the possible economic constraints of building a comprehensive flood protection mechanism for the changing climate. This section discusses the method of analysis the climate factors that may pose threat to the JSTDP based on their historical observation and future projections under climate change.

2.1 Overall approach

The first step in climate change impact assessment is the construction of the future climate change scenarios. The construction of a climate change scenario involves the development of the baseline climate condition and the future climate change projections. Depending on the assessment need, spatial and/or site-specific climate change scenarios are required for impact studies. In this study, the baseline spatial climatology for the project areas was derived from the WorldCLIM database (http://www.worldclim.org). The baseline site-specific climate condition was obtained from station based observed data.

The future climate change is subject to considerable uncertainty. One important aspect in climate change V&A assessment is to comprehend such an uncertainty range in decision making and policy planning process. Within this context, any climate change scenario constructed on single Greenhouse Gas (GHG) emission rate and/or individual GCM outputs is generally considered inappropriate for V&A assessment purposes, because it cannot provide information of the uncertainty range associated with its projection. In this study, to reflect the uncertainties in future GHG emission rates and in the climate sensitivity, a combination of different GHG Representative Concentration Pathways (RCPs) and climate sensitivities is used to characterise the future climate change scenario with associated uncertainty range. RCP6.0 with mid-climate sensitivity represents a middle range future global change scenario, which was used as an indicator of the median scenario projection of the future global change, while RCP4.5 with low-climate sensitivity and RCP8.5 with high-climate sensitivity was used as an indicator of the corresponding low and high bound of the uncertainty range (Table 1). Another important uncertainty in climate change scenario generation is the difference in different GCM simulations. To account for such an uncertainty in V&A assessment, a pattern scaling method was adopted and applied to wide range of GCMs to build a model ensemble. The average of models' simulation of changes for a climate variable is normally used to capture the middle conditions, as that the average often agrees better with observed climate than any individual model estimates (Reichler and Kim 2008). In this study however, the 50 percentile of the GCM model ensemble was used in order to prevent the influence of huge outliers in some GCM simulation on the final change projection values.

The method was thus termed as 'ensemble based pattern scaling'. Details of the method as well as the steps of constructing the future climate change scenario can be found in Appendix 1, while Appendix 2 lists the 40 IPCC AR5 GCMs used for model ensemble.

Table 1: Three climate projections and their input conditions represent the uncertainty ranges

Climate projection	Representative Concentration Pathways	Climate sensitivity
Median scenario	RCP6.0	Mid
Low scenario	RCP4.5	Low
High scenario	RCP8.5	High

2.2 Spatial climate change scenario

Monthly and seasonal climate change impact was assessed spatially over the project areas. The baseline climatology for the project areas was obtained from the WorldCLIM database with a spatial resolution of about 1 Km (http://www.worldclim.org). In generating the climate change scenario for the project areas, the simulation results from 40 GCMs that are assessed in the IPCC AR5 were used (Appendix 2). All 40 models have their monthly simulation results available.

2.3 Site specific climate change scenario

Besides the spatial monthly change projections, site specific climate change scenarios with finer temporal scale are usually required for impact assessment. The site specific temperature change scenario was constructed by perturbing the station observed daily data using the normalised GCM pattern value from the GCM grid where the climate station is located. In this study, all observation data from a station was used to represent the baseline climate condition for the site.

For site specific extreme value analysis, we first chose an intensity value (such as 1:20 year maximum daily precipitation) and then selected its normalised pattern value from the GCM gird where the site is located. The value is then applied to the same precipitation intensity that derived from the observed historical data to generate the future change scenarios.

In the following two sections, the method described above is adopted to generate the change projections for climate variables that may become hazardous to the proposed project. Rainfall and temperature data were collected for 4 stations around the project area. Table 2 lists the information for the four stations. The location of the stations can be found in

Table 2: Location information of the meteorological stations

Station Name	Longitude (°)	Latitude (°)	Altitude (m)	Observation Period
Ji'an	114.92	27.05	71.2	1951-2013
Ganzhou	115.00	25.87	137.5	1951-2013
Jingangshan	114.17	26.58	843.0	1999-2013
Lianhua	113.95	27.13	181.4	2006-2013

Appendix 4 (Figure A4-1). The temperature related climate variables were analysed for Ji'an only, as its impact is only site-specific. With regard to rainfall, of the 4 stations, Ji'an is the local station; Jinggangshan and Lianhua are located in the west of the city at the centre of the torrential rain along the Luoxiao Mountains, hence represent the upper stream hill and mountainous conditions of the Ji'an city catchment. Ganzhou represents the upper-reach condition of the Gan River. Unfortunately, both Jingganshan and Lianhua have relative short periods of observation, making them unsuitable for baseline and climate change analysis. In this study, only Ji'an and Ganzhou data were used for rainfall related climate variable analysis.

3. Climate observation and change projections

3.1 Observational temperature data and their future projections

The temperature related climate variables that have impacts on transport systems include the mean, minimum and maximum temperature; the extreme maximum temperature and related heat waves; and the temperature change range (the difference between minimum and maximum temperature). Appendix 3 lists the temperature related climate variables and their projected future changes in 2050 and 2100 for Ji'an. The baseline annual average mean, minimum and maximum temperatures of Ji'an are 18.5, 15.1 and 23.1°C respectively. By 2050, the median projection was 19.8°C, indicating an increase of 1.3°C, with an uncertainty range of change increase between 0.9 to 2.6°C. By 2100, the median temperature projection is 21.0°C, an increase of 2.5°C, with an uncertainty range of 1.3 to 6°C.

It is likely that the extreme maximum temperature will become more intense. The current 1:50 year observed annual maximum daily temperature is 40.8°C, whilst the event of the same intensity will likely become 41.9°C (1.1°C increase) by 2050 and 43.0°C (2.2°C increase) by 2100, and the corresponding uncertainty ranges are 0.8 to 2.4°C and 1.1 to 5.4°C for 2050 and 2100 respectively. Heat wave thus will likely become more intensified and frequent, as indicated by the 7 day average maximum temperature for Ji'an, but is still under 45°C for the high scenario by the end of this century.

The minimum temperature, both average and extreme low, will likely to increase, which indicates a reduced frost period and snow falls in the area. Given the likelihood of increase of both the daily maximum and minimum temperature, the difference between them may not change or may be slightly reduced: the current difference of the 1:50 year annual daily maximum and minimum temperature is 48.3°C i.e., the difference between 40.8°C and -

7.5°C; the changes of median projection for 2050 and 2100 are 48.2°C and 48.0°C respectively.

3.2 Observational rainfall data and their future projections

The rainfall related climate variables and their aftermath that could become hazardous for the project including torrential rain and flood. No major landslide or debris flow has been observed in Jizhou. Details of the observed rainfall data and their future change projections are demonstrated in Appendix 4. The key findings are discussed below:

Baseline

1) Jizhou district has relatively lower rainfall than its surrounding areas. However, due to its low-lying location, the heavy rainfall from the upper reach of the Gan River leads to a higher flood risk in Jizhou than its surrounding area. The large rainfall in the north and northeast of the province contributes significant runoff to the Gan River, as well as the Luoxiao Mountains in the west which is the centre of torrential rain during the rainy season.
2) The normal rainfall of the rainy season is relatively evenly distributed inside Ji'an city at around 700 mm (Figure A4-4), except for the areas of Jiangganshan in the southwest and the high hilly areas in the east side of the Gan River, which all have relative larger rainfall than the rest area of Ji'an.
3) Derived from the observation of 1951 to 2013, the annual average precipitation at Ji'an is 1488 mm with a coefficient of variation (C_v) of 0.19. Year 2010 recorded the maximum annual rainfall of 2209 mm, while the minimum was only 963 mm in 1963, which is less than half of the maximum. At the upper reach of the Gan River, Ganzhou has an annual average of 1437 mm and C_v of 0.20.
4) For Ji'an, the total average rainfall during the rainy season is 677 mm, which accounts for 45% of annual total. In general, May is the wettest month in a year but most of the severe floods occur in June.

Future projection

1) Applying the ensemble based pattern scaling method to the project area, the median climate change projection indicates that the normal rainfall change during the rainy season is likely to be noticeable. For Jiangxi, the median projection of the annual average precipitation is likely an increase of 1.5 to 4.5% by 2050 and 3 to 9% by 2100 (Figure A4-3). Ji'an has a slightly higher increase rate than the province average, which is 3-4.5% and 6-9% by 2050 and 2100 respectively (Figure A4-4).
2) For both Ji'an and Ganzhou stations, monthly rainfall is projected to increase for all months, though this is not significant for dry seasons (Figure A4-6). The rainy season has more obvious rainfall increase but accompanied with larger uncertainties. The uncertainty range skews quite heavily to the upper bound of the projection, which implies more likelihood of higher risk of climate change.

Extreme rainfall and its projection

According to the extreme value theorem, for normalized maxima (minima) of a sequence of independent and identically distributed random variables such as annual daily maximum rainfall, the generalized extreme value (GEV) distribution is the only possible limit distribution, and it is often used as an approximation to model the maxima (minima) of long (finite) sequences of random variables. In this study, the GEV distribution was applied to the daily observation to investigate extreme rainfall and their future changes. A detailed method description and analysis process can be found from Ye and Li (2011).

Table 3 lists for both stations the baseline intensity and frequency and the future changes of annual maximum rainfall in 2050 and 2100. As shown in Table 3, the current 1:50 year event of the annual maximum 10 day rainfall is 395.34 mm for Ji'an. The median change projection of such an event is 427.58 mm by 2050 and 458.53 mm by 2100, which represent 8% and 16% increase in rain intensity. The uncertainty range of the projection is 6% to 17% for 2050 and 8% to 39% for 2100. Another findings is that the climate change impact is likely to be larger when the extreme rainfall event become more intense: for 2050 at Ji'an, the annual maximum daily rainfall change from median scenario for 1:5 year event is only 5%, i.e., (127.55-121.54)/121.54; but it becomes 8.2%, i.e., (232.28-214.73)/214.73 for 1:50 year event. This is also evident from the enlarged gap between the baseline GEV distribution and its future projections (Figure A4-4 to A4-7).

Similarly, for Ganzhou its current 1:50 year event of the annual maximum 30 day rainfall is 569.65 mm. The median scenario projection of such an event increases to 615.39 and 659.45 mm by2050 and 2100 respectively, which are also 8% and 16% increases in rain intensity, accompanied with a similar uncertainty range of 6% to 17% for 2050 and 8% to 39% for 2100.

In summary, average rainfall is projected to increase gradually for the project area. The average increase is likely to be noticeable by 2050 and beyond, particularly for the rainy season. In contrast to the relatively small increase in average rainfall, the extreme rainfall intensity and/or frequency increase is significant. Such impacts will very likely result in an increased flood risk for the project area in the future.

Table 3: The GEV results of annual maximum rainfall and its future projections

Return period (years)	Annual maximum rainfall (mm)						
	Baseline	2050 scenario			2100 scenario		
		Low	Median	High	Low	Median	High
Ji'an: 1 day rainfall event							
2	88.92	91.47	92.40	95.95	92.37	95.61	104.73
5	121.54	125.93	127.55	133.89	127.49	133.26	149.60
10	146.77	153.02	155.32	164.40	155.25	163.50	186.95
20	174.12	182.75	185.94	198.50	185.83	197.26	229.86
50	214.73	227.55	232.28	250.94	232.13	249.10	297.94
100	249.55	266.51	272.78	297.47	272.57	295.03	360.18
Ji'an: 10 day rainfall event							
50	395.34	418.88	427.58	461.92	427.30	458.53	550.08
100	431.76	461.10	471.93	514.77	471.58	510.53	626.61
Ganzhou: 30 day rainfall event							
50	569.65	603.05	615.39	664.29	614.99	659.45	791.61
100	607.90	648.60	663.63	723.30	663.14	717.38	882.81

3.3 Climate change impact on the JSTDP and the implication to the project design

The climate change information needs to be related to the project components that are sensitive to the climate, in order to support the vulnerability assessment and adaptation options identified. In the context of this project, the target sensitive project components include:

- Change in maximum temperature of the pavement;
- Change in minimum temperature of the pavement;
- Change in the range of temperature of the pavement;
- The change of 1:2 year rainfall events, which is used in design for the storm water drainage for the road networks;
- The change of 1:20, 1:50 year 24 hour heavy rainfall, which is used for urban flood water drain system design; and
- The change of 1:50 year flood water level; which is used for rehabilitation of Yudai River flood protection design.

The pavement temperature has a linear relationship with the air temperature, so the increase of air temperature will lead to increase of pavement temperature. The baseline annual average air temperature of Ji'an is relatively mild. An increase of 1.3°C by 2050 or 2.5°C by 2100 will not cause significant impact to the transport system. The upper bound change from the high scenario projection of the annual maximum daily temperature may require some attention. Under such change scenario, the 1:20 maximum daily temperature is 42.8°C and 45.9°C in 2050 and 2100 respectively, which implies more intense and longer lasting heat waves, but the change temperature is generally under 50°C. The increase in minimum temperature and the reduction of the temperature range will be beneficial to the transport system.

Compared to the potential impact from temperature, the heavy rainfall and it triggered flood pose a much greater risk to road systems, therefore are the major climate induced hazards for the JSTDP. To support criteria adjustment in project design, Table 3 lists the relevant heavy rainfall current observation and their future change projections. As shown in Table 3, the baseline 1:2 year annual maximum rainfall event intensity is 88.92 mm. The median projection of such event in 2050 is 92.40 mm, with an uncertainty range of 91.47 mm to 95.95 mm. The storm water drain system design should take such changes into consideration. If the current drain design criteria become inadequate for 2050 median projection, it is recommended to expend the capacity to accommodate the additional storm and flood water. For drain system components that will become difficult to repair or replace, it would be even more appropriate to use the high scenario change projections as the base for drainage design.

Due to its great damage potential, flood has always been the major consideration in transport system design in Jiangxi. For the purpose of assessing climate change impact on flood, it is necessary to develop a hydrologic model to reveal the relationship between rainfall and flood. The composition of flood water of the Gan River in Ji'an is complicated by its tributaries in its middle reach. The major tributaries inside Ji'an section include the Huolushui River, Gu River, Shushui River, Suichuan River. The combined catchment area from these tributaries is as large as 19323 Km^2. In addition, the human activities in the area have significantly altered the natural river flows. Inside the Ji'an City, there are 5 large reservoirs and 36 middle sized ones, and more than 1000 small dam and man-made water storage ponds (Liu, 2004). Though the small and middle size reservoirs may not have much influence on the natural river flow, the large reservoirs have significantly affected the river flow at its downstream. Wan'an reservoir is the largest hydraulic engineering project in the Gan River upper Ji'an. The height of its dam is 58 metres with a water catchment area of 36900 Km^2. The reservoir has completely altered the downstream river flow from its natural. Thus it is very difficult to determine the flood water level at Ji'an just based on rainfall from its catchments (Mao and Wang, 2002). It appears inappropriate to apply any physical based and/or sophisticated conceptual hydrologic model to the Ji'an catchment, given its complex hydrologic condition. A statistical approach is thus adopted based on available hydro-met observations. In addition to the daily observed rainfall data of Ji'an and Ganzhou, an observed 30 years annual maximum flood height data from 1983 to 2012 was collected from the Hydrology Institute for Ji'an Station. A regression model was developed as follow:

$$Y = 44.1627 + 0.01018X_1 + 0.00924X_2 \tag{1}$$

where: Y is the annual peak flow height (masl); X_1 is the 10 day total rainfall of Ji'an correspond in time to the peak flow height, i.e., the 10 day rainfall immediately preceding to the peak flow date, and X_2 is the corresponding 30 day total rainfall in Ganzhou. Appendix 5 gives the details of the statistical model development. The model has a reasonable performance in simulating the annual peak flow height as illustrated in Figure 3. The correlation coefficiency (R^2) is 0.58 with the standard error of 1.1 m. Thus for a given annual peak flow height prediction, a confidence interval of ±0.34 metre is expected based on the 95% confidence level. The model slightly over-predicts smaller floods and under-predicts larger floods.

With the developed rainfall—flow height model, a climate change impact assessment on river flood height at Ji'an can then be carried out. The detailed steps of calculating the flow height and their future projected changes are demonstrated in Appendix 6,

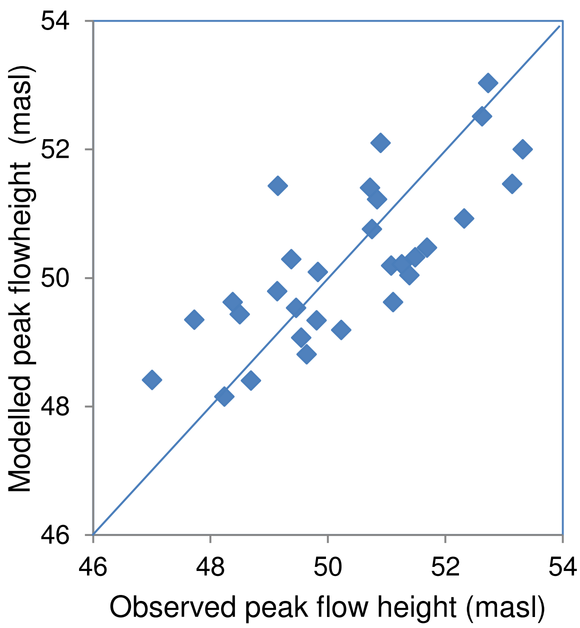

Figure 3: Performance of the statistical model in simulating the observed annual peak flow height.

Because of the linear relationship of extreme flow height to extreme rainfall (Equation 1), to what extent that climate change will impact on a flood depends on the magnitude of the flood event; the larger the flood event (or the higher the maximum flow height), the more impact the climate change may bring in. For the 30 year record, the largest flow height happens in 2010 with a flood water height being 53.14 masl. This particular event was linked to the 1:15 year heavy 10 day rainfall event of Ji'an (331.9 mm) and a normal 30 day rainfall event in Ganzhou (213.1 mm). By 2050 based on the extreme rainfall changes for Ji'an and Ganzhou and derived from Equation 1, an increase of 0.45 metre to 53.59 masl is projected by the median climate change scenario, with an uncertainty range of increase between 0.33 and 0.91 metre. The low and median scenario change is similar to the model's confidence interval of ±0.34 m at 95% confidence level, but the high scenario projection is clearly beyond the interval range. Towards the end of this century, an increase of 0.85 metre is projected by the median scenario, but with an even higher uncertainty range of 0.45 to 2.02 metre. Even with high uncertainty, by 2100 the climate change impact projections are significant larger than the model's confidence interval at 95% confidence level.

From a conservative viewpoint, a potential additional 0.45 metre flood height is still a significant risk increase to a transport system. Careful review of current flood protection design is necessary to analyse any capacity insufficiency and identify any adaptation options to alleviate such negative impact. The urban flood in Ji'an can be distinguished into two basic types:

- The flood from the Gan River;
- The urban waterlogging due to localized torrential rainfall.

In the following part, the climate change impact on the types of flood is analysed individually.

Climate change impact on the Gan River flood and its implication to project design

The JSTDP area is located in low-lying farmland and is fundamentally depends on the levee and dyke along the banks of the Gan River for protection during flood periods. The JSTDP flood protection design is based on 1:50 year flood event. The Ji'an Government has a mid-term objective to strengthen the dykes to protect the urban area from 1:50 year flood and a long term objective of completion of a plan to protect the urban area from 1:100 year flood. The enhancement of the Gan River dykes for flood protection is one of the top priorities in Ji'an government Flood Protection Plan (Ji'an Government, 2014 (1)). The current 1:50 year flood height at Ji'an is 54.41 masl (Tang and Deng, 2008). A 0.9 metre increase as projected by high climate change scenario by 2050 will make the intensity to 55.31 metre.

According to the information provided by SUCDRI, the new road network design criteria is 1:50 year flood level, but the actual height is 59 masl for most parts of the road surface due to other top-geographic requirements. The actual design standard is sufficiently higher than the climate change induced 1:50 year flood height increase. It may become inadequate only by the end of this century for high scenario, when the intensity change may be 2 metres higher. Additional adaptation measures, discussed in the next section, will be needed to further strengthen the resilience of the project against even more severe climate change impact in future.

Climate change impact on waterlogging and its implication for project design

Urban flood of waterlogging is caused by heavy rainfall in the urban catchment. In this project, all storm–water is designed to drain naturally to the Gan River by its own gravity. According to the Ji'an Government Flood Protection Plan, the drainage system must meet the requirement of completely draining the storm water from 1:10 year 24h rainfall event in one day (Ji'an Government, 2014(1)).

A drainage system capacity is commonly calculated by the waterlogging drainage module, as described as:

$$M = \frac{R_t}{3.6Tt}$$

where: M is the waterlogging drainage module ($m^3/s/km^2$);
R_t is the effective rainfall (mm)
T is designed drain duration (days)
t is the total drain time per day (hour).

From the "Jianxi Torrential Rainfall and Flood Manual", the point-to-area rainfall coefficient of Ji'an is 0.995, and the effective rainfall coefficient for urban area is 0.85. Take T as 1 day and t as 24 hours, the water logging drainage modules for the 1:10 year daily maximum rainfall event was calculated as in Table 4. According to Table 4, the waterlogging drainage module may be required to increase by 6% in 2050 and 11% by 2100, in order to meet the Ji'an government flood protection plan.

Climate change impact on urban flood due to high flood water level and waterlogging

As discussed previously, the drainage system is designed to drain storm water to the Gan River outfalls or outlets driven by water gravity. Such flow condition cannot be satisfied when the water level in the Gan River becomes higher than the outfalls or outlets. This may not be an issue if torrential rain does not occur at the same time in the urban area. The most severe flood occurs when the flood of the Gan River coincides with torrential rain in the urban area. Out of the 10 major floods since 1950 to early 2000s (i.e., 1959, 1961, 1962, 1964, 1968, 1982, 1994, 1998, 2002, 2010), three (1962, 1998 and 2010) can be classified as this type of flood. Under such hydrologic conditions, the storm water cannot be drained to the Gan River due to the backwater effects. The urban area may undergo a period of waterlogging, and may potentially affect the sensitive components of the proposed project.

Because the actual height is 59 masl for most parts of the road surface due to other top-geographic requirements (per comm. SUCDRI), the occurrence of flood water overtopping the new road network is unlikely even under high scenario climate change conditions (the current 1:200 year flood water level is 55.42 masl). The main function of the Yudai River area is for recreation. Hence the main design objective will be to protect river bed from flood and prevent soil erosion, which have all been incorporated in the Yudai River Rehabilitation design. Given climate change impact caused increase of both Gan River flood and torrential rain in Ji'an; it is likely that waterlogging may still occur for the Yudai River Rehabilitation area if the two weather events coincide together, but huge cost of damage is unlikely from the inundation of the green field of the recreation area.

Table 4: Ji'an water logging drainage modulus for 1:10 year daily rainfall

Waterlogging drainage modulus ($m^3/s/km^2$)						
Baseline	2050 scenario			2100 scenario		
	Low	Median	High	Low	Median	High
1.43	1.49	1.51	1.60	1.51	1.59	1.82

4. The adaptation options

As discussed previously, flood damage is the major climate risk to the JSTDP. To avoid costly repairing and/or replacement in the future, the sensitive exposure components to flood in the JSTDP should take the climate change impact induced additional flood risk into project design and construction consideration. In the following part, the adaptation options are discussed in three general categories.

4.1 "Hard" options: adjustments to design of relevant project component(s)

Given the safety factor adopted in the project design, together with the Ji'an Government plan of raising the Gan River dykes to protect the urban centre from 1:100 year flood, the current road and bridge design standards are likely to be adequate by the middle of this century. After 2050, further rising of the Gan River dykes may be required. However even the flood water overtopping the dyke, the damage to the new road network and the Yudai River area will be limited due to the relatively higher ground of the road system. On the other hand, the drainage system may need to be adjusted to a higher design standard. A conservative 6% increment of the waterlogging drainage module is recommended, and an 8-10% increment for the critical components would be more appropriate, given the difficulty of repair and replacement of urban drainage system in the future. The induced waterlogging may become even severer under climate change, but the risk of flood damage to the project components will be limited, due to the height of road network and relative low lying area surrounding them. The BRT system is built on existing roads, so its flood protection design needs to be considered carefully with the existing road system. The green space of the Luling Cultural Park downstream of the JSTDP could also help reduce the waterlogging in the project area. Therefore another adaptation could be built on the green space development, based on detailed digital elevation model. However, waterlogging for a substantially long time may still have the potential of damaging the infrastructure of the project components, additional water drainage system--such as flood water pump station--may be considered in the future as an alternative adaptation options. Clearly, at what stage the additional adaptation options may be implemented depends on the financial consideration and future climate change trends. The Ji'an Government has a long term plan to enhance the dykes of the Gan River along the Ji'an to protect the urban area against 1:200 year flood event. The implementation of such plan will no doubt substantially benefit the proposed project against the climate change impact.

4.2 "Soft" measures: ecological solutions, institutional and technical capacity building to enhance risk awareness and ability for ongoing risk assessment &

management, knowledge management to improve risk assessment as new information emerges

Human activity has considerably interfered with both the Gan River flow and other river flows in Ji'an (including Luohushui, the upper stream of Yudai River). It makes the flood prediction a complex task on the one hand, but provides good opportunity as an effective adaptation to alleviate the damage from flood on the other. As mentioned previously, in general, flood from either Gan River or rivers inside Ji'an only cause minor damage. The most severe urban flood is caused by the coincidence of flood of the Gan River and torrential rain in the urban area, i.e., all river systems has high flood levels. In such a case, the hydraulic facilities inside both river systems could provide effective adaptive capacity against flooding in the Ji'an city. For example, the Wan'an Reservoir has strong flood water storage capacity and can reduce peak flood height by 0.5-0.7metre for Ji'an (Li et al. 2007). The Wan'an Reservoir has not yet operated at its full capacity, so it is expected more peak flood water adjustment can be achieved by Wan'an Reservoir in the future. The numerous small and middle sized dams in Ji'an also have the potential to adjust the intensity and duration of flood. These existing hydraulic facilities are; however, heavily depend on accurate and real-time hydro-met information in order to operate in synergy to optimise their capacity against flood. The Ji'an Government has prioritised the task of the development of a comprehensive hydro-met prediction system in its 12th five year development plan (Ji'an Government, 2014 (2)).

4.3 Assessment of climate risk management options

Risk assessment encounters difficulties in estimating the likelihood and magnitude of extreme events and their impacts. Management of the risk associated with climate extremes, extreme impacts and disasters benefits from an integrated systems approach; as opposed to separately managing individual types of risk, or risk in particular locations. The above adaptations are discussed against their targeted vulnerable components. However, one

Table 5: Summary of adaptation options

Adaptation options	Cost	Benefit	Comments
Operation of Wan'an reservoir at full capacity for flood control	Depends on the re-settlement	Current operation already can reduce the peak flood height by 0.5 m. More flood height reduction can be achieved when the reservoir on full operation	The reservoir is not operated at its full capacity due to a historical re-settlement issue.
Increase drainage capacity under the new road netwok	~CNY10million	Reduce the risk of waterlogging in the project area	Cost is approximation. More accurate value will be available when detailed design starts.
Addition of auxiliary pumps for water removal	unknown	Reduce the risk of waterlogging in the project area	This adaptation is not in the scope of this project, so no plan yet.
Cost of raising levees	Will be implemented by Ji'an Government	Reduce the flood risk from the Gan RIver	This option is already in Ji'an government hydraulic plan, and will add no cost to the project

adaptation will not only strengthen the resilience of the target component, but will also benefit all components across the project.

Of the adaptations discussed above, the “Hard” options will likely incur more financial investment. Careful review of the current design, if this has not already done, is required to examine whether the future climate change impact can be covered. If not, a cost-benefit analysis may be required to determine the best adaptation options. The BRT system is built on existing road and any “Hard” options will be constrained by the existing road conditions. The new road system and the Yudai River rehabilitation have a range of adaptation options to consider but the most important one is the review of the adequacy of the drainage system design for the new roads. The Yudai River rehabilitation design provides a good opportunity to re-design the river channels to satisfy the future flood conditions. The “Hard” adaptation review should be as comprehensive as possible. Some adaptation measures may be beyond a project scope, but may bring in substantial benefit to the project such as the Ji’an Government Flood Protection Plan for the JSTDP.

It should also be recognised that the “Soft” options could be much cost effective and equally efficient. The hydraulic facilities in Ji’an have great potential to alleviate the flood risk. The Wan’an Reservoir alone has the potential to reduce the flood height in Ji’an by a half metre if it is operated under on-time hydro-met information during flooding. The ecosystem restoration in the Ji’an will have good potential to prevent river bank collapse, debris flow and other hazards to road systems, hence reduce damage. It has been found that great resilience can also be reached by management options through capacity building and raising awareness; so a comprehensive review of the current institutional capacity and management structure may be a good start to achieve both effective and efficient adaption for climate change impact. Table 5 lists a summary of the adaptations with estimated cost/benefit analysis.

5. Conclusion

The objective of the Jiangxi Ji’an Urban Transport Development Project is to facilitate the socio-economic development in the Western City Development Area of Ji’an City and benefit a future population of 300,000 in the area. Climate change may have significant impact on the future use and maintenance of the project. Immediate actions should be taken to include effective and efficient adaptations as an integral part of project design and construction to alleviate any negative climate change impact consequences. Incorporating effective adaptation measures in project design and construction will prevent costly infrastructure remedy and/or re-construction and warrant the long term economic benefit for which the project is designed.

This report produces quantitative climate change information relevant to the project by making use of the pattern scaling based GCM ensemble method. The advantage of the method is that it not only takes the key uncertainties in climate change science into future projection consideration, but also treats these key uncertainties independently. Therefore climate change projections and their associated uncertainty range can be produced consistently through combination of the different scenarios. A quantitative impact assessment can then be conducted by building the risk profile for the key vulnerable components, and targeted adaptation options can subsequently be identified and evaluated.

As revealed by the study, the biggest climate related risk to the project is river flood and urban flood caused by heavy rainfall. The climate change scenario analysis indicated an enhanced risk profile for both river and urban floods. Several adaptation options were identified and discussed.

This study was constrained by a number of limitations:

- The river flow of the Gan River up Ji'an comes mainly comes three areas:
    1. Western Luoxiao Mountain Area;
    2. Area surrounding Wan'an Reservoir; and
    3. Area in the southeast beyond Wan'an Reservoir.

  Statistically, Mao and Wang (2002) found that the flood in Ji'an is correlated well with the previous 24h rainfall in Area 1; previous 24-48h rainfall in Area 2; and previous 48-72h rainfall in Area 3. In this report, long term rainfall data was not found for Areas 1 and 3, so that the rainfall - flood height is built only on the daily rainfall of Ji'an and Ganzhou (Area 2). The statistical relationship could be improved if Areas 1 and 3 data becomes available.
- Given the size of the project area, it would be appropriate to use climate projections that have finer spatial and/or temporal resolutions, such as outputs of Regional Climate Models (RCMs). However, these data are either not accessible, or not available in sufficient numbers for model ensemble. Nevertheless, the V&A work presented based on the latest GCM outputs is still valid and may even be a better choice because of two reasons. Firstly, for V&A assessment work, the issue of most concern is the uncertainty range in association with the future climate projection. Whether the RCM could reduce the uncertainty range projected by GCM is still an open question. As concluded by Feng et al. (2011) in simulation of extreme climate events over China with different RCMs, even though several important extreme climate events of the 1990s were reproduced, the signals were weak. Secondly, the RCM is useful on local spatially scale climate change assessment with introduction of fine scale bio-physical dynamic processes, which are generally precluded in GCM models. The V&A assessment of JSTDP is focused predominately on site specific climate change impact consequence. Although the fine scale bio-physical dynamic processes may have some role to play at this site scale, the uncertainty is still dominated by the difference in climate model assumptions. Within this context, including more climate modelling outputs in climate change projection is more important than ensuring that fine scale dynamic processes are correctly represented in the modelling process.
- The rainfall - flood height relationship is built on daily rainfall observation of 08:00 to 08:00. For urban flood modelling and assessment normally requires sub-daily hydro-met observations, i.e., hourly time series data. Further study can be carried out when this information becomes available.
- The impact assessment was conducted based on available data. Though considered as adequate for this study, a properly developed impact model will better reveal the detailed relationship between heavy rainfall and the river flood and urban flood. For example, a time series river flow data would help in developing proper hydrologic and

hydraulic models so that the impact on flood due to changes in rainfall could be explored; a detailed digital elevation model (DEM) would help to develop flood area mapping to identify the most vulnerable area for effective adaptation action implementation.

- The adaptation options discussed were presented as initial recommendations. Although the median scenario may be used in supporting design adjustment or adaptation planning, some critical transport infrastructure may be required to sustain high climate risk; hence a projection developed on a higher change scenario may be needed.
- No economic data was available to investigate the cost-benefit of implementing such adaptation options. However, we recommend selection of appropriate adaptations and/or their combination to be considered in project design wherever it is feasible.

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Appendix 1: Climate change scenario generation

The uncertainties in climate change scenario generation

The future climate change projection includes uncertainties, particularly at the regional and local level. The major sources of uncertainties come from: 1) the difference of spatial change projections modelled by different GCMs; 2) the future Greenhouse Gas (GHG) emission rates; and 3) different GCM model parameterisation due to the unknown or not fully understood mechanism and feedbacks in the climate systems. A thoroughly studied uncertainty by scientific community is the difference in GCM model parameterisation, or the climate sensitivity. The climate sensitivity is conventionally defined as the equilibrium change in global mean surface temperature following a doubling of the atmospheric (equivalent) CO_2 concentration simulated by a GCM. It has been found that the uncertainty range is between 2.0°C to 4.5°C (Solomon et al., 2007).

To reflect the uncertainty of future GHG emission rates, a new process has been used for future global climate change projection since IPCC AR5. In this process, GHG emissions and socioeconomic scenarios are developed in parallel, building on different trajectories of radiative forcing over time to construct ***pathways*** (trajectories over time) of radiative forcing levels (or CO_2-equivalent concentrations) that are both ***representative*** of the emissions scenario literature and span a wide space of resulting GHG ***concentrations*** that lead to clearly distinguishable climate futures. These radiative forcing trajectories were thus termed "Representative Concentration Pathways" (RCPs). A RCP was simulated in an Integrated Assessment model to provide one internally consistent plausible pathway of GHG emissions and land use change that leads to the specific radiative forcing target. The full set of RCPs spans the complete range of integrated assessment literature on emissions pathways and the radiative forcing targets are distinct enough to result in clearly different climate signals.

In this study, three RCPs: RCP4.5, RCP6.0 and RCP8.5, is used to characterise the possible climate change scenario for the project area and uncertainty range. RCP6.0 with mid-climate sensitivity represents a GHG concentration reaching 850 ppm and stabilized after 2100, it is a middle range future change scenario. Similarly, RCP4.5 (650 ppm GHG and stabilized at 2100) with low-climate sensitivity and RCP8.5 (concentration larger than 1370 ppm at 2100 and still rising) with high-climate sensitivity represents the low and high bound of the uncertainty range of future global change scenarios as shown in Table 1. The three RCPs represent rising radiative forcing to 4.5, 6 and 8.5 W/m^2 by 2100 respectively.

The General Circulation Model (GCM) is the most reliable tool in generating the future climate change scenarios at large to global scale. However, given the current state of scientific understanding and limitations of GCMs in simulating the complex climate system, for any given region in the world, it is still not possible to single out a GCM that outperforms all other GCMs in future climate change projection. Future climate change projection based on the analysis of a large ensemble of GCM outputs is more appropriate than using any individual GCM outputs (Wilby et al. 2009). This is particularly important if such a projection is used for impact assessments; a large ensemble of GCM simulations can provide a reliable specification of the spread of possible regional changes by including samples covering the widest possible range modelling uncertainties (Murphy et al. 2004, Sortberg and Kvamsto 2006, Murphy et al. 2007, Räisänen 2007). A single GCM projection of future climate made with even the most sophisticated GCM can be of limited use for impact assessment as it lacks the ability to provide information on the range of uncertainties. Within an ensemble approach, provided the members of the ensemble are independent, a larger ensemble size could lead to a more reliable statistical result (Sterl et al. 2007). In this study, the 50 percentile value from the model ensemble sample was used in generating future climate change projections.

The pattern scaling method

The pattern-scaling method (Santer *et al*., 1990) is based on the theory that, firstly, a simple climate model can accurately represent the global responses of a GCM, even when the response is non-linear (Raper et al. 2001), and secondly, a wide range of climatic variables represented by a GCM are a linear function of the global annual mean temperature change represented by the same GCM at different spatial and/or temporal scales (Mitchell, 2003, Whetton et al. 2005). Constructing climate change scenarios using the pattern-scaling method requires the following information:

a) regional patterns of changes in climate (e.g. for precipitation) by specified timeframe (e.g. month) from GCM results, which are normalized to give a spatial pattern of change per degree of global-mean temperature change;
b) time-dependent projections of global-mean temperature change projected by a selected RCP under a selected “climate sensitivities”
c) baseline climate variables derived from observational records.

In generating a “time-slice” scenario for a future year, the normalised pattern (a) is scaled by a time dependent projection of global-mean temperature change (b). The resultant scenario of climate change is then used to perturb the underlying observed spatial climatology (c) to give a “new” climate for the year in question. In this way, the three key uncertainties – the GCM spatial patterns of change, the future GHG emission rates and the climate sensitivity – can be treated independently and combined flexibly and quickly to produce future climate scenarios (as per Wigley, 2003).

The pattern scaling method is also extended to analyse the climate change impact on climate variability, such as the extreme precipitation event. A general extreme value (GEV) function was applied to the daily precipitation data from historical observations and GCM outputs to derive precipitation intensity values. Similar to a normalised pattern for monthly precipitation, normalised patterns of a series of precipitation intensities, such as 1:20 year maximum daily precipitation, is calculated for a GCM following the steps discussed previously. In generating the normalised patterns, the GCM simulated period of 1975 to 2005 was used as GCM baseline.

Out of the 40 GCMs 22 have their daily simulation outputs publically available (see Appendix 2). For the GCM with available daily data, a linear regression method was used to process them in order to derive the normalised pattern for the precipitation intensity series. A more detail discussion of the extreme precipitation change scenario generation can be found from Ye and Li (2011).

Appendix 2: IPCC AR5 GCMs used in this scenario generation and their horizontal and vertical resolutions. Models with daily data available are used for extreme rainfall event scenario generation

Model label	Resolution (longitude°× latitude°)	Daily	Institution
ACCESS1.0	1.875×1.25	No	Commonwealth Scientific and Industrial Research Organisation/Bureau of Meteorology (CSIRO-BOM) Australia
ACCESS1.3	1.875×1.25	Yes	Commonwealth Scientific and Industrial Research Organisation/Bureau of Meteorology (CSIRO-BOM) Australia
BCC-CSM1.1	2.8125×2.8125	No	Beijing Climate Center (BCC) China
BCC-CSM1.1(m)	2.8125×2.8125	No	Beijing Climate Center (BCC) China
BNU-ESM	2.8125×2.8125	No	Beijing Normal University (BNU) China
CanESM2	2.8125×2.8125	Yes	Canadian Centre for Climate Modelling and Analysis (CCCma) Canada
CCSM4	1.25×0.9375	Yes	National Center for Atmospheric Research (NCAR) USA
CESM1(BGC)	1.25×0.9375	Yes	National Center for Atmospheric Research (NCAR) USA
CESM1(CAM5)	1.25×0.9375	No	National Center for Atmospheric Research (NCAR) USA
CMCC-CM	0.75×0.75	Yes	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) Italy
CMCC-CMS	1.875×1.875	Yes	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) Italy
CNRM-CM5	1.4×1.4	Yes	Centre National de Recherches Météorologiques (CNRM-CERFACS) France
CSIRO-Mk3.6.0	1.875×1.875	Yes	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australia
EC-EARTH	1.125×1.125	No	EC-EARTH consortium published at Irish Centre for High-End Computing (ICHEC) Netherlands/Ireland
FGOALS-g2	2.81x1.66	No	Institute of Atmospheric Physics, Chinese Academy of Sciences(LSAG-CESS) China
FGOALS-s2	2.81x1.66	No	Institute of Atmospheric Physics, Chinese Academy of Sciences(LSAG-IAP) China
GFDL-CM3	2.5 × 2.0	No	Geophysical Fluid Dynamics Laboratory (GFDL) USA
GFDL-ESM2G	2.5x2.0	Yes	Geophysical Fluid Dynamics Laboratory (GFDL) USA
GFDL-ESM2M	2.5x2.0	Yes	Geophysical Fluid Dynamics Laboratory (GFDL) USA
GISS-E2-H	2.5×2×L40	No	NASA Goddard Institute for Space Studies (NASA-GISS) USA
GISS-E2-H-CC	2.5×2×L40	No	NASA Goddard Institute for Space Studies (NASA-GISS) USA
GISS-E2-R	2.5×2×L40	No	NASA Goddard Institute for Space Studies (NASA-GISS) USA
GISS-E2-R-CC	2.5x2×L40	No	NASA Goddard Institute for Space Studies (NASA-GISS) USA
HadCM3	3.75x2.5	No	Met Office Hadley Centre (MOHC) UK

HadGEM2-AO	1.875 × 1.2413	No	National Institute of Meteorological Research, Korea Meteorological Administration (NIMR-KMA) South Korea
HadGEM2-CC	1.875 × 1.2413	No	Met Office Hadley Centre (MOHC) UK
HadGEM2-AO	1.875 × 1.2413	No	National Institute of Meteorological Research, Korea Meteorological Administration (NIMR-KMA) South Korea
HadGEM2-CC	1.875 × 1.2413	No	Met Office Hadley Centre (MOHC) UK
HadGEM2-ES	1.875 × 1.2413	Yes	Met Office Hadley Centre (MOHC) UK
INM-CM4	2x1.5	Yes	Russian Academy of Sciences, Institute of Numerical Mathematics (INM) Russia
IPSL-CM5A-LR	3.75x1.875	Yes	Institut Pierre Simon Laplace (IPSL) France
IPSL-CM5A-MR	2.5x1.25874	Yes	Institut Pierre Simon Laplace (IPSL) France
IPSL-CM5B-LR	3.75x1.875	Yes	Institut Pierre Simon Laplace (IPSL) France
MIROC-ESM	2.8125x2.8125	Yes	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology (MIROC) Japan
MIROC-ESM-CHEM	2.8125x2.8125	Yes	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology (MIROC) Japan
MIROC4h	0.5625x0.5625	No	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology (MIROC) Japan
MIROC5	1.40625 × 1.40625	Yes	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology (MIROC) Japan
MPI-ESM-LR	1.875x1.875	Yes	Max Planck Institute for Meteorology (MPI-M) Germany
MPI-ESM-MR	1.875 × 1.875	Yes	Max Planck Institute for Meteorology (MPI-M) Germany
MRI-CGCM3	1.125x1.125	Yes	Meteorological Research Institute (MRI) Japan
NorESM1-M	2.5x1.875	Yes	Bjerknes Centre for Climate Research, Norwegian Meteorological Institute (NCC) Norway
NorESM1-ME	2x2	No	Bjerknes Centre for Climate Research, Norwegian Meteorological Institute (NCC) Norway

Appendix 3: Ji'an temperature related observed climate variables and their future projections

Table A3-1: Annual average temperature and future change projections (°C)

	Baseline	2050 scenario			2100 scenario		
		Low	Median	High	Low	Median	High
Mean	18.5	19.4	19.8	21.1	19.8	21.0	24.5
Minimum	15,1	16.0	16.4	17.7	16.3	17.5	20.9
Maximum	23.1	24.0	24.4	25.8	24.4	25.7	29.3

Table A3-2: Annual extreme daily temperature and future change projections (°C)

	Return period (year)	Baseline (°C)	2050 scenario			2100 scenario		
			Low	Median	High	Low	Median	High
Maximum	10	40.1	41.0	41.3	42.5	41.3	42.4	45.6
	20	40.5	41.3	41.6	42.8	41.6	42.7	45.9
	50	40.8	41.6	41.9	43.2	41.9	43.0	46.2
Minimum	10	-5.3	-4.4	-4.0	-2.6	-4.0	-2.8	0.5
	20	-6.3	-5.3	-5.0	-3.6	-5.0	-3.7	-0.5
	50	-7.5	-6.6	-6.3	-4.9	-6.3	-5.0	-1.8

Table A3-3: Annual 7 day maximum temperature and future change projections (°C)

Return period (year)	Baseline	2050 scenario			2100 scenario		
		Low	Median	High	Low	Median	High
20	39.2	40.0	40.4	41.6	40.3	41.5	44.7
50	39.6	40.4	40.8	42.0	40.8	41.9	45.1
100	39.8	40.7	41.0	42.2	41.0	42.1	45.3

Appendix 4: Precipitation related observed climate variables and their future projections

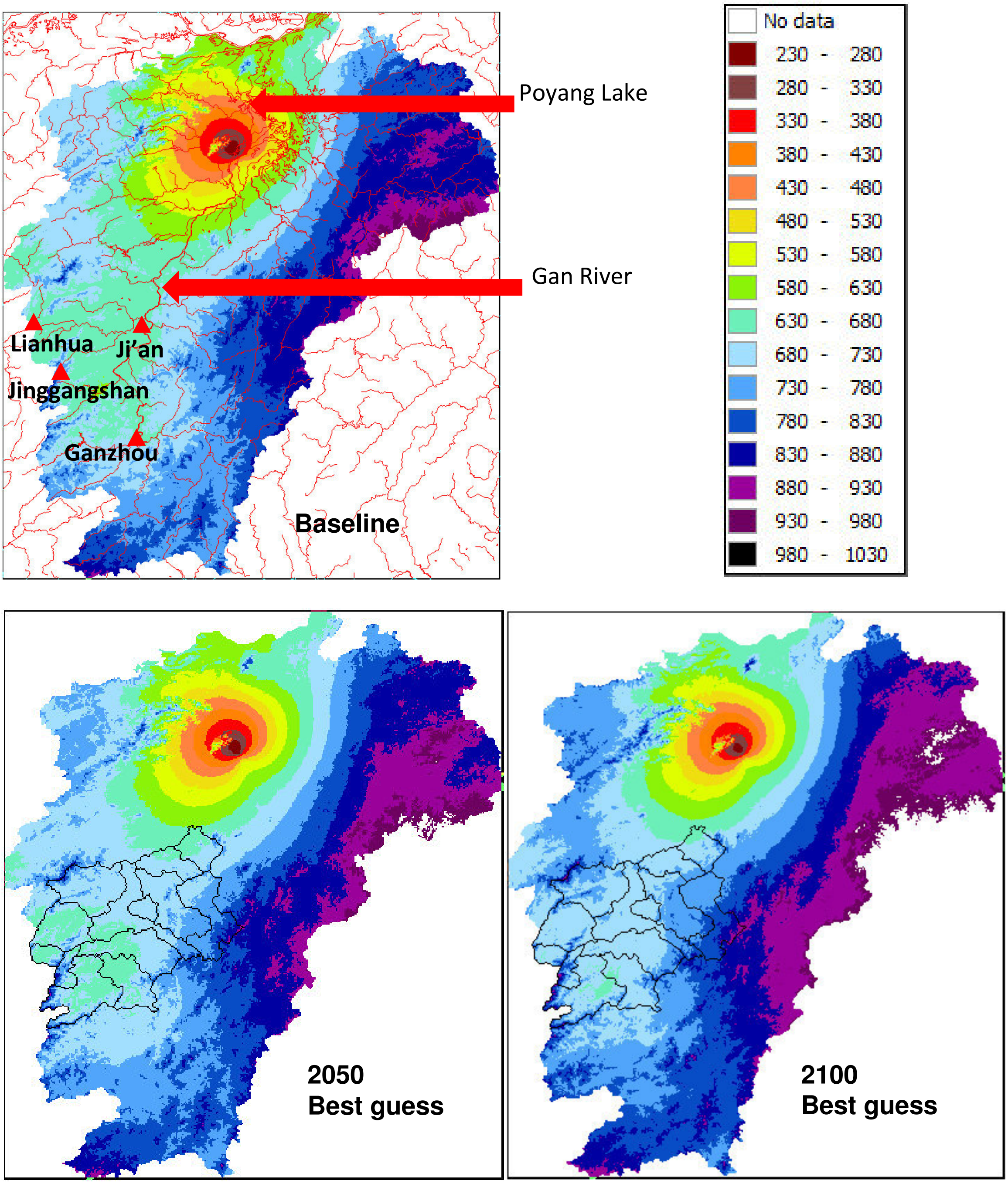

Figure A4-1: Jiangxi rainy season (Apr-Jun) rainfall distribution (mm): baseline and 2050, 2100 best guess projections. Ji'an is in the mid-west of the province shown by the black lines. The red lines are the river network and the red triangles indicates the meteorological stations.

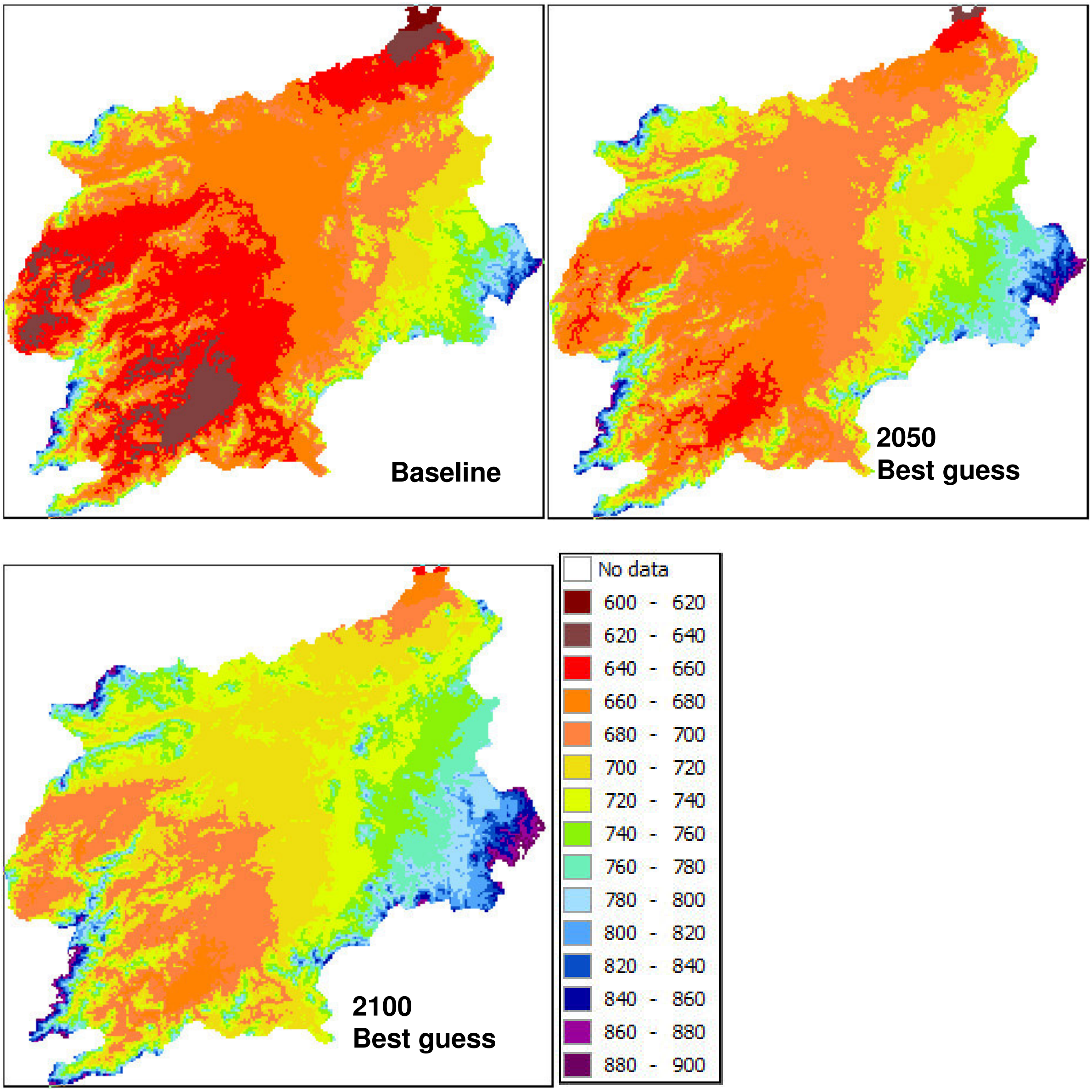

Figure A4-2: Ji'an rainy season (Apr-Jun) rainfall distribution (mm): baseline and 2050, 2100 best guess projections

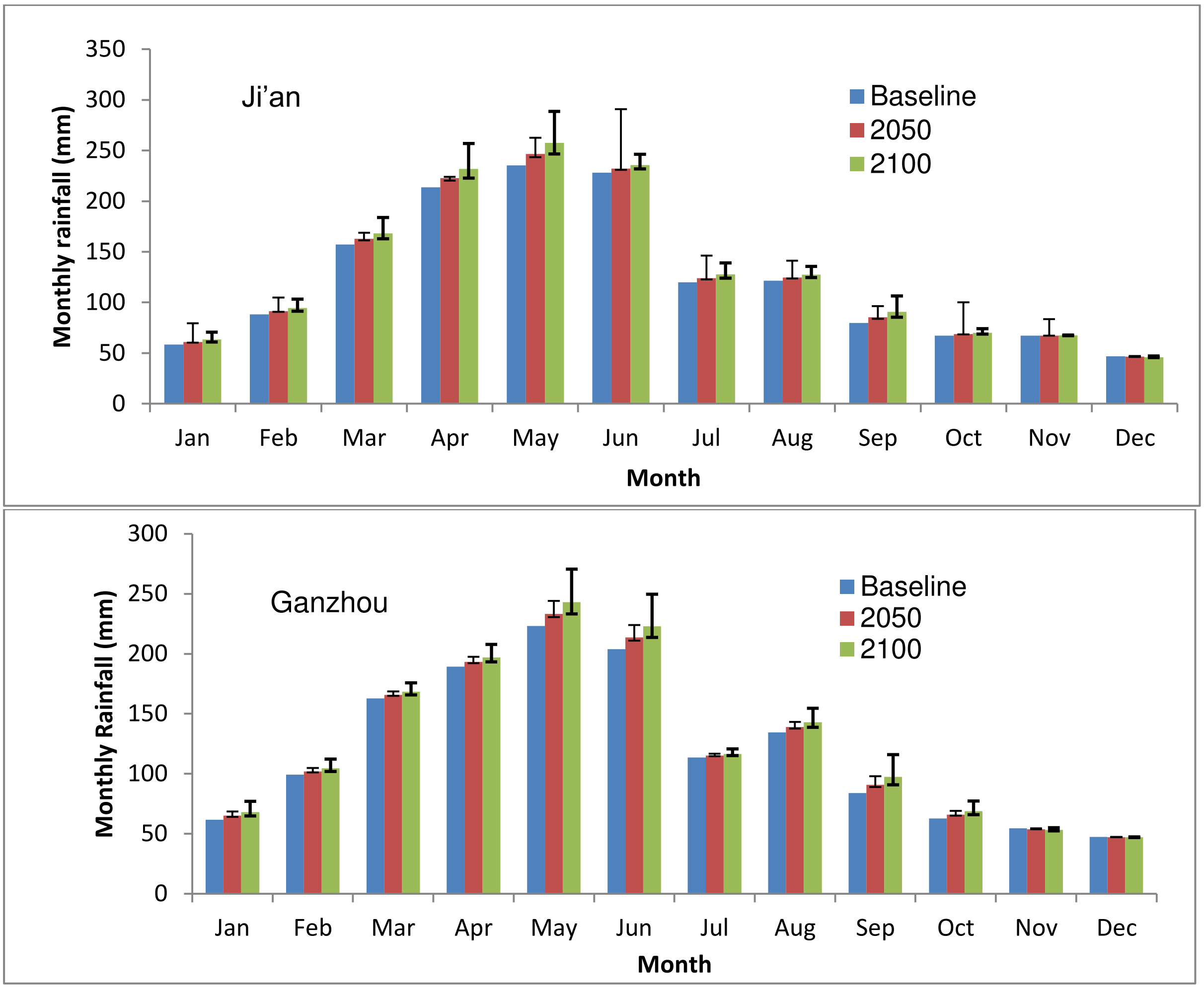

Figure A4-3: Ji'an and Ganzhou site specific monthly normal rainfall and future projection. The bar indicates the uncertainty range of the climate change projection as defined in Table 2

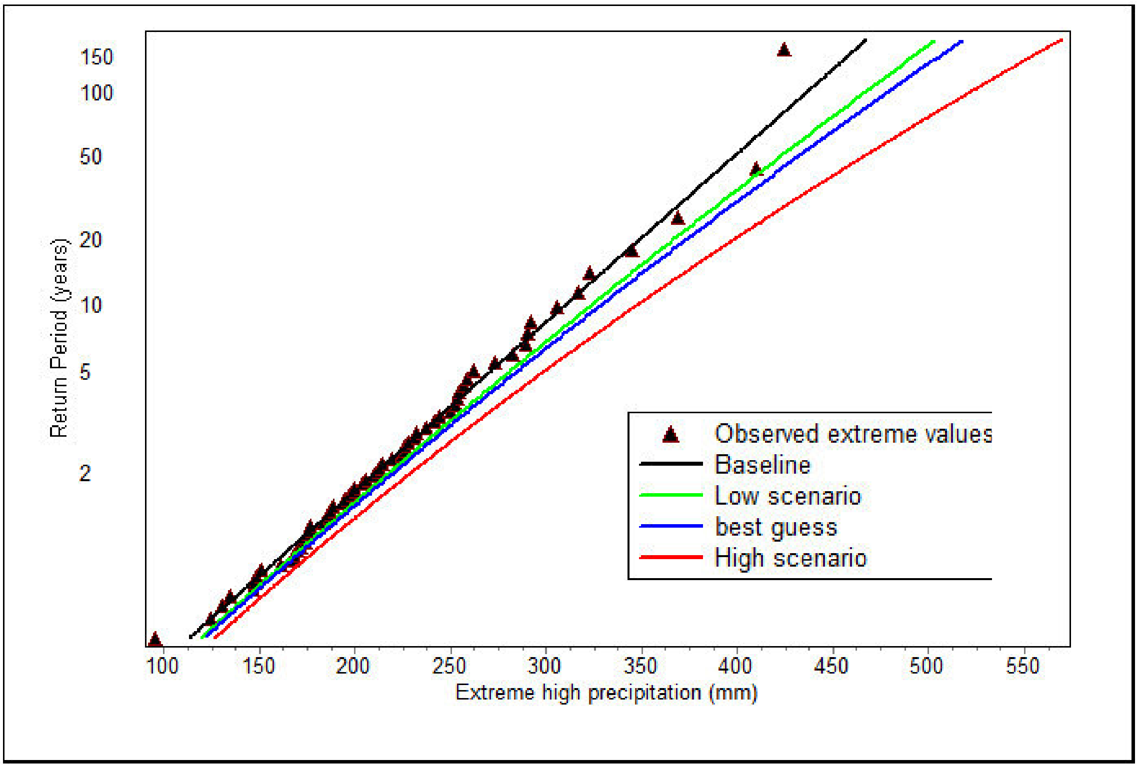

Figure A4-4: Ji'an annual maximum 10 day rainfall GEV distribution and 2050 projection. Black line is the baseline from historical data; blue and red lines represent the uncertainty range as defined in Table 2; green line is low projection; red line is high projection. The horizontal difference between green and red lines indicates the uncertain range of rainfall intensity for a given rainfall frequency; the vertical difference between green and red lines indicates the uncertain range of rainfall frequency for a given rainfall intensity

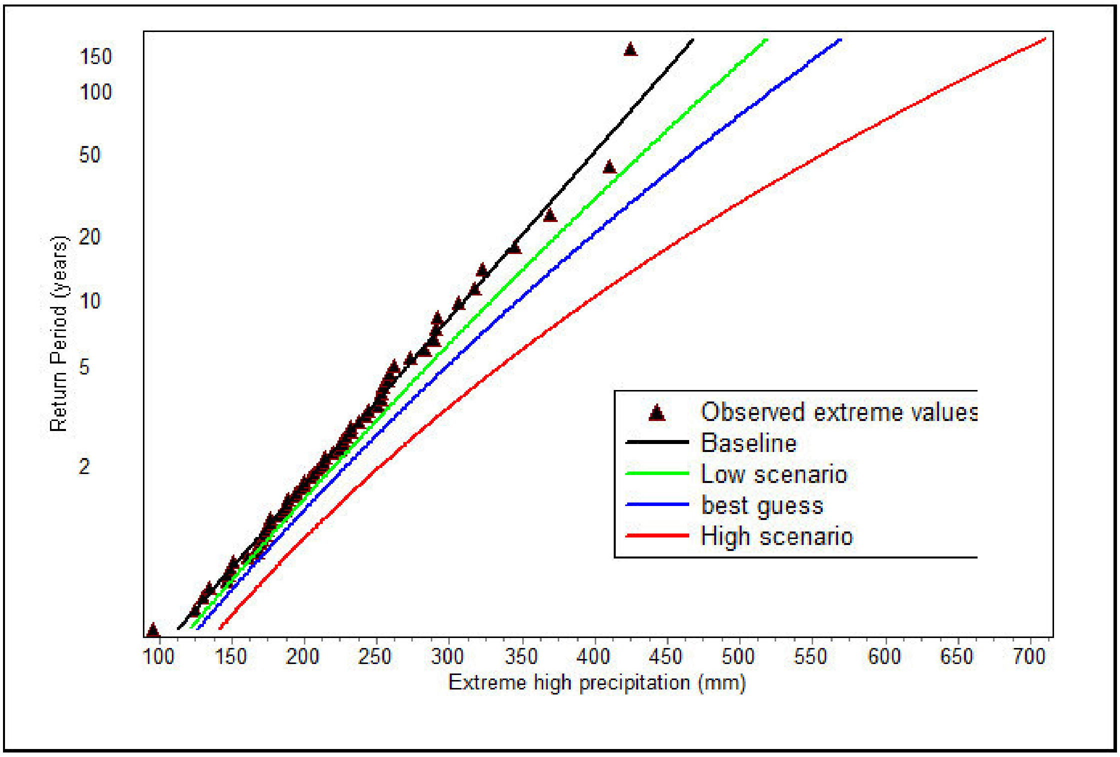

Figure A4-5: Same as Figure A4-4 but for Ji'an 2100 projection

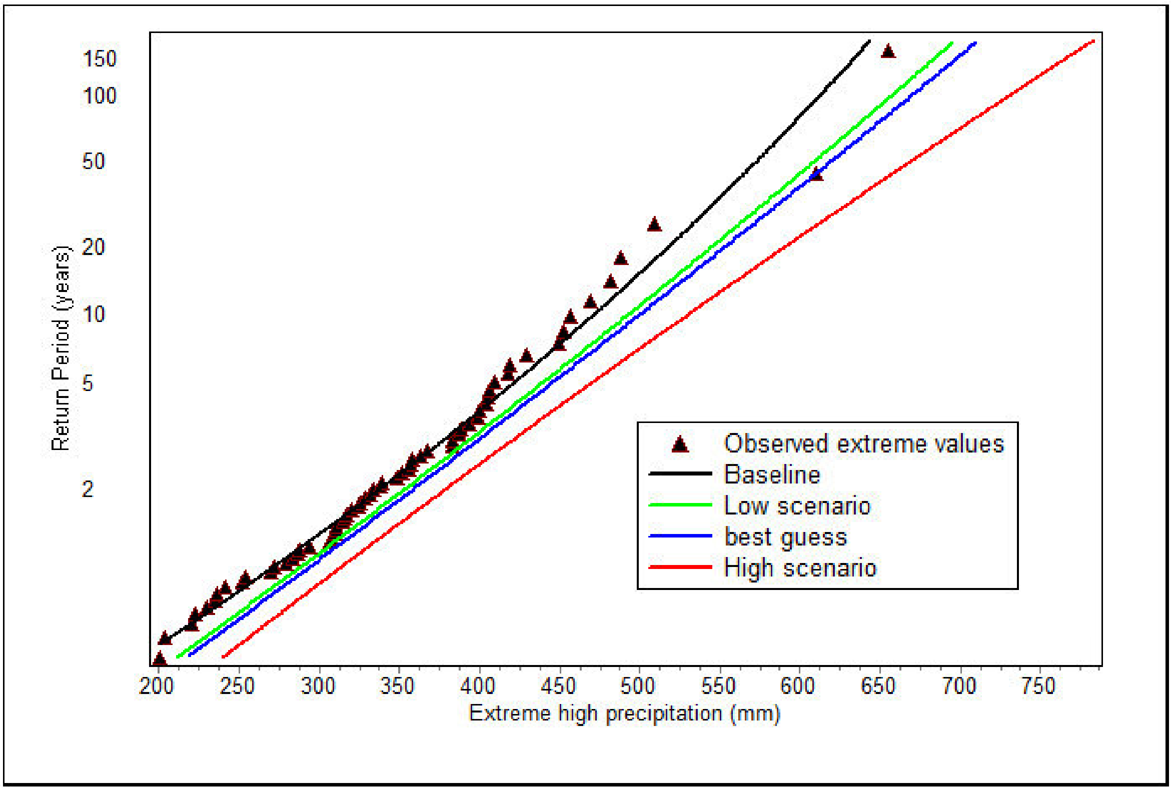

Figure A4-6: Same as Figure A4-4 but for Ganzhou 30 day 2050 projection

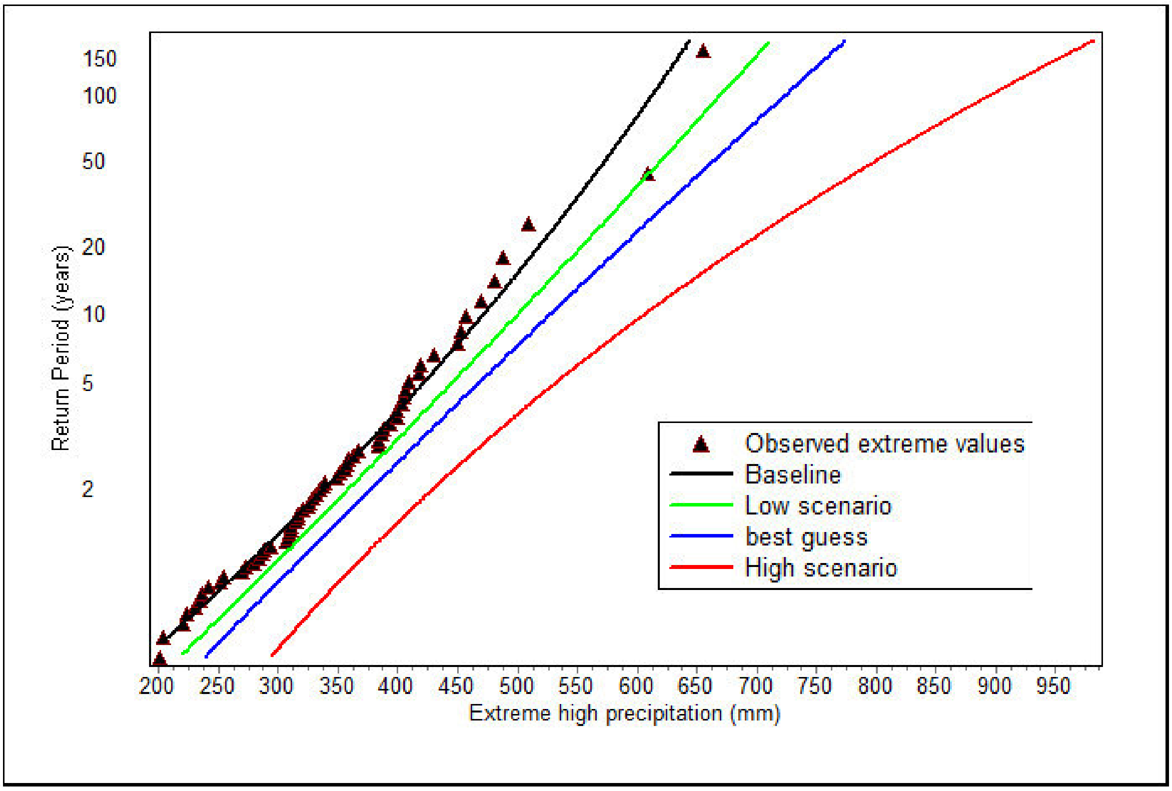

Figure A4-7: Same as Figure A4-4 but for Ganzhou 30 day 2100 projection

Appendix 5: The development of the rainfall-flood model for Ji'an

A statistical modelling method was adopted to find the relationship between rainfall and the flood. An 30 years of observed annual maximum river flow height data was collected from the Hydrology Institute for Ji'an station. Corresponding to these flow events, their previous 1,3,10 and 30 days total rainfall was selected from the daily time-series observations for Ji'an and Ganzhou (Table A5-1). A statistical analysis was carried out to examine the relationship between the annual maximum flow heights and all the rainfall events of different durations, and it was found that that the flow height has most significant relationship with 30 day rainfall of Ganzhou and 10 day rainfall of Ji'an. These two rainfall events were examined in detail with results presented in Appendix 4. A regression model was developed as below:

$$Y = 44.1627 + 0.01018X_1 + 0.00924X_2 \quad (1)$$

where: Y is the annual maximum flow height (masl); X_1 is the previous 10 day total rainfall of Ji'an, and X_2 is the previous 30 day total rainfall in Ganzhou. The developed model has a reasonable performance in simulating the annual peak flow height with a correlation coefficiency (R^2) of 0.58 with standard error of 1.1 m (Figure 3).

Table A5-1: Observed annual maximum flow height at Ji'an hydrology station and its corresponding observed rainfall of different durations from Ji'an and Ganzhou.

Date	Flow height (masl)	Rainfall (mm)				
		Station	30 day	10 day	3 day	1 day
30/31983	51.08	Ji'an	195.6	61.7	41.2	37.0
		Ganzhou	373.0	133.3	117.8	80.3
2/9/1984	50.90	Ji'an	380.5	295.0	196.6	152.5
		Ganzhou	322.8	202.9	151.4	118.4
6/6/1985	49.14	Ji'an	262.8	214.3	153.4	75.6
		Ganzhou	162.4	58.6	27.4	14.7
1/41986	48.24	Ji'an	164.1	24.7	24.7	21.8
		Ganzhou	193.4	128.6	78.9	76.5
25/3/1987	47.73	Ji'an	127.8	87.2	20.7	10.4
		Ganzhou	254.8	77.1	102.1	68.0
14/5/1988	49.55	Ji'an	190.0	129.3	83.3	57.0
		Ganzhou	177.7	116.9	58.9	31.3
24/5/1989	49.83	Ji'an	244.3	151.5	56.3	23.3
		Ganzhou	263.6	152.8	107.5	65.4
13/9/1990	48.69	Ji'an	75.1	50.0	39.4	16.7
		Ganzhou	192.7	138.7	79.5	33.2
1/4/1991	49.38	Ji'an	297.4	201.5	97.9	25.8
		Ganzhou	230.1	144.9	108.6	44.4
29/3/1992	52.73	Ji'an	437.5	298.8	119.1	50.5
		Ganzhou	419.9	260.7	144.3	47.1

2/7/1993	49.15	Ji'an	451.9	288.8	214.7	107.4
		Ganzhou	257.4	100.6	10.4	3.8
18/6/1994	53.32	Ji'an	303.9	238.0	124.1	67.6
		Ganzhou	375.3	242.7	142.0	69.9
20/6/1995	51.11	Ji'an	271.4	79.6	68.7	0.3
		Ganzhou	291.7	198.9	160.5	93.7
4/8/1996	51.49	Ji'an	267.7	146.7	146.7	87.5
		Ganzhou	294.3	200.9	133.5	110.5
12/7/1997	51.69	Ji'an	263.0	168.3	128.1	15.2
		Ganzhou	286.2	136.8	79.2	38.5
10/3/1998	52.63	Ji'an	343.8	226.5	141.5	47.0
		Ganzhou	443.0	219.4	150.3	68.4
27/5/1999	50.84	Ji'an	325.2	214.1	123.9	53.6
		Ganzhou	316.8	250.5	215.3	60.5
12/6/2000	48.38	Ji'an	245.5	187.1	163.3	78.8
		Ganzhou	173.5	78.9	70.7	44.9
14/6/2001	50.23	Ji'an	289.7	107.4	63.6	30.2
		Ganzhou	214.9	157.4	89.0	72.8
17/6/2002	52.32	Ji'an	236.5	194.1	186.8	116.5
		Ganzhou	306.2	165.1	117.9	44.5
17/5/2003	51.39	Ji'an	268.3	224.9	179.6	178.0
		Ganzhou	177.0	107.5	65.3	44.7
9/7/2004	48.50	Ji'an	192.7	56.0	55.6	18.8
		Ganzhou	297.0	159.6	159.3	141.1
25/5/2005	50.75	Ji'an	466.5	208.4	60.2	16.5
		Ganzhou	273.5	125.0	80.3	56.3
8/6/2006	50.72	Ji'an	283.6	187.5	149.5	93.9
		Ganzhou	366.0	169.7	35.0	21.1
12/6/2007	49.81	Ji'an	189.5	141.2	44.2	5.1
		Ganzhou	193.4	181.9	52.5	16.4
15/6/2008	49.46	Ji'an	153.8	83.7	47.2	45.0
		Ganzhou	277.2	163.8	121.1	115.2
5/7/2009	49.64	Ji'an	179.5	113.3	127.5	6.2
		Ganzhou	167.3	141.0	127.3	118.1
21/6/2010	53.14	Ji'an	442.2	331.9	303.0	113.1
		Ganzhou	213.1	131.8	46.4	33.1
18/5/2011	47.01	Ji'an	96.3	42.3	6.5	4.7
		Ganzhou	202.1	138.5	75.7	42.1
25/6/2012	51.26	Ji'an	281.4	123.9	95.1	4.3
		Ganzhou	307.0	212.5	93.8	52.5

Appendix 6: Ji'an Hydrologic Station observed maximum flow height and projections (masl)

The calculation process for the future flow height:

- Firstly, the return period for the 10 day rainfall of Ji'an and 30 day rainfall of Ganzhou corresponding to each year peak flow height was calculated from their baseline GEV distribution;
- Secondly the future values of these rainfall events were calculated based on their future GEV distributions (refer to previous section on the detail of GEV calculation);
- Thirdly the future model calculated flood height was calculated from the future rainfall based on Equation 1, and a change ratio of model calculated future and baseline flood height was calculated for every year;

Finally, the future projected flood height was calculated by adding the change ratio to its corresponding observed value for each year.

Table A6-1: Values included in the maximum flow height projection calculation:

Observed	Modelled	2050 scenario								
		Low	Change (%)	Projection	Median	Change (%)	Projection	High	Change (%)	Projection
51.08	50.19	50.3	0.32	51.24	50.38	0.39	51.28	50.60	0.82	51.50
50.90	52.10	52.3	0.53	51.17	52.45	0.67	51.24	52.83	1.41	51.62
49.14	49.79	49.8	0.14	49.21	49.89	0.19	49.23	49.98	0.38	49.33
48.24	48.15	48.3	0.31	48.39	48.36	0.44	48.45	48.59	0.91	48.68
47.73	49.35	49.5	0.33	47.89	49.56	0.42	47.93	49.77	0.84	48.13
49.55	49.07	49.4	0.75	49.92	49.52	0.92	50.00	49.81	1.50	50.29
49.83	50.09	50.3	0.45	50.05	50.35	0.51	50.09	50.65	1.11	50.38
48.69	48.40	48.5	0.32	48.85	48.62	0.45	48.91	48.84	0.92	49.14
49.38	50.29	50.5	0.45	49.60	50.59	0.59	49.67	50.89	1.19	49.97
52.73	53.03	53.3	0.56	53.02	53.42	0.73	53.12	53.84	1.53	53.54
49.15	51.43	51.7	0.58	49.43	51.81	0.74	49.51	52.18	1.47	49.87
53.32	52.00	52.2	0.47	53.57	52.31	0.59	53.64	52.65	1.24	53.98
51.11	49.62	49.7	0.32	51.28	49.81	0.39	51.31	50.02	0.80	51.52
51.49	50.32	50.5	0.45	51.72	50.60	0.55	51.78	50.87	1.09	52.05
51.69	50.47	50.7	0.45	51.92	50.75	0.56	51.98	51.03	1.11	52.26
52.63	52.51	52.7	0.49	52.89	52.85	0.64	52.97	53.21	1.34	53.34
50.84	51.22	51.4	0.45	51.07	51.51	0.57	51.13	51.81	1.15	51.43
48.38	49.62	49.6	0.13	48.44	49.71	0.17	48.46	49.79	0.33	48.54

50.23	49.19	49.5	0.66	50.56	49.59	0.81	50.63	49.86	1.36	50.91
52.32	50.92	51.1	0.44	52.55	51.20	0.55	52.61	51.49	1.12	52.90
51.39	50.04	50.4	0.75	51.78	50.50	0.93	51.87	50.83	1.59	52.21
48.50	49.43	49.5	0.33	48.66	49.62	0.40	48.69	49.83	0.81	48.89
50.75	50.76	51.0	0.47	50.99	51.06	0.59	51.05	51.36	1.17	51.35
50.72	51.40	51.6	0.43	50.94	51.68	0.54	50.99	51.98	1.11	51.29
49.81	49.34	49.5	0.40	50.01	49.61	0.56	50.09	49.90	1.14	50.38
49.46	49.53	49.6	0.33	49.62	49.72	0.40	49.66	49.93	0.81	49.86
49.64	48.81	48.8	0.11	49.70	48.89	0.15	49.71	48.94	0.27	49.78
53.14	51.46	51.7	0.63	53.47	51.90	0.85	53.59	52.34	1.71	54.05
47.01	48.41	48.6	0.39	47.19	48.66	0.51	47.25	48.88	0.96	47.46
51.26	50.21	50.4	0.38	51.45	50.45	0.48	51.51	50.72	1.01	51.78

Observed	Modelled	2100 scenario								
		Low	Change (%)	Projection	Median	Change (%)	Projection	High	Change (%)	Projection
51.08	50.19	50.4	0.42	51.29	50.56	0.75	51.46	51.10	1.82	52.01
50.90	52.10	52.4	0.70	51.26	52.77	1.30	51.56	53.73	3.14	52.50
49.14	49.79	49.8	0.19	49.23	49.97	0.36	49.32	50.22	0.86	49.56
48.24	48.15	48.3	0.45	48.45	48.56	0.84	48.65	49.10	1.98	49.20
47.73	49.35	49.5	0.44	47.94	49.73	0.76	48.09	50.24	1.79	48.58
49.55	49.07	49.5	0.92	50.01	49.77	1.42	50.25	50.48	2.87	50.97
49.83	50.09	50.3	0.59	50.12	50.60	1.02	50.34	51.28	2.37	51.01
48.69	48.40	48.6	0.46	48.91	48.81	0.85	49.10	49.36	1.98	49.66
49.38	50.29	50.6	0.61	49.68	48.33	1.02	49.88	51.59	2.59	50.66
52.73	53.03	53.4	0.75	53.13	53.79	1.43	53.48	54.86	3.45	54.55
49.15	51.43	51.8	0.76	49.52	49.36	1.32	49.80	53.07	3.19	50.72
53.32	52.00	52.3	0.62	53.65	52.60	1.14	53.93	53.43	2.75	54.79
51.11	49.62	49.8	0.42	51.33	46.92	0.73	51.48	50.48	1.73	52.00
51.49	50.32	50.6	0.58	51.79	50.83	1.00	52.01	51.50	2.33	52.69
51.69	50.47	50.7	0.59	51.99	50.98	1.02	52.22	51.67	2.38	52.92
52.63	52.51	52.8	0.66	52.98	53.17	1.25	53.29	54.10	3.02	54.22
50.84	51.22	51.5	0.59	51.14	51.76	1.06	51.38	52.51	2.52	52.12
48.38	49.62	49.7	0.17	48.46	49.78	0.32	48.53	49.99	0.74	48.74
50.23	49.19	49.5	0.82	50.64	49.82	1.28	50.87	50.50	2.67	51.57

52.32	50.92	51.2	0.58	52.62	51.44	1.03	52.86	52.16	2.43	53.59
51.39	50.04	50.5	0.93	51.87	50.79	1.50	52.16	51.61	3.14	53.00
48.50	49.43	49.6	0.43	48.71	49.79	0.73	48.86	50.29	1.74	49.34
50.75	50.76	51.0	0.61	51.06	51.31	1.08	51.30	52.05	2.54	52.04
50.72	51.40	51.6	0.57	51.01	51.93	1.02	51.24	52.67	2.46	51.97
49.81	49.34	49.6	0.56	50.09	49.86	1.07	50.34	50.58	2.51	51.06
49.46	49.53	49.7	0.43	49.67	49.89	0.74	49.83	50.39	1.75	50.32
49.64	48.81	48.8	0.15	49.71	48.94	0.26	49.77	49.09	0.58	49.93
53.14	51.46	51.9	0.86	53.59	52.29	1.61	53.99	53.41	3.80	55.16
47.01	48.41	48.6	0.52	47.25	48.84	0.90	47.43	49.38	2.00	47.95
51.26	50.21	50.4	0.51	51.52	50.67	0.92	51.73	51.33	2.23	52.40