MAHAWELI WATER SECURITY INVESTMENT PROGRAM

CLIMATE RISK AND VULNERABILITY ASSESSMENT

JUNE 2015

ABBREVIATIONS

ADB	–	Asian Development Bank
CC	–	Climate Change
CP	–	Concept Paper
DOI	–	Department of Irrigation
EIA	–	Environment impact assessment
GOSL	–	Government of Sri Lanka
IA	–	implementing agency
ISEWP	–	improving system efficiencies and water productivity
KMTC	–	Kalu Ganga-Moragahakanda Transfer Canal
MAP	–	Mean Annual Precipitation
MASL	–	Mahaweli Authority of Sri Lanka
MDP	–	Mahaweli Development Program
MRB	–	Mahaweli River Basin
MLBCRP	–	Minipe Left Bank Canal Rehabilitation Project
MFF	–	multitranche financing facility
MMDE	–	Ministry of Mahaweli Development and Environment
NCPCP	–	North Central Province Canal Program
NWPCP	–	North Western Province Canal Project
PDA	–	project design advance
PMDC	–	program management and design consultant
PPTA	–	project preparatory technical assistance
SIWRM	–	strengthening integrated water resources management
SLPI	–	Sri Lanka Prosperity Index
UEC	–	Upper Elahera Canal
UECP	–	Upper Elahera Canal Project

WEIGHTS AND MEASURES

ACE	–	annual per capita endowment
ha	–	Ha
km	–	Kilometer
MCM	–	million cubic meters
mm	–	Millimeter
m^3	–	cubic meter
MW	–	Megawatt

CONTENTS

I. OVERVIEW

A. Introduction

1. **Agriculture and natural resources** is key sector in Sri Lanka contributing to improving household food and financial security, as 80% of the population are rural and of which 70% are dependent on the sector for their livelihood. The sector as a whole accounts for more than 10% of GDP, 30% of employment and 25% of export revenue. However, the contribution to GDP has declined in recent years, and productivity needs to increase to keep pace with rising demand for domestic consumption and to achieve national goals of food self-sufficiency and poverty reduction.

2. The sector is a major contributor to national food security, particularly attainment of self-sufficiency in rice and other staple crops. More than 80% of rice production nationally is from the 750,000 ha (1.8 million acres) of irrigated lands. Paddy production is highly dependent on seasonal rainfall and irrigation water sources, traditionally from tanks (local storage reservoirs) and in recent times transfer from large dams in the Mahaweli River Basin.

3. The climate is tropical with two monsoon periods; Southwest Monsoon (SWM) (May to September) (referred to as the *Yala* season) and Northeast Monsoon (NEM) (December to February) (or *Maha* season).[1] The rainfall pattern and distribution is a function of both the monsoons and topographic relief, with highland in the southwest. As a result the country is divided into two principal and relative agro-climatic zones; a wet zone of the south west covering about 30% of the land area, and a dry zone of the north and east.

4. The majority (70%) of the irrigated lands are located within the dry zone, within which water availability is a major constraint during the Yala season and as a result cropping intensities are generally restricted to 100 to 130%. Whereas within the wet zone they are generally 150 to 180%, due to higher water availability.

5. Historically water availability, for both irrigation and drinking water supply, was improved through construction of tanks for intra and inter seasonal use, of which there are estimated to be nearly 30,000 nationally. In the past 50 years the government has been proactive in the development of large scale water resources projects to improve water supply and use for both consumptive use and hydropower generation. Under the Mahaweli Development Program (MDP), started in the 1960s, water is being harvested within the water 'rich' Mahaweli Ganga (largest river basin) for use within and transfer to dry zone areas, principally to the north but also to the south.

6. The Mahaweli Water Security Investment Program ("investment program") is the penultimate stage in the MDP, as part of the North Central Province Canal Program (NCPCP), with the extension of water transfers to the north and northwest, both regions severely limited by water availability and areas recovering, physically and socio-economically from the recent conflicts.

B. North Central Province Canal Program

7. As mentioned above, the investment program fits within the overall NCPCP, and as it will be the first part to be implemented it is referred to as Phase 1 of the NCPCP in this report. The

[1] There are also two inter-monsoonal periods; inter-monsoonal I (IM1) March to April, and inter-monsoonal II (IM2) October to November.

NCPCP as a whole when complete will transfer approximately 1,100 MCM per annum of water from the Mahaweli River Basin to irrigation systems in the northern provinces.[2] Approximately 1,040 MCM of this will be supplied to 84,000 ha of irrigation systems, and 160 MCM to community water supplies. The key elements of the NCPCP, include those listed below under the investment program, plus construction of the Lower Uma Oya Dam to increase storage volume and hydropower production, Randenigala-Kalu Ganga canal for water transfer to the Kalu Gala reservoir (and thence further north), North Central Province Canal for transfer from the Upper Elahera Canal to cascade tank systems, and Kalinga Nuwara pump station to lift water from the lower Mahaweli River to the Elahera-Minneriya – Yoda Ela (EMYE) systems. These additional works will form the next part of the NCPCP's development (Phase 2).

8. The investment program includes Infrastructure works for water transfers and storage (as listed

[2] These northern provinces are the North Central, North Western and Northern.

9. **Table 1** and shown in Figure 1) including:

(i) The Upper Elahera Canal Project (UECP) comprises two components. The first component is the 9 km Kalu Ganga-Moragahakanda Transfer Canal (KMTC) (including a 8km tunnel) that transfers water between the Kalu Ganga and Moragahakanda Reservoirs.[3] The second component is the Upper Elahera Canal that connects the Moragahakanda Reservoir to the existing reservoirs: Huruluwewa, Manankattiya, Eruwewa and Mahakanadarawa via 82 km of canals (including a 26 km tunnel). These reservoirs supply existing irrigation and water supply schemes.

(ii) The North Western Province Canal Project (NWPCP) will construct 96 km of new and upgraded canals (including a 940 m tunnel) and two new 25 m tall earth gravity dams impounding the Mahakithula and Mahakirula Reservoirs. It will transfer water from the Dambulu Oya River and the existing Nalanda and Wemedilla Reservoirs to command existing irrigation and water supply reservoirs.

(iii) Minipe Left Bank Canal Rehabilitation Project (MLBCRP), located in the downstream reaches of the Mahaweli River, will: (a) add upstream storage by heightening the headwork's weir by 3.5 m, (b) construct new intake gates to the left bank canal and emergency spill weirs to both left and right bank canals; and (c) rehabilitate the 74 km Minipe Left Bank Canal to improve conveyance and reliability of service to existing farmers.

10. The investment program also includes the following studies to improving water sector management:

(i) Improving System Use Efficiencies and Water Productivity (ISEWP); the purpose of the study is to identify ways and means of improving cascade water system efficiencies, which are currently very low. The potential benefits may include adaptation to anticipated climate change impacts, such as increased water demand and/or reduced water availability.

(ii) Strengthening Integrated Water Resources Management (SIWRM); the study will help the government further develop IWRM, including development of intra-basin management and trans-basin management plan(s).

[3] These reservoirs are currently under construction.

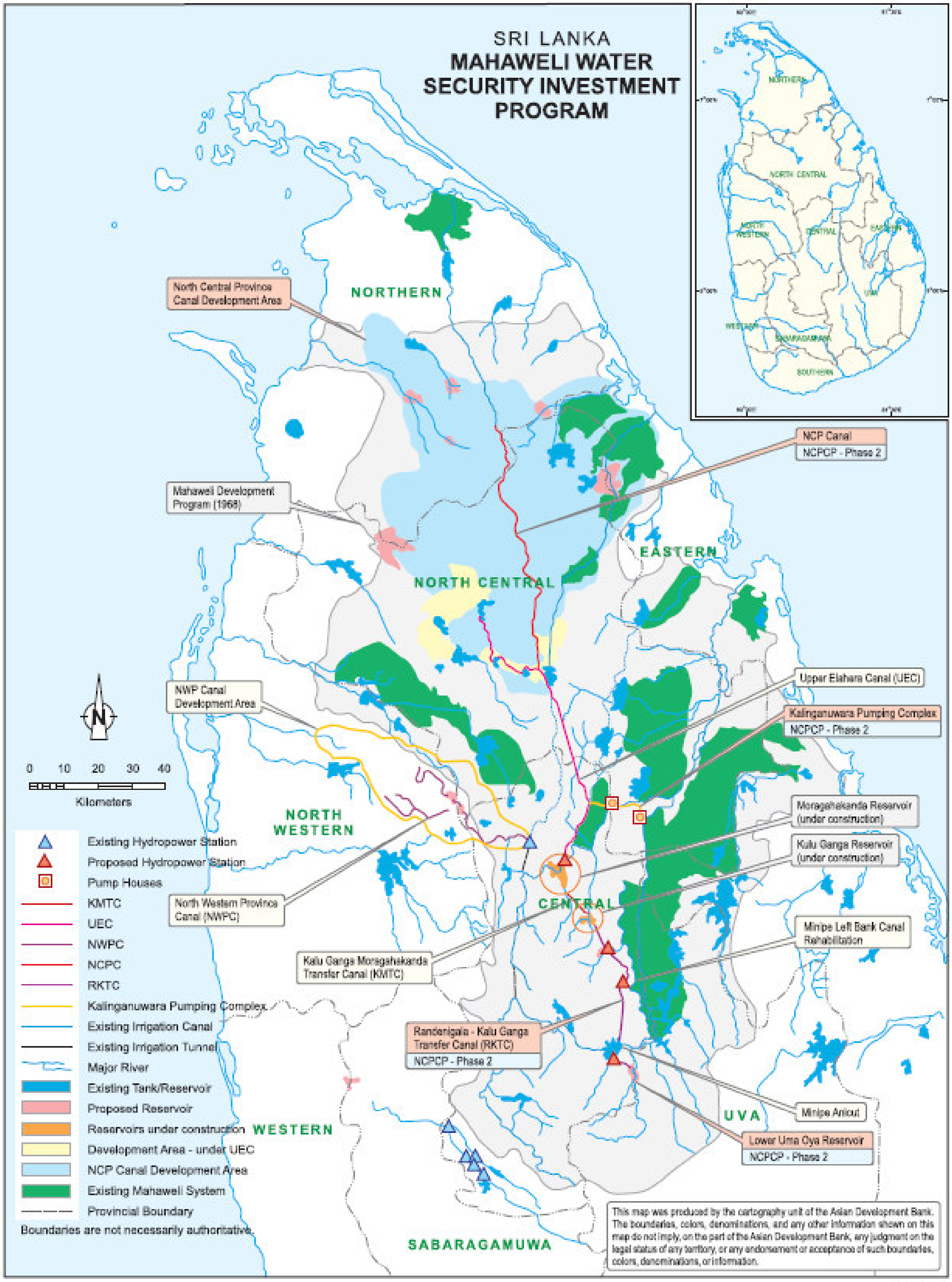
Table 1: Summary of Project Components

Project	Area (ha)	Canal (km)	Annual Volume (MCM)
KMTC	-	9	100
			(770)
UECP	12,381	70	300
	(53,000)[4]		(970)
NWPCP	11,492	80	130
MLBCP	7,530	76	318
Total	**31,403**	**235**	**430[5]**
	(84,403)		**(1,100)**

KMTC = Kalu Ganga – Moragahakanda Transfer Canal, MCM = million cubic meters,
Source: PPTA Consultant

[4] () areas and volumes for Stage 2
[5] Volume transferred as part of NCP development (UEC and NWPC)

Figure 1: Project Base Map



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II. CLIMATE RISK SCREENING

11. The project climate risk screening includes the preparation of a screening report based on the project (ADB, 2014) and AWARE risk assessment for the program and projects. The screening report is presented in Annex 1 and the AWARE assessment in Annex 2.

12. The screening report identified the climate changes under the A2 scenario[6] for the Mahaweli Basin as a rise of 1.8°C in average annual mean temperature, and an increase of 4.2% (85 mm) in annual precipitation, but with a higher increase in the lower catchment (>4%) and a lower increase in the upper catchment (<4%). It also identified seasonal differences in precipitation with a decrease of 3.8% in the December to April period (corresponding to the NEM (Maha season)) and 11% increase for the May to November period (corresponding to the SWM (Yala season)).

13. The climate sensitive components are identified as: (i) changes in hydrology of the Mahaweli River Basin due to a decline in annual runoff resultant reduction in water availability; and (ii) a reduction in reservoir capacity due to siltation as a result of increase SWM precipitation exacerbating soil/bank erosion in the upper catchment and loss of reservoir storage capacity.

14. However, there appears to be some inconsistencies between the climate change projections and climate sensitive components, namely anticipated increase in annual precipitation and decline in annual run-off and the projection of higher siltation though the increase in precipitation is likely to be relative small.

15. Natural hazard risks and rates include (i) landslides – medium risk due to high precipitation in the upper catchment, (ii) flooding – medium/high due to more intensive precipitation, and (iii) drought – medium/high due to higher temperatures and more variable precipitation. The overall hazard risk is rated in the screening report (Annex 1) as medium[7].

16. The screening report concludes with the statement that "*rainfall variability is identified as the most important contributing factor to increased climate risk in the Mahaweli Basin. And as such water availability is very likely to be affected by climate change if the current trend continues*". And goes on to say "*the project team is advised to factor in the impact of climate change on future scenarios of water availability and its seasonal variability during project design (e.g. reservoir capacities) as well as implementation (e.g. water allocation). The risks of natural hazards (landslides and flooding) may also need to be taken into account during project design*".

17. Additional risk analysis was also prepared by ADB using the AWARE project assessment (Annex 2). The AWARE assessment evaluates risks within sixteen individual topic categories and provides an overview final project risk. The individual risks are presented on a radar chart within three color bands; green band (inner circle) suggests a lower level of risk in relation to a risk topic, red band (outer band) suggests a higher level of risk and orange band (middle band).

18. Table 2 presents a summary of the risk topic for the overall investment program as a whole as well as the individual projects; UECP (inclusive of the KTMC), NWPCP and MLBCP.

[6] The A2 "*storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines*". IPCC Special Report, Emissions Scenarios, 2000.

[7] Rating as per the ADB 'Climate Change Screening Report', 2014 (as presented in Annex 1).

The project and sub-projects are all rated as high risk and therefore warrant further assessment of potential impacts.

Table 2: Summary Risk Assessment

Risk Topic	Investment Program	UECP	NWCP	MLBCRP
A) Temperature increase	High	Medium		
B) Wild fire	Low			
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				

Source: PPTA Consultant adapted from AWARE analysis

19. The key risk topics include temperature increase rated high, precipitation increase, precipitation decrease, water availability, wind speed increase and onshore category 1 storms. The most relevant to the specific project activities and infrastructure include:

- **Temperature increase**; higher temperatures and heatwaves may increase crop water demand (due to higher evapotranspiration) and reduce crop productivity (due to temperature sensitivity).
- **Increased SWM precipitation** may lead to increased runoff and therefore erosion and siltation of water courses, reservoirs, and flooding and landslide events
- **Decreased NEM precipitation** may result in higher soil moisture deficits, and therefore increase irrigation demand and reduce crop yields.
- **Water availability** at local project command area level and for transfer from the Mahaweli River Basin is directly linked to the changes in precipitation above.
- **Wind speed increase:** high peak speeds may be associated with more extreme weather events particularly onshore storms.
- **Extreme events:** due to more frequent and intensified rainfall events.

III. ASSESSING ADAPTATION NEEDS AND OPTIONS

20. The adaptation measures appropriate to the project are derived in a three step process namely: impact, vulnerability and adaptation analysis.

21. Impact assessments are typically "top-down", drawing from largely global and regional climate change models to project future climate changes at the local level. The vulnerability assessment also takes into consideration observed current vulnerability and climate patterns, or a "bottom-up" assessment, for example trends based on information collected by meteorological

stations and experienced by local communities. Both of these carry with them a certain amount of uncertainty but together provide the best available knowledge, which can provide insights into decision making for adaptation.

22. Based on the above, an assessment of the various adaptation options (ideally including those already in practice) is made from expert opinion and stakeholder consultations. This is carried out on both engineering and non-engineering solutions, such as improved irrigation efficiency and water resource management, respectively. The options are then weighed against each other through a cost-benefit/cost-effectiveness analysis to help identify the most effective adaptation measures.

23. Consideration of the likelihood of climate change impacts based on current conditions and future trends are used to assess the most appropriate design and adaptation options. These priority adaptations will be implemented through the program and monitored through identified indicators. Given the uncertainties in projecting climate change, options which provide other co-benefits are likely to be lower risk. For this study, this latter step is presented in principal only and will be further developed during program implementation.

A. Impact Assessment

1. Recent Climate Trends

24. While there are a number of climate change parameters, the principal ones directly relevant to the project for the assessment of risk and adaptation measures are changes in temperature and rainfall.

25. The analysis of temperature records over a 100-year period shows an increase in air temperature in all meteorological stations from 1961 to 1990 (Fernando and Chandrapala, 1992). The rate of increase over this period is in the order 0.016ºC per annum or the equivalent of 1.6ºC per 100 years.

26. Rainfall in Sri Lanka is characterized by high annual variability with alternate dry and wet periods observed from 1880 until about 1970 and a significant reduction thereafter.[8] Over the period 1931 to 1990 the average annual rainfall is reported to have decreased from 2,005 mm to 1,861 mm, a decline of 7% (Jayatilake et al, 2005).[9] The decrease differed between seasons, with the highest decline in the March to April inter-monsoonal period. Also it was noted that intensities have strengthened and return period of extreme events appear to have become shorter.

27. Rainfall trends over the past 40 to 60 years for locations within the Mahaweli River Basin and project areas appear to agree with the decreasing trend.

28. Table **3** presents a summary rainfall trends for five locations: two within the upper basin 'wet' zone (Kotmale and Pologolla) and three in the 'dry zone' (Anuradhapura, Polonaruwa and Iranamadu). Annual rainfall within the upper basin over the past 60 years (1949-2010) has declined by 15 to 20% and in the lower basin by 7 to 8%. The rate of decline is generally greater

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[8] Ministry of Irrigation and Water Resources Management. 2010. *Sri Lanka Water Development Report: 2010*. Colombo.

[9] Jayatillake, H.M., Chandrapala, L, Basnayake, B.R.S.B, Dharmaratne, G.H.P, (2005). Water Resources and Climate Change. *Proceedings of the Workshop on Sri Lanka National Water Development Report*, World Water Assessment Programme, Paris.

for the SWM in both the upper and lower basins, at around 20%. While the decline for the NEM is about 6%. **Annex 3** presents the plots of annual rainfall for the five stations.

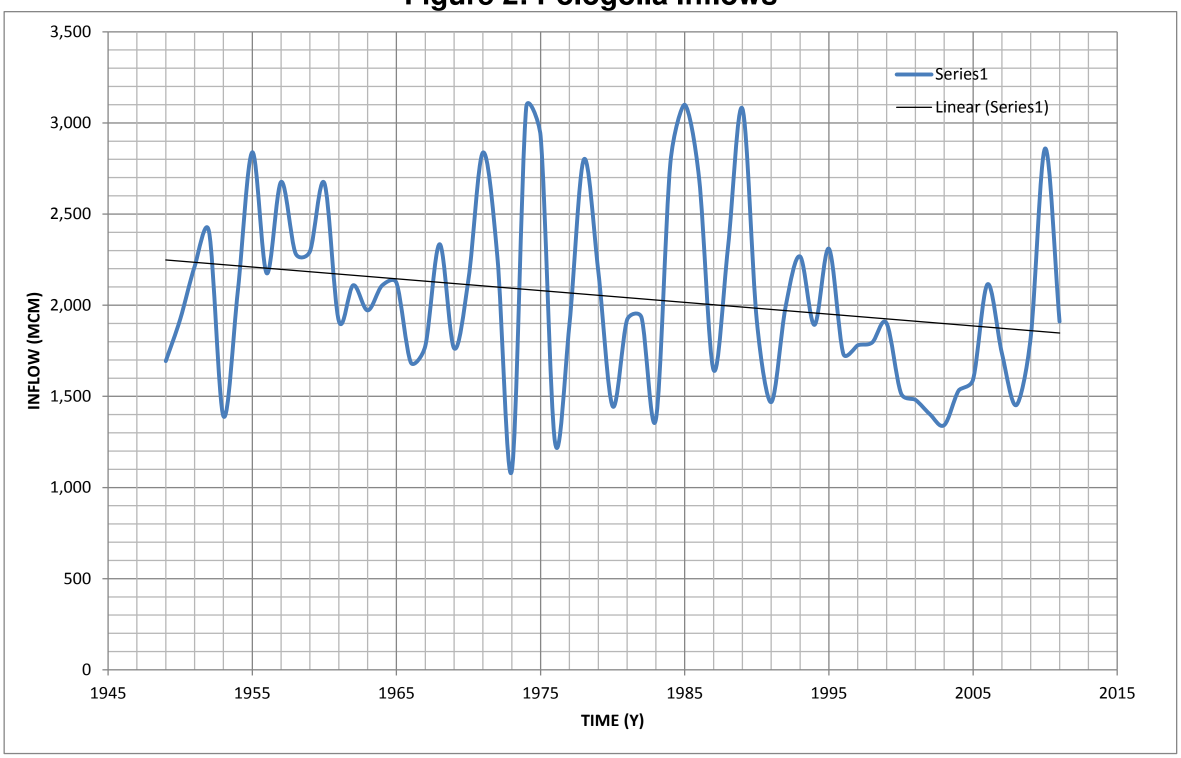
Table 3: Rainfall Trends between 1949-1959 and 2000-2010

Location	Zone	Annual		Maha (NEM)*		Yala (SWM)	
		MAP mm	%change	MAP mm	%change	MAP mm	%change
Kotmale	Wet	2,548	-20%	998	-12%	1,550	-25%
Pologolla	Wet	3,009	-15%	1,162	-8%	1,848	-20%
Anuradhapura	Dry	1,298	-7%	903	-1%	394	-19%
Polonnaruwa	Dry	1,656	-8%	1,284	-7%	372	-10%
Iranamadu	Dry	1,656	-4%	1,017	1%	264	-24%

MAP = Mean Annual Precipitation
* For the purpose of the analysis NEM is the period from October to March, and SWM April to September. Source: MASL rainfall records

29. The trend in rainfall is also reflected in the flow records for the Mahaweli River. A comparison on mean annual flow at Pologolla in the upper catchment shows that between the 1940s and 2000s annual average flow declined by about 20% (from 2,300 to 1,900 MCM).

Figure 2: Pologolla Inflows



Source: MCB – Water Balance Study

2. Climate Projections

30. Climate change projections vary between sources, models and emission scenarios.

31. Based on the HadCM3 circulation model and emission scenarios A2 and B2[10], De Silva (2013)[11] projects[12] an increase in SWM rainfall between 38% (A2) and 16% (B2) and a decrease in NEM rainfall between 34% (A2) and 26% (B2) by the 2050s and temperature increases of 1.5 to 2ºC, and maximum potential soil moisture deficit increase by 11% (A2) and 4% (B2). And goes on to recommend that adaptations focus on storage of excess run-off during the SWM for dry months and diversion if possible to the dry zone.

32. Muthuwaththa et al (2013)[13] projects (also based on HadCM3 model) an increase in mean annual precipitation (MAP) from 2,094 mm (from the baseline 1970-2000) to 2,249 mm by 2050 (7% increase). The impact on agro-ecological zones is a contraction of the dry zone area by 8% and increase in the intermediate zone by 22%, and with the extent of the wet zone unchanged.

33. In a 2010 IWMI publication[14] mean temperature is projected to increase by 0.9 to 4ºC (over the 1961-1990 baseline) by the year 2100, as a result Maha season irrigation water requirements for paddy could increase by 13 to 23% by 2050.

34. All models project an increase in mean annual temperature, with the A2 and B2 generally being within the range of 1.2 to 4ºC. However, rainfall projections are highly variable and contradictory, but with the majority projecting a higher MAP. Those projecting higher MAP envisage an increase in SWM rainfall, and decrease in NEM rainfall. De Silva (2006) projects MAP increase by 14% for A2 and 5% for B2 (baseline 1961-1990); a NEM rainfall decrease by 34 to 26% (for A2 and B2 respectively), and increase of SWM rainfall by 38% to 16% (for A2 and B2 respectively). The projections also infer an increase in the variability and intensity of rainfall events.

In the Second National Communication on Climate Change[15] the MOE reports a trend (1961-2000) of increasing temperature of up to 0.46ºC per decade (per station) and rainfall decline in all stations of 1.5 to 19 mm per year. And a projected temperature rise to 2100 of 2ºC (best estimate), consistent with IPCC values for South Asia. While rainfall changes are more complex and seasonally dependent, with an increase in MAP of between 400 mm (A2 scenario) to 133 mm, of which most is in the SWM. However, there are also projections of a decrease in MAP of 166 mm.

35. **Table 4** lists the estimated range of change in SWM rainfall by 2100 for three emission scenarios and three climate change models.

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[10] The B2 "*storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels*". IPCC Special Report, Emissions Scenarios, 2000.

[11] De Silva, C.S. 2013. Impact of Climate Change on Water Resources and Agriculture in Sri Lanka. *Climate Change Impacts and Adaptations for Food and Environmental Security, Proceedings of the International Conference Colombo,* Sri Lanka, 30-31st July 2013.

[12] Baseline of 1961 - 1990

[13] Muthuwaththa, L.P. and Liyanage, P.K.N.C. Impact of Rainfall Change on the Agro-Ecological Regions of Sri Lanka. *Climate Change Impacts and Adaptations for Food and Environmental Security*. *Proceedings of the International Conference,* Colombo, Sri Lanka, 30-31st July 2013.

[14] IWMI. 2010. *Impacts of Climate Change on Water Resources and Agriculture in Sri Lanka: A Review and Preliminary Vulnerability Mapping*. Report No. 135. International Water Management Institute, Colombo.

[15] MOE. 2011. *Sri Lanka's Second National Communication on Climate Change*. Ministry of Environment, Colombo.

Table 4: SWM Rainfall Changes (2100)

Changes in SWM Rainfall to 2100 (mm)				
Scenario	**HadCM3**	**CSIRO**	**CGCM**	**Mean***
A1FI	0 to 476	2 to 157	-190 to 6	-94 to 213
A2	0 to 403	2 to 133	-161 to 5	-180 to 80
B1	0 to 215	1 to 71	-86 to 3	-43 to 96

* Mean is the average of the minimum and maximum values for the three models.
Source: MOE, 2011 (Second National Communication on Climate Change)

36. The current trends and model projections for temperature indicate that it is most likely to increase over the project lifetime, to 2050 and beyond. As outlined above, the best estimate is an increase of up to 2ºC by 2100. As discussed below the project implications are likely to be an increase in irrigation water demand and potential adverse impact on crop productivity.

37. The situation regarding precipitation patterns is somewhat contradictory, with current trends indicating a general decline in rainfall over the past 60 or more years, and climate change models giving mixed projections of both higher and lower future rainfall. Though there appears to be consistency that in terms of seasonal change, with SWM precipitation increasing and NWM precipitation declining. Changes in precipitation would have a number of impacts on the project, lower rainfall would reduce water availability, both at field level (reduce effective rainfall) and basin level i.e. transfer from the Mahaweli, and higher rainfall would increase water availability and reduce irrigation demand, and therefore could be an opportunity for increased productivity (increase irrigated areas and higher cropping intensity). Changes in rainfall intensity may also have implications for system design, on duties of canals, cross drainage structures and reservoirs capacities.

B. Vulnerability Assessment

38. The goal of a vulnerability assessment is to identify current and future vulnerabilities and understand the key determinants of this assessed vulnerability.[16] '*Vulnerability refers to the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change.'*

39. The impact assessment shows the principal climate change effects likely to directly impact on the project are air temperature which impacts on water demand and agricultural productivity, and those related to precipitation; annual and seasonal changes and frequency and intensity of events, which determine water availability and hazard risks (droughts, flooding, landslides and siltation).

40. Reference to long-term studies done by IRRI's shows that rice yields dropped by 10% for each 1ºC increase in growing season minimum temperature in the dry season.[17] Thus, productivity would have to improve just to maintain the status quo; the design of the investment program provides support to the irrigation sector and to improve productivity and system efficiencies.

[16] ADB. 2012. *Guidelines for Climate Proofing Investment in Agriculture, Rural Development and Food Security*. Manila.
[17] Peng, S., et al. 2004. "*Rice yields decline with higher night temperature from global warming*." Proc. Nat. Academy of Sci., Vol. 101(27)9971-9975.

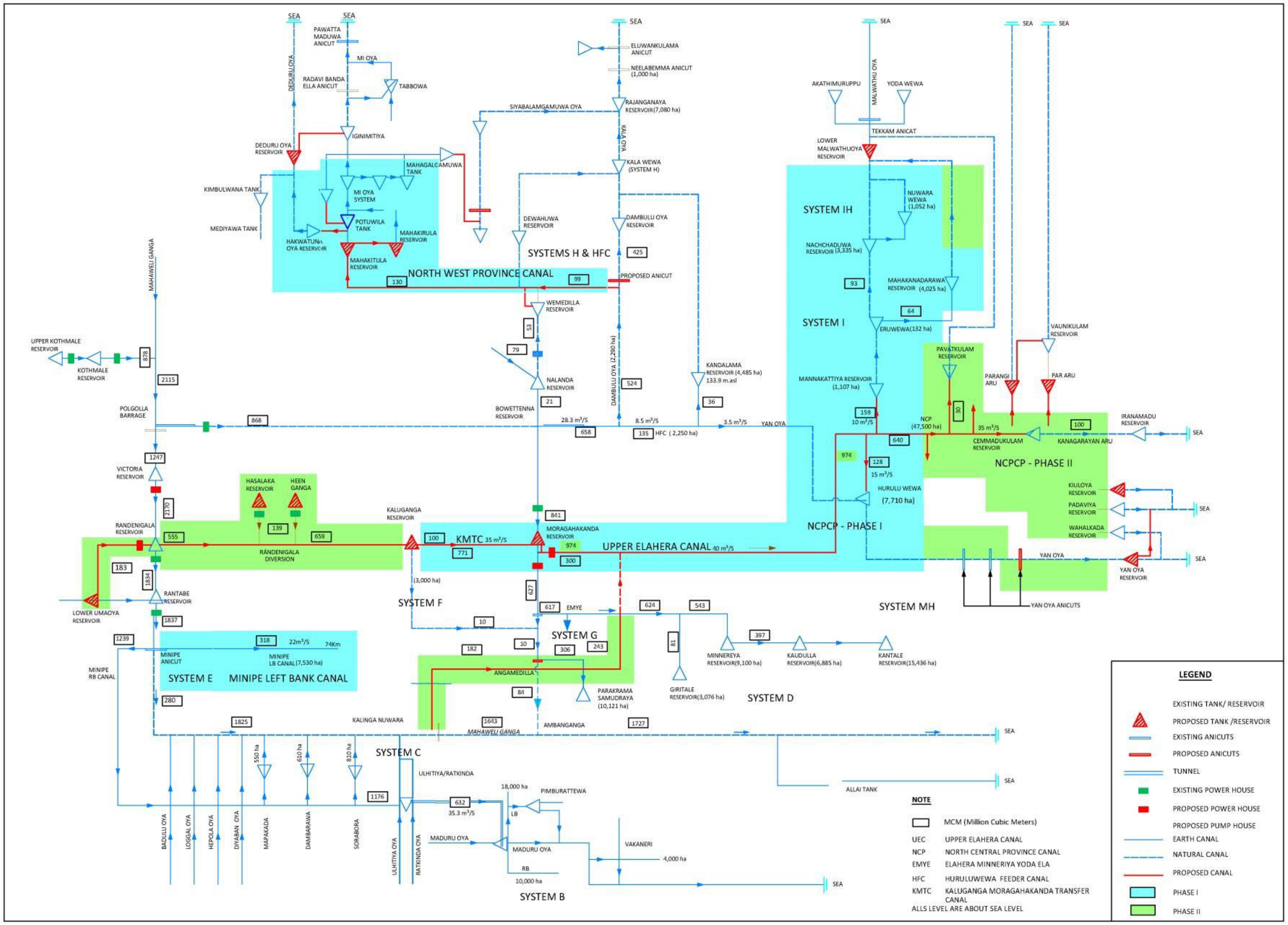
41. The approach to assessing vulnerability is to determine the sensitivity of the project to likely climate change driven changes in water demand and availability. Sensitivity was tested for the scenarios of **increased water demand** (Scenario 1) and **decreased water availability** (Scenario 2) at three levels (5%, 10% and 15%), which are likely to exceed likely change levels.

42. The scenarios were applied to the Mahaweli Water Balance model[18] over a 40-year time series, to determine the impact on scheme water balances, water availability and hydropower generation to Mahaweli Scheme at full development[19]. Figure 3 shows the scheme schematic layout to aid the following description.

[18] The Mahaweli Water Balance Model is a mathematical computer used for the planning and management of the Mahaweli Scheme. The model integrates scheme inputs, functions and outputs, including inflows, reservoir storage, hydropower generation and water issues (allocations) for irrigation and domestic drinking water supplies. It was developed in the 1980s by the Canadian consulting firm, ACRES, as a purpose-built package for MASL. It is used for preparation of seasonal operational plans (Maha and Yala) and system management. The model was used in preparation of the Water Balance Study Report (MCB, 2013) for assessment of development options for the NCPCP.

[19] This is as planned under the NCPCP.

Figure 3: Mahaweli Scheme Schematic



Source: MCB updated from Water Balance Study Report

43. The key points to note include:

(i) The supply side of the system is the Mahaweli Basin,[20] with an average annual flow volume of 5,474 MCM, and associated storage dams (Kotmale, Victoria, Randenigala and Rantambe (and Upper Uma Oya and Lower Oma Oya) cascade on the Mahaweli, and Nalanda, Bowatenne and Moragahakanda and Kalu Ganga[21] on the Amban Ganga, as well as the Hasalaka Oya and Heen Ganga on tributaries of the lower Mahaweli) with a combined storage volume of more than 2,700 MCM.

(ii) The points for water transfer from the Mahaweli to the northern areas include; Pologolla to the Bowatenne reservoir thence on to the Dambulu (including supply to the NWPC), Moragahakanda for transfer to the UEC, Randgenigala for transfer to the Kalu Ganga and onto the Moragahakanda, (and thence onto the UEC) and Kalinga Nuwara and Angamedilla for pumping to the EMYE, a diversion canal from Amban Ganga at downstream of Moragahakanda to feed Minneriya and Giritale Reservoirs and command area from the Mahaweli Ganga and Amban Ganga respectively (in lieu for water transfer upstream from the Amban Ganga to the UEC).

(iii) On the demand side the command areas in the investment program include the project areas (NWP and NCP), which are located in river basins to the north. The exception being the Minipe system on the Mahaweli left bank below the dam cascade.

44. The Mahaweli scheme is characterized by the high storage volume (more 50% of the mean annual volume) and the multiple transfer points, from the Pologolla in the upper catchment, Randenigala below the main dam cascade and (planned) pumping from the lower catchment at Kalinga Nuwara. The multiple storage dams and multiple transfer points offer a number of options for system operation to optimize water transfer and hydropower generation. There are well established operating rules for both, and which vary according to reservoir levels (rule curves) and levels of irrigation and hydropower demand. Under normal operating conditions the first criteria is to maintain hydropower production, and secondly to optimize water deliveries for irrigation according to priority rules, riparian and development order.

45. The scheme design and operation include water allocations for irrigation based on not exceeding three progressive levels of service reliability,[22] these are:

- *Irrigation failure* (occurs when the supply deficit exceeds 5% of Yala seasonal demand[23]) should not exceed 20%
- *Significant failure* (occurs when the supply deficit exceeds 10% of Yala seasonal demand) should not exceed 10%
- *Total failure* (occurs when the supply deficit exceeds 20% of Yala seasonal demand) should not exceed 5%

46. The scheme and operation enables a number of options to meet water demand, both for irrigation and hydropower under a range of water supply situations. In essence the scheme under normal hydrological conditions has more than enough water to meet demands with average annual available volume of 5,500 MCM compared annual demand of 3,700 MCM. However, one constraint is to maintain hydropower generation and water availability during prolonged droughts.

[20] The Mahaweli basin includes the Mahaweli Aru and Amban Ganga (major tributary of the Mahaweli Aru).
[21] The Moragahakanda Reservoir is currently under construction. Kalu Ganga Reservoir scheduled for construction and the Lower Uma Oya, Hasalaka and Heen Ganga planned for as part of the NCPCP.
[22] Over the forty year modelled period 1971 - 2010
[23] The Yala season is the critical period for water demand within the command areas.

47. The potential impacts of climate change were tested under two scenarios at three levels as listed below. The approach was to look at a range of possible impacts so to provide an indication of the scale of impacts as the basis for determining the scale of necessary adaption measures, if any. However, it is stressed that this is only indicative of the potential impacts only.

48. The scenarios and levels assessed are:

(i) Scenario 1: Increase in water demand; irrigation demand is a function of the crop water demand and effective precipitation. Crop water demand was determined based on estimated crop evapotranspiration (calculated using the reference evapotranspiration (ETo) and crop coefficient (Kc) approach). A rise in air temperature will lead to an increase in crop evapotranspiration. Effective rainfall is dependent not only the total quantity but also on the frequency and intensity of rainfall events. The projection of lower NEM precipitation and greater variability of precipitation mean that effective rainfall is likely to decline within the project command areas (dry zone) and therefore increase irrigation demand. The magnitude of the demand increase is likely to be of the order of 5 to 15%, therefore to establish a likely range of impacts three levels of increase were assessed; +5%, +10% and +15%.

(ii) Scenario 2: Decrease in water availability from the Mahaweli Scheme. While the general consensus is that annual water demand will increase, though with a seasonal shift, the current trend is of decreasing rainfall and inflows, and there are projections of decreased supplies. A decline in rainfall, and consequently run-off, could have a significant impact on the water supply for the investment program and the scheme as a whole. Therefore, to test the potential vulnerability a decrease in inflows was assessed at three levels; -5%, -10% and -15%.

49. A third potential scenario is for increased water availability in the Mahaweli scheme due to the projected increase in annual precipitation, and specifically in SWM precipitation. This is likely to increase benefits for the project through additional water resources for consumptive use, irrigation and drinking water and hydropower generation, and could be further investigated during project implementation. However, the present assessment conducted during the PPTA is based on Scenarios 1 and 2 above, as these are most likely to require adaptation measures.

50. The increase in irrigation demand was applied as a percentage increase in reference evapotranspiration (for the six main climate stations), and thus carried through into irrigation water demand and combined system demand.

51. The decrease in water availability was applied to inflow values at the key flow nodes including Kotmale, Pologolla, Victoria, Randenigala, Lower Uma Oya, Rantambe and Kalinga Nuwara.

52. The model output includes: (i) the number of years for the three reliability criteria over the modelled period (40 years) that were not met; (ii) the volume of water pumped at Kalinga Nuwara to compensate for upstream diversions (at Pollonuwara and Randenigala) to the NWPC and UEC; and (iii) the scheme's annual energy production. **Annex 4** presents the scenario output tables.

53. A summary of the assessment of increased irrigation demand (Scenario 1) for the sub-projects, with the NCP divided between major and minor systems is shown in **Table 5**. The highlighted cells (yellow) occur when the irrigation reliability criteria have been exceeded in 8, 4 and 2 years (out of 40 years) for 5%, 10% and 20% of Yala season respectively. It shows full

reliability at 5% ETo increase for all sub-projects, and full reliability for both the NCP major systems and MLBC at the higher demand levels. However, partial failure for the NCP minor and NWP systems occurs at a 10% ETo increase, and full failure at a 15% ETo increase. As discussed in the next section, there are a number of adaptation options that can be adopted to reduce demand and increase supply reliability.

54. A point to note with the simulation is that impacts on reliability between the sub-projects and other systems with the Mahaweli Scheme point to the fact that allocation rules vary between systems, with those with prior riparian rights ranked higher (such as MLBC) and more recent additions to the scheme ranked lower.

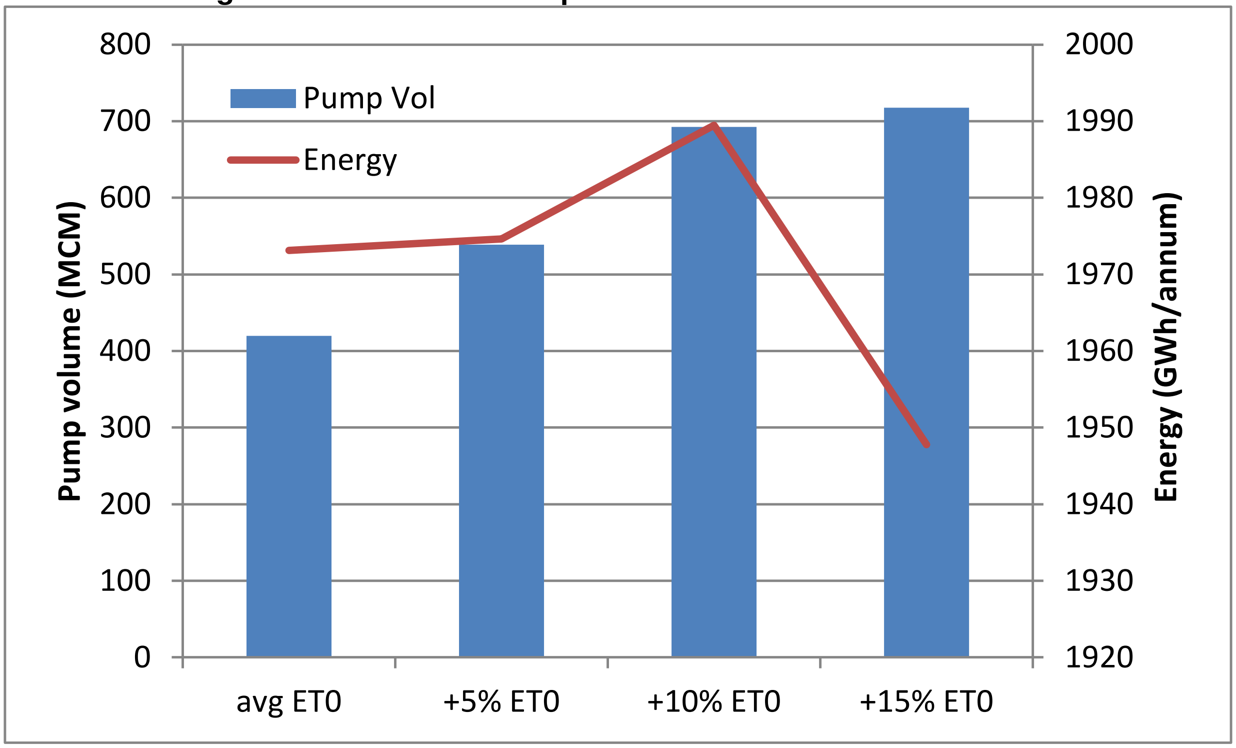
55. Figure 4 shows the increase in pumping from the Lower Mahaweli at Kalinga Nuwara needed to compensate for addition diversion of water to meet the increase in irrigation demand within the scheme as a whole. The base case annual volume of 400 MCM would have to increase to about 700 MCM with an increase of in crop water demand of 15%, which would create an additional scheme cost. There is little impact on the hydropower generation, with a decline by only 1% due to the additional water diverted upstream at Pologolla to meet increased demand.

Table 5: Scenario 1 – Increased Irrigation Demand (Number of Failure Events)

Scheme	Eto Increase		+15% ET0						+10% ET0						+5% ET0						avg ET0					
	Season		Yala			Maha			Yala			Maha			Yala			Maha			Yala			Maha		
	Failure criteria		8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2
	Yala	Maha	A43A			A43A			A42A			A42A			A41A			A41A			A40A			A40A		
	Issue	Issue	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%
NCP (major)	151	123		0			0			0			0		4	2	2	2	2	1	3	2	1	2	1	1
NCP (minor)	343	301	20	10	6	6	4	2	10	7	2	4	4	0	2	2	0	1	0	0	2	1	0		0	
NWP	115	102	36	27	8	2	2	1	12	3	1	3	3	1	3	2	2	1	1	0	3	3	1	1	1	0
MLBC	223	124	3	1	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0

Source: MCB – Water Balance model simulation

Figure 4: Scenario 1 - Pumped Volume and Power Production



Source: MCB – Water Balance model simulation

56. The results of the assessment for a decrease in inflow for water transfers (Scenario 2) is shown in Table 6 with the highlighted cell (yellow) showing when reliability criteria have been exceeded. It shows a similar result to the increase scenario of increased irrigation demand, with no failures for the 5% decline in inflows, but with failure at the 10% and 15% for NCP minor cascades and NWP. The NCP major cascades and MLBC remain reliable at the 10% and 15% levels.

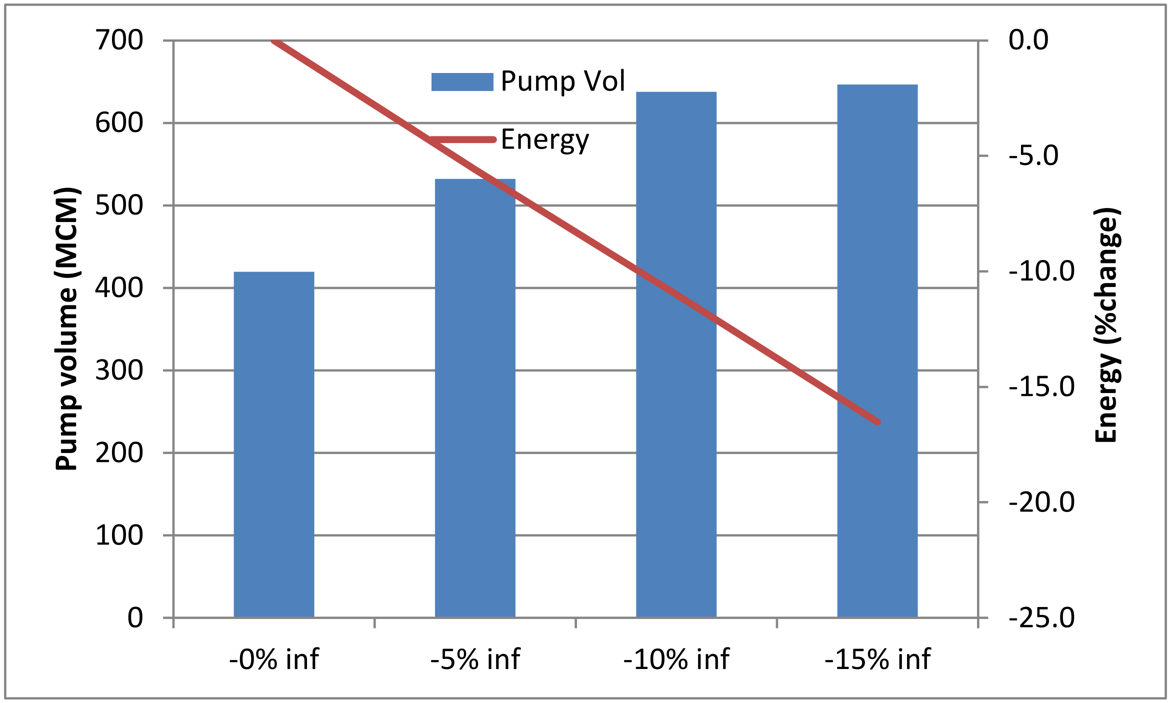
57. A similar trend to Scenario 1 is shown in Figure 5 for Scenario 2 which indicates that increased volumes of water have to pumped at Kalinga Nuwara to compensate for increased diversion upstream at Pologolla and Randenigala. Energy production progressively declines due to the lower volumes of water with the system, by 16% of annum generation with a 15% reduction in inflows.

Table 6: Scenario 2 – Decreased Water Availability (Number of Failure Events)

Scheme	Info		-15% inf						-10% inf						-5% inf						-0% inf					
	Season		Yala			Maha			Yala			Maha			Yala			Maha			Yala			Maha		
	Failure criteria		8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2
	Yala	Maha	A53A			A53A			A52A			A52A			A51A			A51A			A50A			A50A		
	Issue	Issue	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%
NCP (major)	137	114	5	2	0	1	1	0	3	2	0	1	1	0	2	2	2	1	1	1	3	2	1	2	1	0
NCP (minor)	323	285	15	11	6	4	4	2	4	4	2	2	1	0	1	1	1		0		2	1	0		0	0
NWP	109	96	15	13	5	2	1	0	11	8	4	1	1	0	4	4	2	1	1	0	3	3	1	1	1	0
MLBC	213	120	1	1	0	0	0	0	1	0	0	0	0	0		0		0	0	0	1	0	0	0	0	0

Source: MCB – Water Balance Model

Figure 5: Scenario 2 - Pumped Volume and Power Production



Source: MCB – Water Balance model simulation

58. In addition to increased water demands for irrigation, temperature rise may also adversely impact on rice production. Rice is highly sensitive to temperature during the reproductive stage, with significant increases in grain sterility occurring when temperatures reach above 34ºC.[1] This is more likely to occur during the Yala season, when temperatures can exceed this threshold. Given that rice is the principal crop within the project areas (and in Sri Lanka) any decline in productivity could adversely impact on project area's financial and economic performance, as well as household food security and income. However, what is not clear from the current literature is the likely level of yield impact with varying estimates. In some cases it is speculated that the effect of temperature rise will be partially offset by plant response to higher CO_2 levels. Therefore, while there is potential for a decline in rice productivity it is not possible with a reasonable degree of certainty to assess the probability or scale of such an impact (spatially). However, as outlined in the next section there are potential adaptation measures that could be implemented should this potential become a reality.

59. Changes in precipitation with higher intensity storm events may result in higher run-off and flood events. A potential project impact could be higher flood flows than those applied in irrigation and dam designs, particularly for the design of spillways and cross drainage structures. Typically, these structures are designed for an event magnitude (based on real and/or calculated data) and return period (1 in 100 years for cross drainage up to 1 in 10,000 years for major dam spillways).

[1] Horie T., J.T. Baker, H. Nakagawa, T. Matsui. and H.Y. Kim. (2000). Crop Ecosystem Responses to Climatic Change: Rice. In: *Climate Change and Global Crop Productivity*. (Editors K.R. Reddy and H.F. Hodges). CAB International, Wallingford, UK. pp. 81-106.

C. Adaptation Assessment

60. ADB (2012)[2] states that "*the purpose of adaptation assessment is to identify and prioritize the most appropriate adaptation measures to incorporate into the project. This includes the identification of strategies to minimize damages caused by the changing climate and to take advantage of the opportunities that a changing climate may present".*

61. Potential climate adaptation options in the agriculture sector can be classified into four groups (ADB, 2012): (i) engineering options (structural; specifications, design standards, irrigation etc.); (ii) non-engineering (management, operation, maintenance, capacity building etc.); (iii) biophysical (plant breeding); and (iv) maintaining the status quo (ie, 'do nothing'). The following paragraphs outline a number of adaptions options for the potential project climate change vulnerabilities.

62. Options for adapting to an <u>increase in water demand</u> include:

- Improve irrigation efficiencies[3] to reduce overall irrigation demand. The current system efficiencies are low due in part to significant conveyance losses (estimated to be of the order of 30-40% some project areas), and there is considerable room for improvement through investments in canal and water control infrastructure (at cascade tank and farm levels).
- Reduce cropping intensities.[4] A reduction in cropping intensity would reduce overall irrigation demand, and however, while relatively low cost to administer this would reduce project and farm benefits.
- Improve cascade system water management. There is potential for improvement of the scheduling of irrigation diversions to reduce losses to percolation and drainage, thus improve system conveyance efficiency.
- Improve farm irrigation management; current application efficiencies are reportedly low and there is potential to improve on-farm irrigation scheduling. Introduce low water demanding farming techniques such as alternative wetting and drying for paddy.
- Change cropping regimes; the promotion of lower water demand and higher value cropped (vegetables) is part of the ongoing development planning, which should reduce water demand.

63. Options for adapting to a <u>decrease in water availability</u> include:

- Reduce irrigation demand using the above options.
- Increase water storage capacity. There is some potential to increase storage capacity within the project command areas through construction of new reservoirs and heightening of existing tanks.

64. Options for adapting to a <u>decrease in rice productivity</u> include:

- Improve farming practices; changes to on-farm practices such adjustments to planting dates to avoid flowering during high temperature periods, and selection of more heat tolerant varieties
- Improved plant breeding; the development of heat tolerant varieties less sensitive to peak temperatures.

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[2] ADB. 2012. *Guidelines for Climate Proofing Investment in Agriculture, Rural Development and Food* Security. Manila

[3] Engineering option

[4] Non-engineering option

- Crop diversification; as mentioned above there is potential for diversification to other more profitable crops with lower water demand as is planned under the Stage III of the NCPCP.

65. Options for adapting to an <u>increase in flood risks</u> include

- Design standards; review current design standards for water infrastructure (dams, cross drainage and protection) to verify compliance with potential increase in flood event magnitudes and return periods and if necessary (during project implementation) modify detailed design.
- Water resources management; improve catchment and river basin management to better capacity, planning and monitoring to reduce flood risk.

D. Implementation

66. During project implementation the above options will be further developed within the investment program to support improved water resources and irrigation planning and management, within the project areas and more generally within the Mahaweli Basin. These components consist of two major consultancy packages:

(i) Improving System Water Use Efficiencies and Water Productivity (ISEWP). The primary purpose of the component is the formulation of a strategy for the improvement of water use efficiency and productivity of the cascade tank irrigation systems. This will be achieved through a comprehensive assessment of case example systems (within the NWPC, NCPCP and MLBCR project areas) to identify current constraints, physical and non-physical, towards improving irrigation water use and farm productivity and the development of a program for irrigation system and on-farm improvements. This will be achieved through system and field assessments and in consultation with key stakeholders. The range of improvements is anticipated to be physical improvements to system and on-farm irrigation infrastructure and non-physical irrigation and farm management. The component will integrate climate adaptation options into the assessment of improvement options and analysis of cost and benefits of improvements.

(ii) Strengthening of Integrated Water Resources Management (SIWRM). The objective of this component is to support the improvement of capacity for integrated water resources management at basin, trans-basin and national levels, with a specific focus on the Mahaweli Basin and the greater Mahaweli scheme (including the NCPCP and NWPC). It is envisaged this will include the updating of the current scheme simulation modeling and management and operation plans, to refine and improve current planning procedures and operational rules. This process will also include the assessment of and planning for prospective climate change conditions and options are presented above.

67. Both of the above components shall take into account anticipated climate change issues including quantification of impacts and benefits, cost benefit analysis of options and formulation of suitable implementation programs.

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ANNEX 1: CLIMATE CHANGE SCREENING

Water Resources Development Investment Program – **Sri Lanka**

Climate Change

Under the A2 scenario, average annual mean temperature within the Mahaweli Basin is projected to rise 1.8^{0}C by 2050s. Annual precipitation is projected to increase 85mm (4.2%). Precipitation in the December-April period (largely corresponds to the Northeast Monsoon) is projected to decrease by 3.8% while an increase of 11% is proejcted for the May-November period which corresponds to the Southwest Monsoon.

Climate-Sensitive Components

1). Changes in Hydrology of the River Basin and Reduced Water Availability.
A significant amount of rainfall in the upper catchment of Mahaweli Basin has been observed to have declined by 39.12% during the past century consequently the stream flow in the Mahaweli Basin is declining. Under the A2 scenario, total annual runoff within the upper catchment is projected to decrease by 2050s and the reduction is much greater during the Northeast Monsoon. Water availability is very likely to be affected by climate change if the current trend continues.

2). Reduction in Reservoir Capacity due to Siltation
The projected increase in Southwest Monsoon precipitation is likely to cause exacerbated soil/bank erosion within the upper catchment resulting in reduced water storage capacity.

Draft Report

C Y Ji
February 17, 2014

Date: 2014-02-11

Project Information				
Project Title/Number	**Country/Province**	**Sector/Type/Sections**	**Modality**	**Stage**
Water Resources Development Investment Program /47381	Sri Lanka/	Agriculture/water Resources Management	MFF	Concept Paper
Project Components	**1**). Construction of Kaluganga - Moragahakanda Transfer Canal with capacity of 771M m^3/yr to downstream irrigation and water supply schemes; **2**). Construction of Upper Elahera Canal which will annually convey up to 974M m^3 northwards from Moragahakanda Reservoir along a 70km canal to the existing Huruluwewa and Mannakattiya reservoirs which feed existing irrigation and water supply schemes; **3**). Construction of North Western Province Canal and associated infrastructure to withdraw 130M m^3 from Dambulu Oya River and the existing Nalanda Reservoir to command new and existing irrigation and water supply reservoirs located throughout North Western Province via 80km of new and upgraded canals; **4**). Minipe Anicut heightened, and Left Bank Canal and associated infrastructure rehabilitated (located downstream of the Mahaweli Hydro Power Complex on the Mahaweli River). The project will add upstream storage by heightening the headwork's weir by 4 meters to regulate generation inflows, and rehabilitate the 76km left bank canal to improve conveyance and reliability of service to existing farmers.			
	Climate Projection – 2050s/A2/Multi-Model Ensemble Mean			**Maps**
Temperature	The baseline (1960-1990) average annual mean temperature within the Mahaweli River Basin is about 24.55^0C. Seasonal variation is weak, the highest occurs in May (~26^0C) and lowest in January (22.7^0C). Temperature varies strongly with elevation and is substantially lower within the upper catchment (~18^0C). Average annual mean temperature in 2050s is projected to rise by 1.8^0C under the A2 scenario. Temperature rise is projected to be lower during August-January period (<1.8^0C) and higher during the rest of the year. The highest temperature rise is projected for the month of April (>2^0C). No marked spatial variation in temperature rise is projected.			Map 1
Precipitation	Annual total precipitation within the Mahaweli River Basin is about 2054mm (baseline, 1960-1990, WorldClim). The upper catchment is endoewed with much high precipitation (>2,400mm). Annual precipitation is projected to increase by 85mm (or 4.2%) under the A2 scenario by 2050s. The increase is proejted to be higher within the lower catchment (>4%) and lower in the upper catchment (<4%). Precipitation in the December-April period (corresponds to the Northeast Monsoon is projected to decrease by 3.8% while an increase of 11% is proejcted for the May-November period which corresponds to the Southwest Monsoon. A study[1] using Statistical Downscaling Model (SDSM 4.2) for a neighboring basin (Kelani) arrived at similar results.			Map 2
Natural Hazards				
Type	**Risk/Score**	**Evaluation**	**CC Implications**	**Maps**
Landslide Triggered by Precipitation[2]	Medium	Annual precipitation within the upper catchment area is high	Increased intensity of storms during the monsoon season has been observed during	Map 3

[1] Silva, S. B. Weerakoon, Srikantha Herath, Analysis of future rainfall trebds in the Kelani River Basin under the impact of climate change. Water Board of Sri Lanka.

[2] Slow moving slides have significant economic consequences for constructions and infrastructure, but rarely cause fatalities.

		(>2400mm). The Left Bank Canal downstream from the Mahaweli Hydropower Complex appears to be prone to landslides due to excessive rainfall and steep slopes of the central hills.	the past decades. Under the A2 scenario, precipitation during the Southwest Monsoon in 2050s is projected to increase by about 11%. When the HadCM3 model is used alone, annual runoff in the wet zone is expected to increase by 40 to 100% and the risks of landslide and flooding are expected to be much exacerbated[3].	
Flood	Medium/High	All project sites are prone to flash floods[4]. There is high risk for the Left Bank Canal downstream from Mahaweli Hydropower Complex. Other project sites appear to be under moderate risk.	Under the conditions of rising temperature, precipitation is more likely to arrive in the form of heavy rains accompanied by an increase in flood risk[5,6,7,8,9]. Flood risks are very likely to aggravate in the future.	Map 4
Drought	Medium/High	A large part of the island is drought prone from February to April and, if the subsidiary rainy season from May to June is deficient, drought may continue into September. North-Central and Northwestern provinces are prone to high risk of drought. Droughts occur in the south-eastern, north-central and north-western areas of Sri Lanka mainly due to low rainfall during monsoons. Droughts of a serious nature occur every	Sri Lanka has recently been experiencing prolonged and frequent dry spells or drought periods as a result of increased variability of seasonal rainfall coupled with increased temperatures[11]. Increased frequency of dry periods and droughts are expected[12]. Increased precipitation intensity and variability are projected to increase the risk of both flooding and drought in any area[13].	Map 5

[3] De Silva C. S., 2009. Impact of climate change predictions on food production in Sri Lanka and possible adaptation measures. Abstract of the National Symposium on promoting knowledge transfer to strengthen disaster risk reduction and climate change adaptation, BMICH, Colombo, p7.
[4] Our experiences strongly suggest that the actual flood hazard is much underestimated and underrepresented by the global flood hazard dataset at local scales. This is largely due to the relatively coarse spatial resolution at which the dataset was compiled.
[5] Allen, M. R., and W. J. Ingram, 2002. Constraints on the future changes in climate and the hydrological cycle, Nature, 419, 224–232, doi:10.1038/nature01092.
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		3-4 years and severe droughts of national significance occur every 10 years or so. In 2004, the north-western, north-central and south-eastern provinces experienced severe drought. It also affected hydropower generation[10].		
Overall Scoring	**Multi-Hazard Index**	Standard Deviation	Category	
	Medium		**B/C**	
Sector-Specific Climate Risks				
Sensitive Components	**Climate Variable**	**Climate Change Analysis**		
Capacity of Reservoirs	Changes in the amount and intensity of precipitation; Flooding; Increased soil erosion	Climate change may impose a negative impact on reservoir capacity due to projected increase in both the amount and intensity of Southwest Monsoon. Large-scale deforestation occurred in the Upper Mahaweli Catchment (UMC) during the last 2 centuries for plantation agriculture and the watershed is exposed to severe soil erosion and landslides. The rate of soil loss on hill slopes and sediment yields in the streams of the UMC indicates that the anthropogenic activities have increased rates of ongoing erosion by more than 100 times over the rate of natural erosion. Mahaweli River and its tributaries carry enormous amounts of sediments during the rainy seasons, both as bed and suspension loads downstream and a large amount is deposited in the reservoirs leading to a reduction of their storage capacities[14]. Climate change-related weather aberrations (e.g. high precipitation events and longer dry periods) also aggravates land erosion in the upper and mid catchments causing sedimentation of reservoirs leading to reduced storage capacity[15]. The Multi-Model Ensemble projects an increase of 11% in Southwest Monsoon precipitation. Increased intensity of precipitation will exacerbate soil erosion particularly from rain-fed cultivation lands (tea, rubber, coffee, cocoa, vegetables, etc.) in the UMC leading to more sedimentation load. Erosion of river banks is also likely to be worsening due to projected increase in river flow during intensive rainfall events. The reservoirs within the upstream areas (Minipe Anicut, Kalu Ganga Dam, Nalanda Reservoir, and Moragahakanda Reservoir) are likely to be affected the		

[11] UNDP, 2007. Managing risks of a changing climate to support development. Report of the Asia Regional Workshop 23-26 April 2007, Kathmandu, Nepal.
[12] Department of Meteorology/ Adapted from the National Adaptation Strategy 2011-2016.
[13] IPCC, 2007. Executive Summary.
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[15] World Food Programme. Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin of Sri Lanka.

	2). Water availability is likely to be affected by the changing precipitation pattern.	
Project's Relevance to Climate Change		
	Irrigation agriculture is the mainstay of Sri Lanka's rural economy. The need for water for irrigation and domestic use is particularly acute in the downstream of Mahaweli River. Due to projected increase in temperature, dry-zone boundary being pushed outward, bringing more land under lower rainfall regime. The combined effect of higher temperatures and less rain is projected to lead to a greater than 11% loss in revenue from paddy by 2050[22]. It has been reported that if the current rate of irrigation water use continues in the future several districts with major irrigated rice areas will have severe water scarcities according to IWMI criteria by the year 2025. Some districts will be in serious water scarce conditions so that the available water resources may not be adequate to meet their projected demand[23]. Water predictions for Sri Lanka indicate that water scarcity will increase[24]. The projected precipitation change in Sri Lanka for 2080 indicates that the entire dry and intermediate zones, which represent 75% of the island, are projected to become drought prone with 30% less rainfall in worst hit areas if the prevailing climate change trends continue[25]. Sustenance of systems, particularly in the Mahaweli River Basin of Sri Lanka that contributes towards the majority of food production in the country are identified as critical areas of focus to ensure long-term food security in the country[26]. Diverting and transferring water from the central hills region to major irrigation schemes within the dry zone through the construction of reservoirs and canal networks is indispensable to sustain rice production (especially during the Yala season as precipitation at the beginning of the season – April is projected to decrease) and provide adequate drinking water supply. Rehabilitation of dams and river banks would minimize wastage through leakage, avoid water related disasters, and ensure water security. The proposed project is therefore classified as an adaptation project.	
	Recommendations	
	Rainfall variability is by far the most important contributing factor to increased climate risk in the Mahaweli Basin[27]. As such, water availability is very likely to be affected by climate change if the current trend continues. Understanding climate and environment at sufficiently small scales is necessary to understand hydrological variability and change. The project team is advised to factor in the impact of climate change on future scenarios of water availability and its seasonal variability during project design (e.g. reservoir capacities) as well as implementation (e.g. water allocation). The risks of natural hazards (landslides and flooding) may also need to be taken into account during project design.	

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[23] Senanayake Nanda & M.T.M.D.R. Perera, Global climate change: Effect on agriculture food sector in Sri Lanka in the year 2025.
http://sci.martinkoechy.de/Climate_Change_and_the_Middle_East_2006_Proceedings/05_land_use_systems.pdf
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[27] Expert views presented at the Project Design Workshop, hosted by Ministry of Environment, Kandy, September 31 to October 1, 2011.

		most.	
Water Resources		Mahaweli is the longest river in Sri Lanka and serves as a principal source of water for irrigation in the dry zone. A significant amount of rainfall in the upper catchment of Mahaweli Basin has been observed to have declined by 39.12% during the past 100 years[16]. A 16.6% reduction is estimated for the next 21-year period which is expected to severely affect power generation, agriculture and domestic use[17]. While there are large year-to-year fluctuations, the stream flow within the basin has been observed to be declining. The existing reservoirs constructed on the basis of historical stream flow have only filled up three times in two decades[18]. Over the last 50 years, the stream flow into Victoria Reservoir has declined by 40%, and rainfall declined by 30%. Much of Victoria's capacity cannot be used as was the case[19]. In the tropical humid regions, runoff regimes are very much influenced by the timing and duration of the rainy season or seasons. Climate change therefore may affect river flows not only through a change in the magnitude of rainfall but also through possible changes in the onset or duration of rainy seasons (such as those caused by monsoon) (IPCC, 2007). For mid-latitudes and some subtropical regions, the general increase in evaporation means that some areas that see an increase in precipitation will experience a reduction in river runoff (IPCC, 2007). The results from the monthly water balance model simulation indicate a decrease (>5%) in total annual runoff within the upper catchment by 2050s under the A2 scenario, and 14% reduction within the middle and lower catchment area. Reduction in runoff is projected to be much greater during the Northeast Monsoon. Additionally, the river flow within Mahaweli Basin is strongly influenced by ENSO[20].	
Summary of Screening Results			
Natural Hazard	Climate change in the Mahaweli Basin is manifested in increased natural disasters such as landslides, drought, and floods, increased land degradation in the upper and mid elevations which are attributable to both temperature increase and rainfall variability[21]. 1). Landslides: The risks of landslide appear to be higher within the Left Bank Canal project area. 2). Flooding: Projected increase in Southwest Monsoon precipitation and increase in the intensity of extreme weather events are likely to aggravate the risks of flooding.		
Project Components	1). Siltation of reservoirs due to flooding and soil/bank erosion.		

[16] Shantha, W.W.A., and Jayasundara J.M.S.B. Study on Changes of Rainfall in the Mahaweli Upper Watershed in Sri Lanka, Due to Climatic Changes and Develop a Correction Model for Global Warming. http://stabilisation.metoffice.com/posters/Shantha_WWA.pdf.
[17] Shantha, W.W.A., and Jayasundara J.M.S.B. Study on Changes of Rainfall in the Mahaweli Upper Watershed in Sri Lanka, Due to Climatic Changes and Develop a Correction Model for Global Warming. http://stabilisation.metoffice.com/posters/Shantha_WWA.pdf.
[18] https://www.jamstec.go.jp/frcgc/jp/publications/news/no19/eng/topic3.html.
[19] https://www.jamstec.go.jp/frcgc/jp/publications/news/no19/eng/topic3.html.
[20] IRI (International Research Institute for Climate Prediction), Climate Risk Management in the Mahaweli River Basin, Sri Lanka. http://iri.columbia.edu/~lareef/reports/MahaweliRiverBasin/CRMinMahaweliRBrev2.pdf.
[21] World Food Programme. Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin of Sri Lanka.

ANNEX 2: AWARE RISK ASSESSMENT

aware
Aware for Projects

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™ 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:	SRI: Water Resources Development Investment Program
SUB PROJECT:	WRDIP
REFERENCE:	Concept Paper
SECTOR:	Agriculture
SUB SECTOR:	Irrigation (surface & groundwater) and drainage
DESCRIPTION:	

02

Chosen Locations

1) Sri Lanka
2) Sri Lanka
3) Sri Lanka
4) Sri Lanka

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.

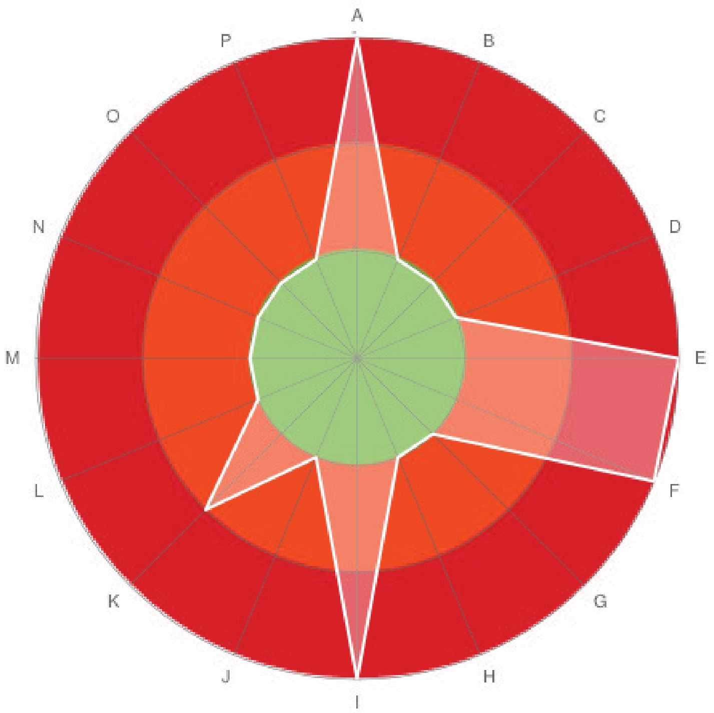
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher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

TEMPERATURE INCREASE

ACCLIMATISE COMMENTARY

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

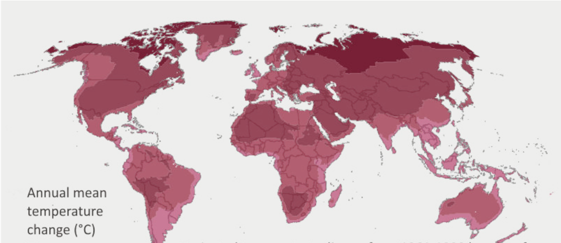
• The project is considered to have high sensitivity to increased temperature and there is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of 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 do not agree that seasonal temperature will increase beyond 2 ˚C in the project location.
• 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.

05 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.

06
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.

07
HIGH RISK

PRECIPITATION DECREASE

ACCLIMATISE COMMENTARY

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

• The project is considered to have high 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.

08
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.

09

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:

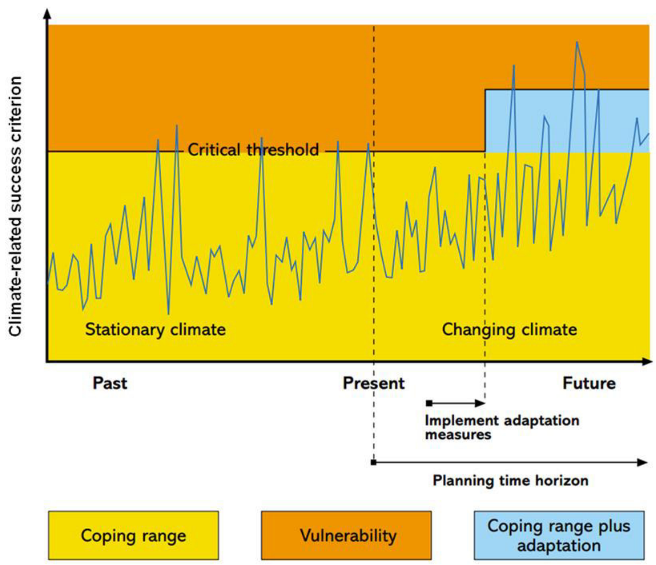
Model agreement and uncertainty:

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:



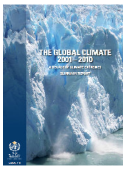
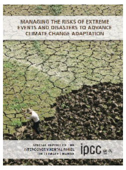
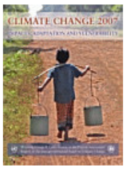
The relationship between a critical threshold and a climate change related success criterion for a project. [Source: Willows, R.I. and Connell, R.K. (Eds.) (2003). *Climate adaptation: Risk, uncertainty and decision-making*. UKCIP Technical Report, UKCIP, Oxford].

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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Aware for Projects

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™ 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:	Sri Water resources Development Project
SUB PROJECT:	Upper Elehera Canal
REFERENCE:	Concept paper
SECTOR:	Agriculture
SUB SECTOR:	Irrigation (surface & groundwater) and drainage
DESCRIPTION:	Irrigation

02 Chosen Locations

1) Sri Lanka

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.

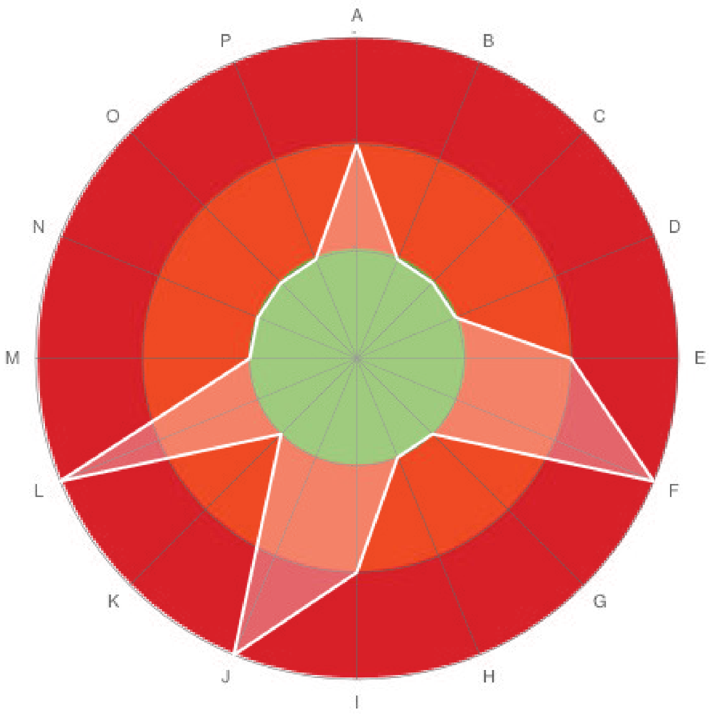
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher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

aware
Aware for Projects

04
HIGH
RISK

FLOOD

ACCLIMATISE COMMENTARY

Our data suggest that the project is located in a region which has experienced recurring major flood events in the recent past. A high exposure in Aware means that between 1985 and 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.

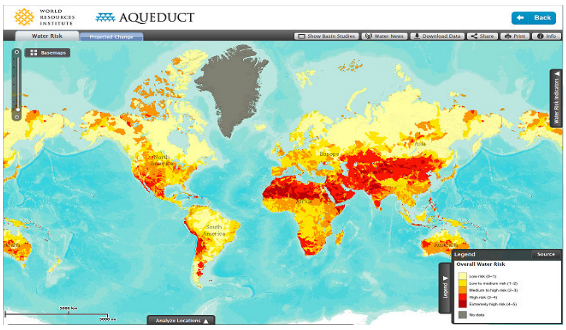
☐ I have acknowledged the risks highlighted in this section.

05

HIGH RISK

WATER AVAILABILITY

ACCLIMATISE COMMENTARY



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

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

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

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

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

3. What next?

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

☐ I have acknowledged the risks highlighted in this section.

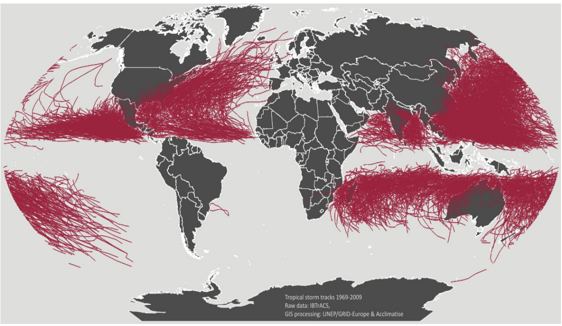
aware
Aware for Projects

06

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.

07
MEDIUM RISK

TEMPERATURE INCREASE

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

Chosen Answer

Cannot answer.

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

ACCLIMATISE COMMENTARY

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

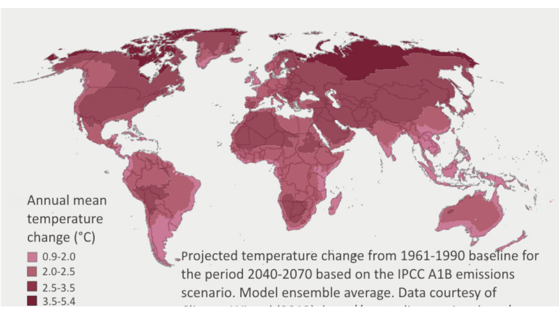
• Although you have stated that you could not answer whether the project is sensitive to increases in temperature it is recommended that you consider that an increase in mean seasonal and annual temperature could have implications for a number of hazards.
• There is a potential for an increase in incidences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

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

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

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

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



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 model projections do not agree that seasonal temperature will increase beyond 2 ˚C in the project location.
• 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.

Climate Wizard (2013), http://www.climatewizard.org/.

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.

08
MEDIUM RISK

PRECIPITATION INCREASE

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

Chosen Answer

Cannot answer.

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

ACCLIMATISE COMMENTARY

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

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

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

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

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

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

• If you want to know more about projected changes in the project location across a range of GCMs and 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

PRECIPITATION DECREASE

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

Chosen Answer

Cannot answer.

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

ACCLIMATISE COMMENTARY

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

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

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of 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?

• 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.

10

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:

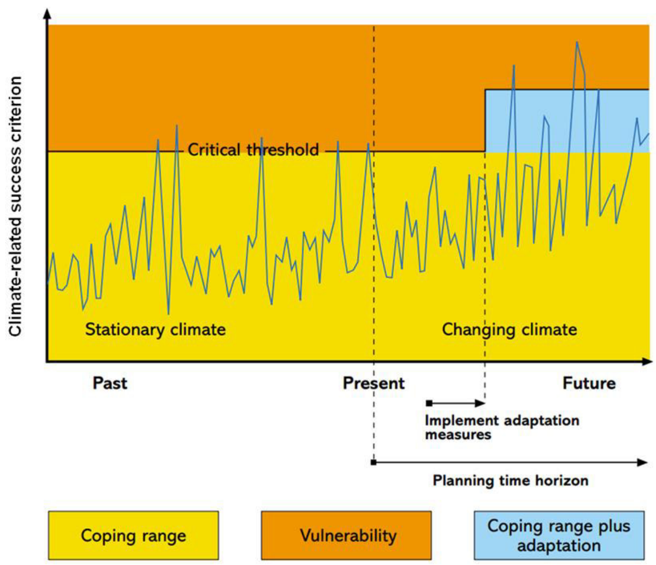
Model agreement and uncertainty:

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:



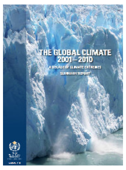
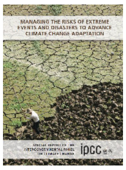
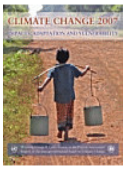
The relationship between a critical threshold and a climate change related success criterion for a project. [Source: Willows, R.I. and Connell, R.K. (Eds.) (2003). *Climate adaptation: Risk, uncertainty and decision-making*. UKCIP Technical Report, UKCIP, Oxford].

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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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:	SRI Water Resources Development Investment Program
SUB PROJECT:	North Western Province
REFERENCE:	Concept Paper
SECTOR:	Agriculture
SUB SECTOR:	Irrigation (surface & groundwater) and drainage
DESCRIPTION:	Irrigation

02 Chosen Locations

1) Sri Lanka

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[TM]. Projects with a final “High risk” rating are always recommended for further more detailed climate risk analyses.

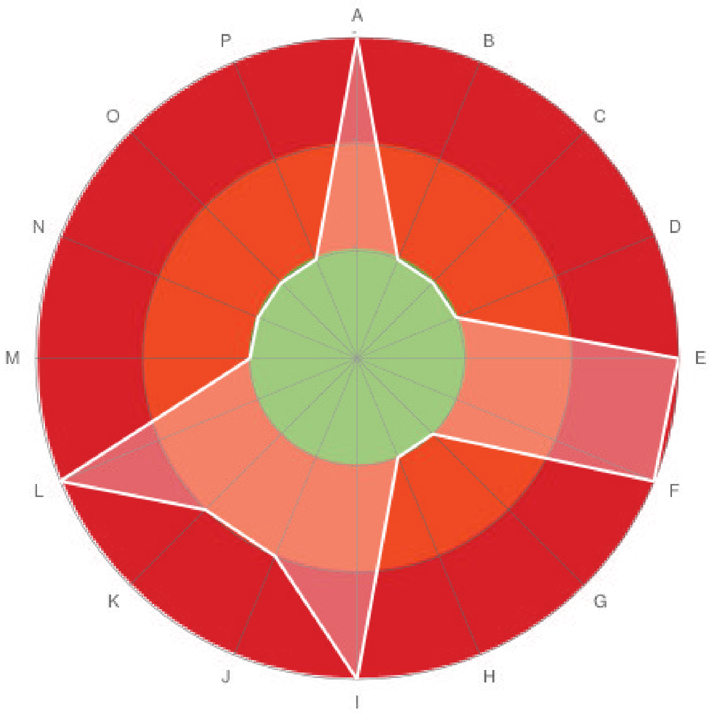
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher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

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

Final project 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

TEMPERATURE INCREASE

ACCLIMATISE COMMENTARY

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

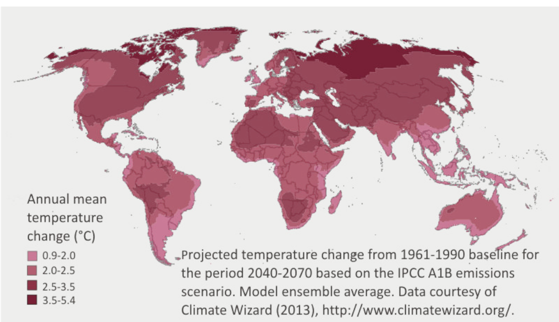
• The project is considered to have high sensitivity to increased temperature and there is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of 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 do not agree that seasonal temperature will increase beyond 2 ˚C in the project location.
• 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.

05

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 do not agree that seasonal precipitation will increase 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 decrease (see elsewhere in the report for more details of projections related to precipitation decrease).
• 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.

06
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.

07
HIGH
RISK

PRECIPITATION DECREASE

ACCLIMATISE COMMENTARY

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

• The project is considered to have high 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.

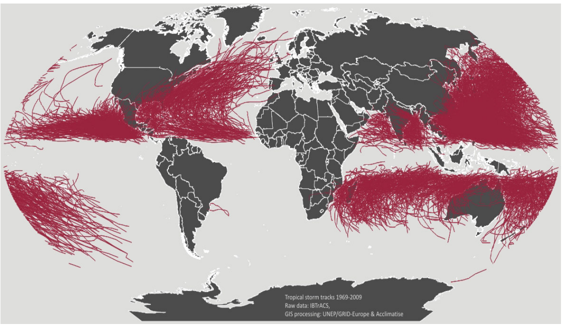
☐ I have acknowledged the risks highlighted in this section.

08

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?

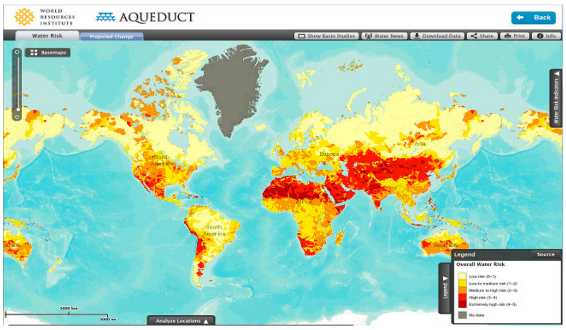
• See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
• Click here or here for the latest news and information relating to storms and climate change.

☐ I have acknowledged the risks highlighted in this section.

09
MEDIUM RISK

WATER AVAILABILITY

ACCLIMATISE COMMENTARY



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

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

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

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

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

3. What next?

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

☐ I have acknowledged the risks highlighted in this section.

10
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.

11

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:

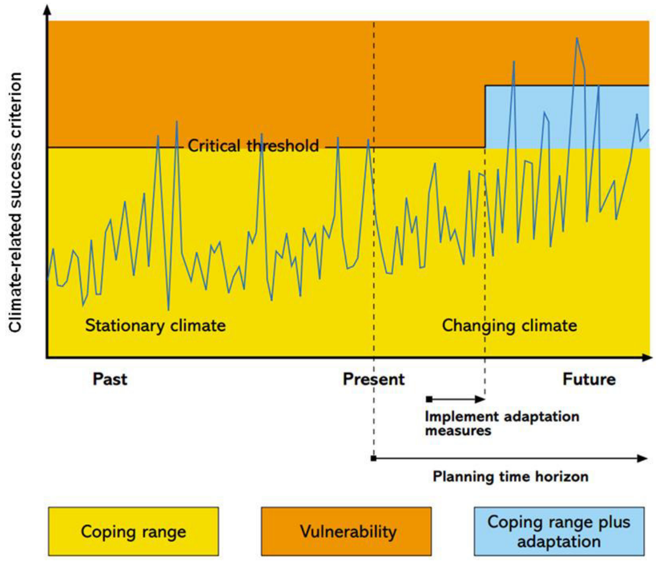
Model agreement and uncertainty:

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:



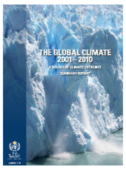
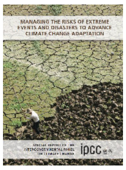
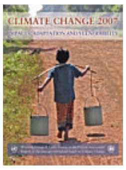
The relationship between a critical threshold and a climate change related success criterion for a project. [Source: Willows, R.I. and Connell, R.K. (Eds.) (2003). *Climate adaptation: Risk, uncertainty and decision-making*. UKCIP Technical Report, UKCIP, Oxford].

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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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™ 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:	SRI: Water Resources Development Investment Program
SUB PROJECT:	Minipe Anicut and left bank canal
REFERENCE:	Concept paper
SECTOR:	Agriculture
SUB SECTOR:	Irrigation (surface & groundwater) and drainage
DESCRIPTION:	

02

Chosen Locations

1) Sri Lanka

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.

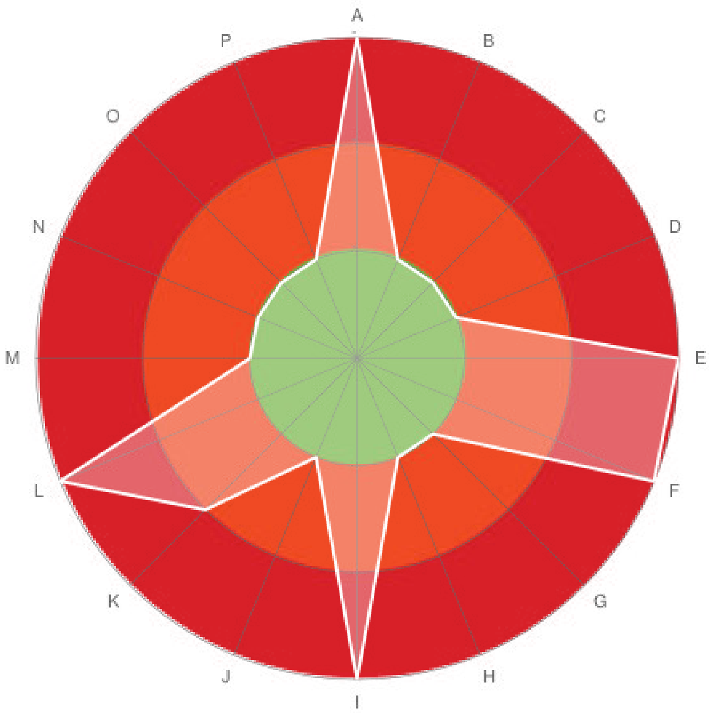
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher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

TEMPERATURE INCREASE

ACCLIMATISE COMMENTARY

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

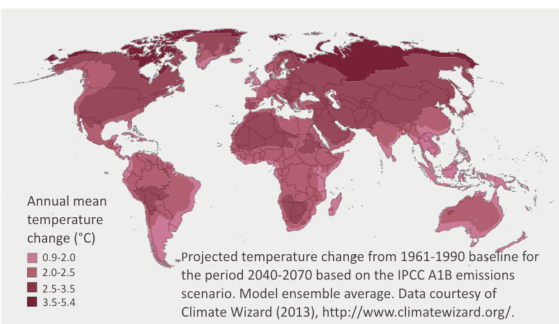
• The project is considered to have high sensitivity to increased temperature and there is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of 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 do not agree that seasonal temperature will increase beyond 2 ˚C in the project location.
• 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.

05
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.

06

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.

07
HIGH
RISK

PRECIPITATION DECREASE

ACCLIMATISE COMMENTARY

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

• The project is considered to have high 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.

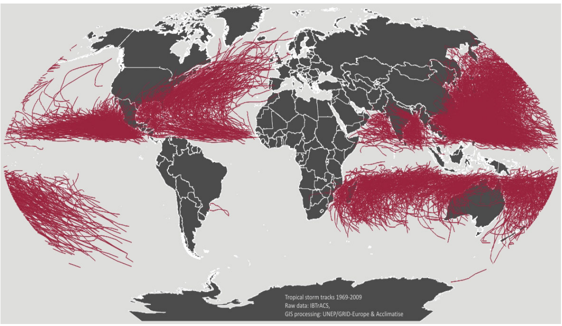
☐ I have acknowledged the risks highlighted in this section.

08

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.

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

The sections above detail all High and Medium risks from Aware™. 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:

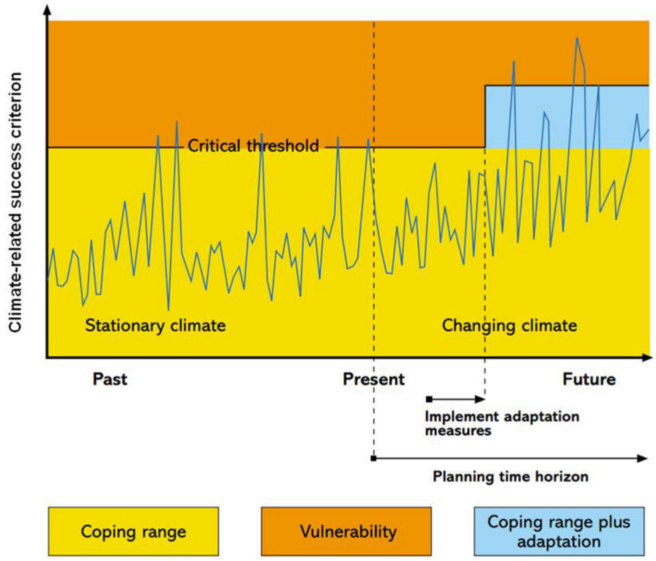
Model agreement and uncertainty:

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:



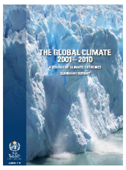
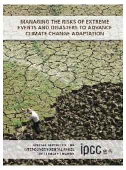
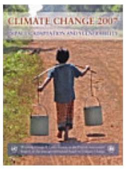
The relationship between a critical threshold and a climate change related success criterion for a project. [Source: Willows, R.I. and Connell, R.K. (Eds.) (2003). *Climate adaptation: Risk, uncertainty and decision-making*. UKCIP Technical Report, UKCIP, Oxford].

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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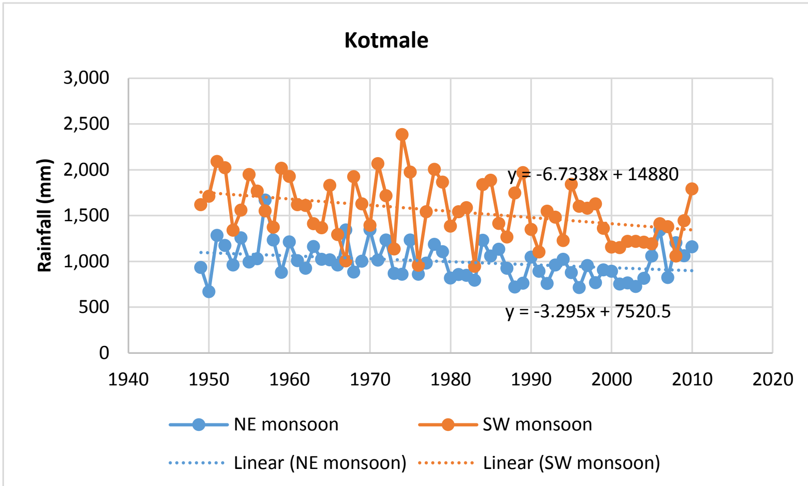
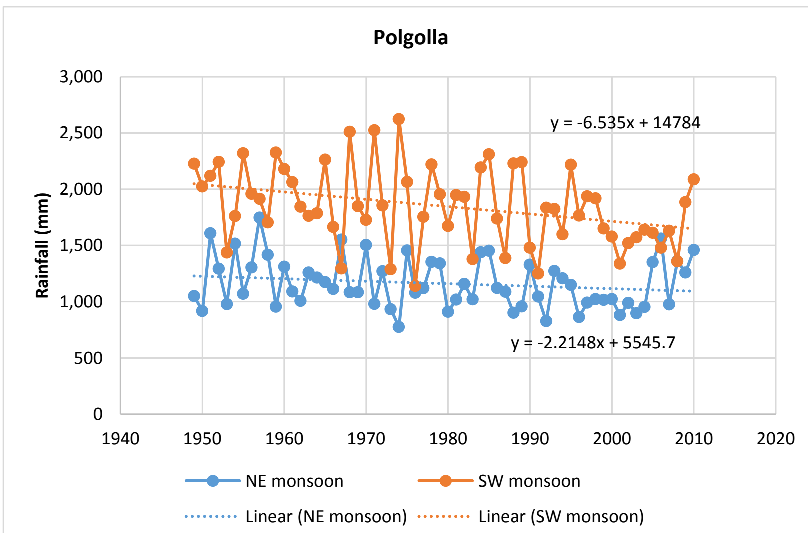
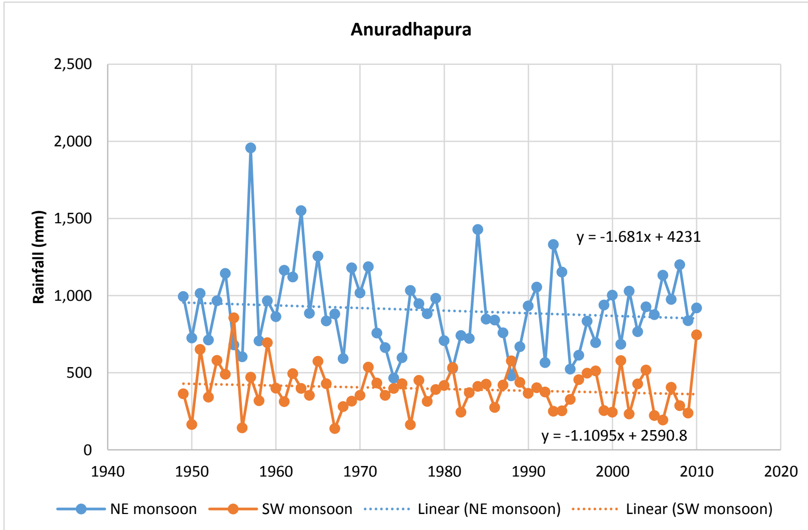
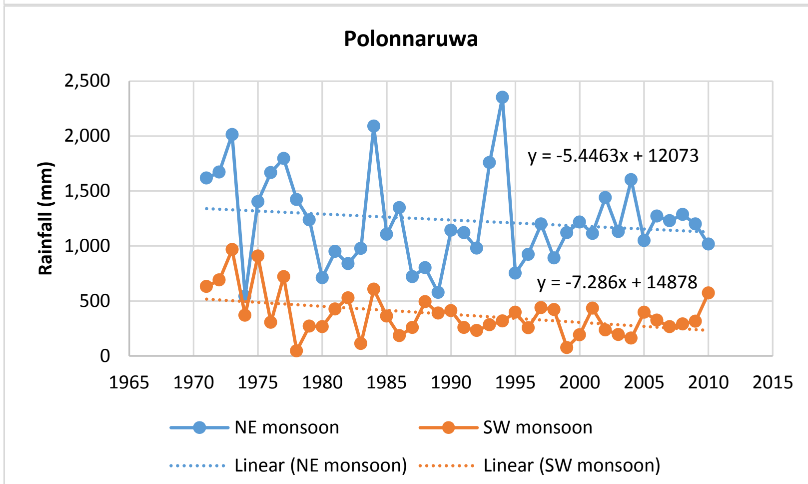
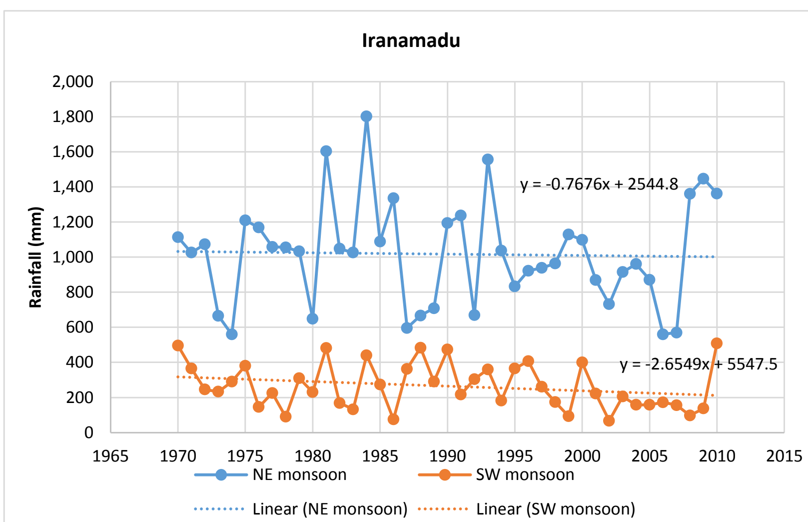
ANNEX 3: RAINFALL TRENDS






Anuradhapura
Rainfall (mm)
2,500
2,000
1,500
1,000
500
0
1940
1950
1960
1970
1980
1990
2000
2010
2020
y = -1.681x + 4231
y = -1.1095x + 2590.8
NE monsoon
SW monsoon
Linear (NE monsoon)
Linear (SW monsoon)


Polonnaruwa
Rainfall (mm)
2,500
2,000
1,500
1,000
500
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
y = -5.4463x + 12073
y = -7.286x + 14878
NE monsoon
SW monsoon
Linear (NE monsoon)
Linear (SW monsoon)


Iranamadu
Rainfall (mm)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
y = -0.7676x + 2544.8
y = -2.6549x + 5547.5
NE monsoon
SW monsoon
Linear (NE monsoon)
Linear (SW monsoon)

ANNEX 4: VULNERABILITY ASSESSMENT

Scenario 1 – Increase in Irrigation Demand

Scheme	Eto Increase		+15% ET0						+10% ET0						+5% ET0						avg ET0					
	Season		Yala			Maha			Yala			Maha			Yala			Maha			Yala			Maha		
	Failure criteria		8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2
	Yala	Maha	A43A			A43A			A42A			A42A			A41A			A41A			A40A			A40A		
	Issue	Issue	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%
KalawewaRB	284	266	9	4	2	2	1	0	8	4	2	1	0	0	8	4	1	1	0	0	4	3	1		0	
KalawewaLB																										
KalawewaYE																										
DambuluOya	26	18	1	1	1		0			0			0		2	2	2		0		1	1	1		0	
Kandalama	43	37	1	1	1		0			0			0		5	3	2	1	0	0	3	3	0		0	
Huruluwewa	81	56	1	1	1		0		1	1	1		0		2	2	1		0		2	1	1		0	
Nachchaduwa	51	31	1	1	1		0		1	1	1		0		1	1	1		0			0			0	
Nuwarawewa	15	9		0			0			0			0			0			0			0			0	
Tisawewa	5	6		0			0		1	1	1		0			0			0			0			0	
Allai	149	130	1	0	0		0			0			0			0			0			0			0	
System B	489	352	1	1	0		0			0			0		1	0	0		0			0			0	
SYSTEM B-RB				0			0			0			0			0			0			0			0	
System C	489	262	4	3	2		0		3	2	1		0		4	2	1		0		1	1	1		0	
Minneriya	102	64		0			0			0			0			0			0			0			0	
Giritale	50	29		0			0			0			0			0			0			0			0	
Kaudulla	86	42		0			0			0			0		4	3	1		0		1	1	0		0	
Kantale	205	115	4	3	2	1	1	0	2	2	0	1	0	0	5	3	1	1	1	1	4	3	1	1	1	0
PSS	158	109	3	2	0	2	1	0	1	0	0	1	0	0		0		1	0	0		0			0	
Minipe LB	223	124	3	1	0		0		3	0	0		0		1	0	0		0		1	0	0		0	
System G	128	87	1	1	1		0		1	1	1		0		2	2	2		0		2	1	1		0	
KHF	53	41	8	4	1	1	0	0	10	2	1		0		2	2	2		0		2	2	2		0	
Manankattiya	13	10.3		0			0			0			0			0			0			0			0	
Eruwewa	2	1.1		0			0			0			0			0			0			0			0	
Mahakandarawa	48	38.9	2	2	1	1	0	0	2	1	0		0		4	4	1		0		3	3	2		0	
Kalu Ganga	51	26.5		0			0			0			0			0			0			0			0	
NCP2(major)	151	123		0			0			0			0		4	2	2	2	2	1	3	2	1	2	1	1
NCP1(minor)	343	301	20	10	6	6	4	2	10	7	2	4	4	0	2	2	0	1	0	0	2	1	0		0	
NWP(minor)	115	102	36	27	8	2	2	1	12	3	1	3	3	1	3	2	2	1	1	0	3	3	1	1	1	0

Source: MCB – Water Balance model simulation

Scenario 2 – Decrease in Water Availability

Scheme	Info		-15% inf						-10% inf						-5% inf						-0% inf					
	Season		Yala			Maha			Yala			Maha			Yala			Maha			Yala			Maha		
	Failure criteria		8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2	8	4	2
	Yala	Maha	A53A			A53A			A52A			A52A			A51A			A51A			A50A			A50A		
	Issue	Issue	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%
KalawewaRB	266	252	6	4	1		0		5	3	1		0		7	3	1		0		4	3	1		0	
KalawewaLB																										
KalawewaYE																										
DambuluOya	25	17	1	1	1		0		1	1	0		0		2	2	2		0		1	1	1		0	
Kandalama	41	35	4	3	1		0		2	2	2		0		3	3	2		0		3	3	0		0	
Huruluwewa	76	53	1	1	1		0		1	1	1		0		2	2	2		0		2	1	1		0	
Nachchaduwa	48	29	1	1	1		0		1	1	1		0		2	1	1		0			0			0	
Nuwarawewa	14	9		0			0			0			0			0			0			0			0	
Tisawewa	5	5		0			0			0			0			0			0			0			0	
Allai	140	122		0			0			0			0			0			0			0			0	
System B	464	337	1	1	1		0		1	0	0		0			0			0			0			0	
SYSTEM B-RB				0			0			0			0			0			0			0			0	
System C	462	250	5	4	3		0		3	3	2		0		3	2	1		0		1	1	1		0	
Minneriya	95	61		0			0			0			0			0			0			0			0	
Giritale	47	27		0			0			0			0			0			0			0			0	
Kaudulla	80	39	3	2	1		0		1	0	0		0		1	1	0		0		1	1	0		0	
Kantale	188	104	6	4	2	1	0	0	4	3	2		0		4	2	1	1	0	0	4	3	1	1	1	
PSS	148	103		0		1	0	0		0			0			0			0			0			0	
Minipe LB	213	120	1	1	0		0		1	0	0		0			0			0		1	0	0		0	
System G	122	84	2	2	1		0		2	2	0		0		4	3	2		0		2	1	1		0	
KHF	49	39	2	2	2		0		1	1	1		0		2	2	2		0		2	2	2		0	
Manankattiya	12	9.7		0			0			0			0			0			0			0			0	
Eruwewa	2	1.1		0			0			0			0			0			0			0			0	
Mahakandarawa	45	36.7	2	2	1		0		2	1	0		0		4	3	2		0		3	3	2		0	
Kalu Ganga	49	25.3		0			0			0			0			0			0			0			0	
NCP2(major)	137	114	5	2	0	1	1	0	3	2	0	1	1	0	2	2	2	1	1	1	3	2	1	2	1	
NCP1(minor)	323	285	15	11	6	4	4	2	4	4	2	2	1	0	1	1	1		0		2	1	0		0	
NWP(minor)	109	96	15	13	5	2	1	0	11	8	4	1	1	0	4	4	2	1	1	0	3	3	1	1	1	

Source: MCB – Water Balance model simulation