AWCI Training Course on Improved Bias Correction and Downscaling Techniques for Climate Change Assessment including Drought Indices

18-20 JUNE 2013, UNIVERSITY OF TOKYO

# Estimation of Future Design Rainstorm under the Climate Change Scenario in Peninsular Malaysia

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# Objective of Technical Guideline

- To assist engineers, hydrologists and decision makers in designing, planning and developing water-related infrastructure under changing climatic conditions.
- To introduce an approach of quantifying the scale of climatic change to surface water systems.
- The main purpose of this guideline is to derive climate change factor (CCF)
- CCF – defined as the ratio of the design rainfall for each of the future periods (time horizons) to the control periods (present rainfall)

## FLOOD RISK MANAGEMENT & CLIMATE CHANGE

## Sub-Catchment of River Drainage System – what is really needed?


**Design Floods Estimation**

- Event based data - calibration & validation
  - Rainfall
  - Flood flow
  - Evaporation
- Design based information
  - **Design rainstorm – Intensity - Duration-Frequency (IDF)**
  - Design floods by means of rainfall-runoff model
  - **Design floods by means of regional frequency analysis**
- Area-Reduction Factor

- **Historical design rainstorm/flood need to be updated**
- **To use recent data**
- **To incorporate with climate change factor**

# Technical Approach

**Part 1**

**IDF formulation**

**Obtain observed annual maximum rainfall over various durations** → **Review, update & reformulate IDF relationships (1970 – 2007)**

**Part 2**

**Derivation of CCF**

STEP 1:
**Obtain downscaled climate data projection**

- Statistical Downscaling Model: 18 GCMs (2046-2065)
- Dynamic Downscaling Model: RegHCM-PM (2025-2034, 2041-2050)

STEP 2:
**Bias correction of downscaled data**

STEP 3:
**Derivation of CCF**

STEP 4:
**Disaggregation of 1-day design rainfall to short duration and reformulation of IDF Curves**

STEP 5:
**Rainfall-runoff modelling: Obtain future $Q_p$**

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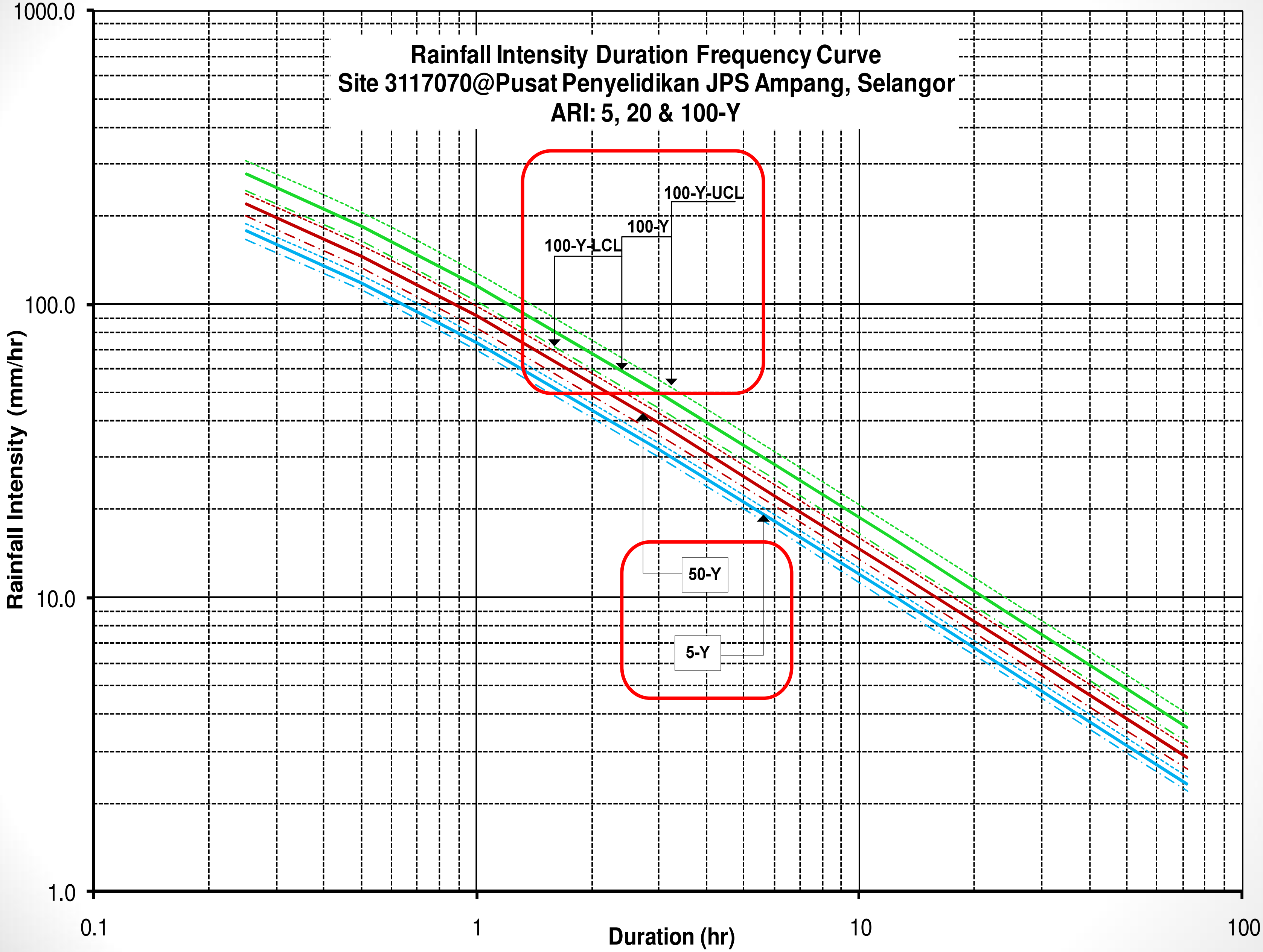
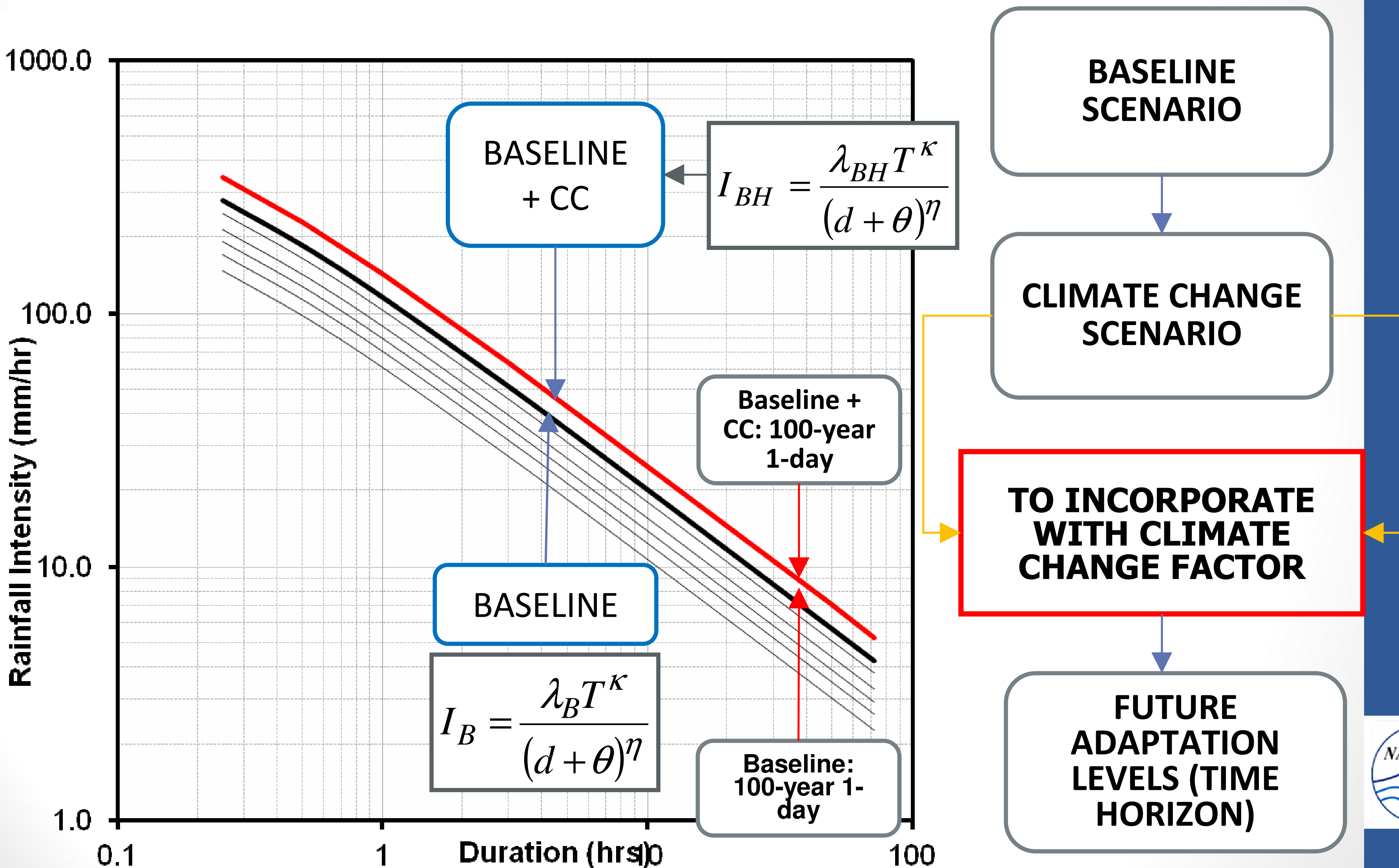
# IDF Stations

# Derived New IDF Curve




1000.0
100.0
10.0
1.0
0.1
1
10
100
Rainfall Intensity (mm/hr)
Duration (hrs)
BASELINE + CC
$I_{BH} = \frac{\lambda_{BH} T^{\kappa}}{(d+\theta)^{\eta}}$
Baseline + CC: 100-year 1-day
BASELINE
$I_B = \frac{\lambda_B T^{\kappa}}{(d+\theta)^{\eta}}$
Baseline: 100-year 1-day
BASELINE SCENARIO
CLIMATE CHANGE SCENARIO
TO INCORPORATE WITH CLIMATE CHANGE FACTOR
FUTURE ADAPTATION LEVELS (TIME HORIZON)

# Derivation of CCF

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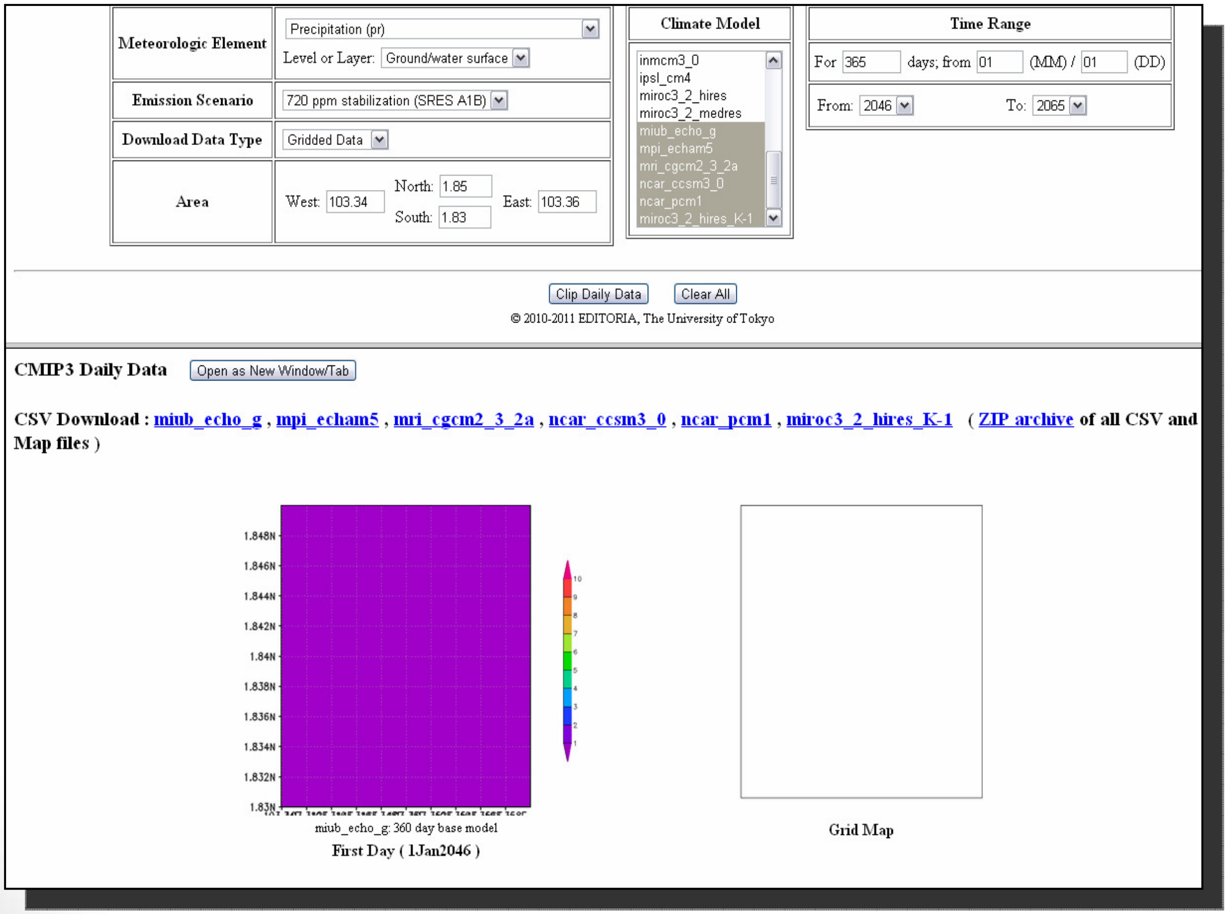
# STATISTICAL DOWNSCALING MODEL

**GCM from DIAS system**

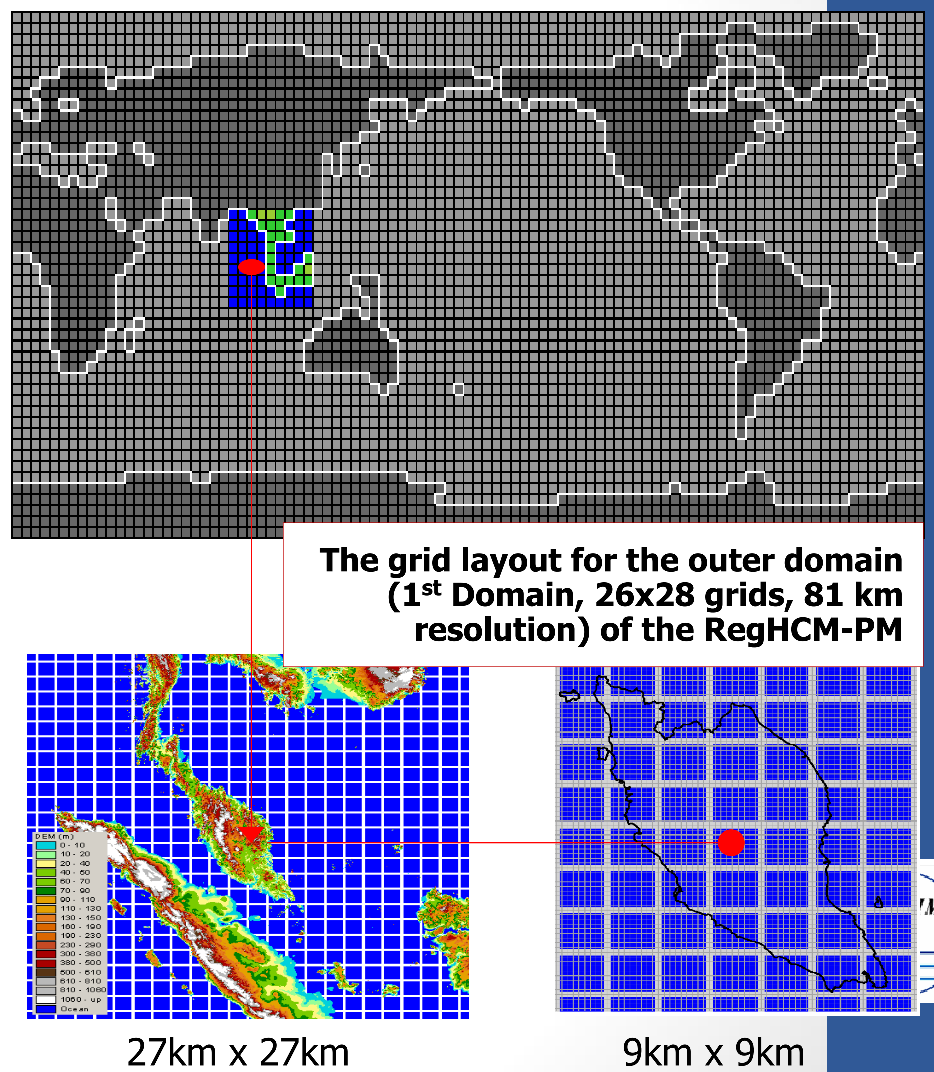



**List of Climate Model**

| |
|---|
| cccma_cgcm3_1 |
| cccma_cgcm3_1_t63 |
| cnrm_cm3 |
| csiro_mk3_0 |
| csiro_mk3_5 |
| gfdl_cm2_0 |
| gfdl_cm2_1 |
| giss_aom |
| iap_fgoals1_0_g |
| ingv_echam4 |
| inmcm3_0 |
| ipsl_cm4 |
| miroc3_2_hires_K-1 |
| miroc3_2_hires |
| miroc3_2_medres |
| miub_echo_g |
| mpi_echam5 |
| mri_cgcm2_3_2a |

# DYNAMIC DOWNSCALING MODEL - RegHCM-PM

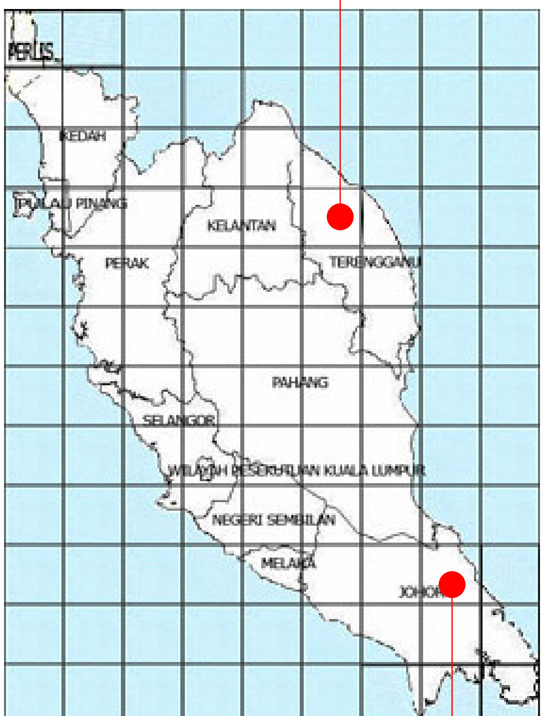
- **2006:** A regional hydrologic-atmospheric model of Peninsular Malaysia called as '**Regional Hydro-climate Model of Peninsular Malaysia (RegHCM-PM)** was developed
- **Downscaling** global climate change simulation data (Canadian GCM1 current and future climate data) that are at very **coarse resolution** (~ 410km), to Peninsular Malaysia (West Malaysia) at **fine spatial resolution** (~9km) – for future period of 2025 to 2050 (2025-2034 & 2041-2050)




**The grid layout for the outer domain (1st Domain, 26x28 grids, 81 km resolution) of the RegHCM-PM**

# Adaptation Tool - **Regional Future Hydroclimate Data Retrieval System** for extreme events (9km x 9km)

## http://www.futurehydroclimate.nahrim.gov.my

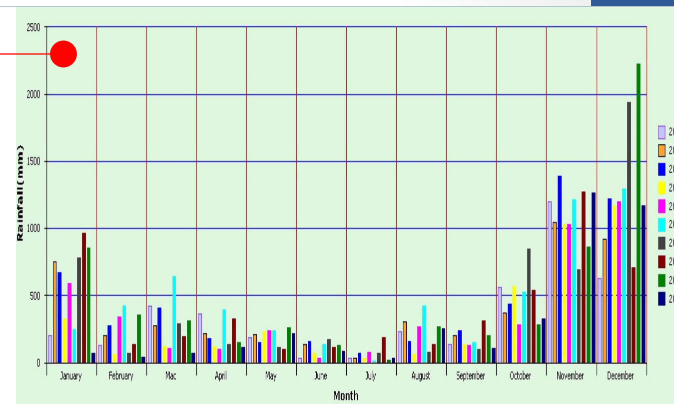


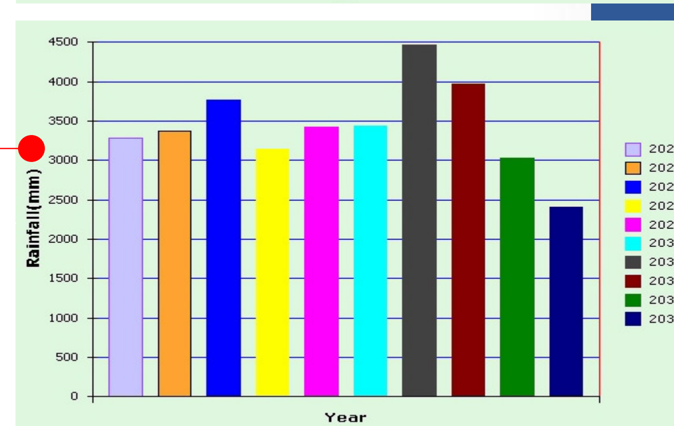

**FUTURE HYDROCLIMATE DATA RETRIEVAL SYSTEM**

| | | | | | |
|---|---|---|---|---|---|
| 102.5667 5.5405 | 102.6476 5.5405 | 102.7286 5.5405 | 102.8095 5.5405 | 102.8905 5.5405 | |
| 102.5667 5.4599 | 102.6476 5.4599 | 102.7286 5.4599 | 102.8095 5.4599 | 102.8905 5.4599 | 102.9714 5.4599 |
| 102.5667 5.3793 | 102.6476 5.3793 | 102.7286 5.3793 | 102.8095 5.3793 | 102.8905 5.3793 | 102.9714 5.3793 |
| 102.5667 5.2987 | 102.6476 5.2987 | 102.7286 5.2987 | 102.8095 5.2987 | 102.8905 5.2987 | 102.9714 5.2987 |
| 102.5667 5.2181 | 102.6476 5.2181 | 102.7286 5.2181 | 102.8095 5.2181 | 102.8905 5.2181 | 102.9714 5.2181 |
| 102.5667 5.1375 | 102.6476 5.1375 | 102.7286 5.1375 | 102.8095 5.1375 | 102.8905 5.1375 | 102.9714 5.1375 |

| | | | | | |
|---|---|---|---|---|---|
| 103.4571 2.9574 | | | | | |
| 103.4571 2.8765 | | | | | |
| 103.4571 2.7957 | 103.5381 2.7957 | | | | |
| 103.4571 2.7148 | 103.5381 2.7148 | 103.619 2.7148 | | | |
| 103.4571 2.6339 | 103.5381 2.6339 | 103.619 2.6339 | 103.7 2.6339 | 103.7809 2.6339 | |
| 103.4571 2.5531 | 103.5381 2.5531 | 103.619 2.5531 | 103.7 2.5531 | 103.7809 2.5531 | 103.8619 2.5531 |
| 103.4571 2.4722 | 103.5381 2.4722 | 103.619 2.4722 | 103.7 2.4722 | 103.7809 2.4722 | 103.8619 2.4722 |

**9km x 9km grid size**




- **Daily Rainfall**
- **Monthly Rainfall**
- **Annual Rainfall**
- **Daily Average**
- **1-Day Max**
- **2-Day Max**
- **3-Day max**
- **5-Day Max**

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# Derivation of CCF

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→

STEP 2:
**Bias correction of downscaled data**

↓

STEP 3:
**Derivation of CCF**

↓

STEP 4:
**Disaggregation of 1-day design rainfall to short duration and reformulation of IDF Curves**

↓

STEP 5:
**Rainfall-runoff modelling: Obtain future $Q_p$**

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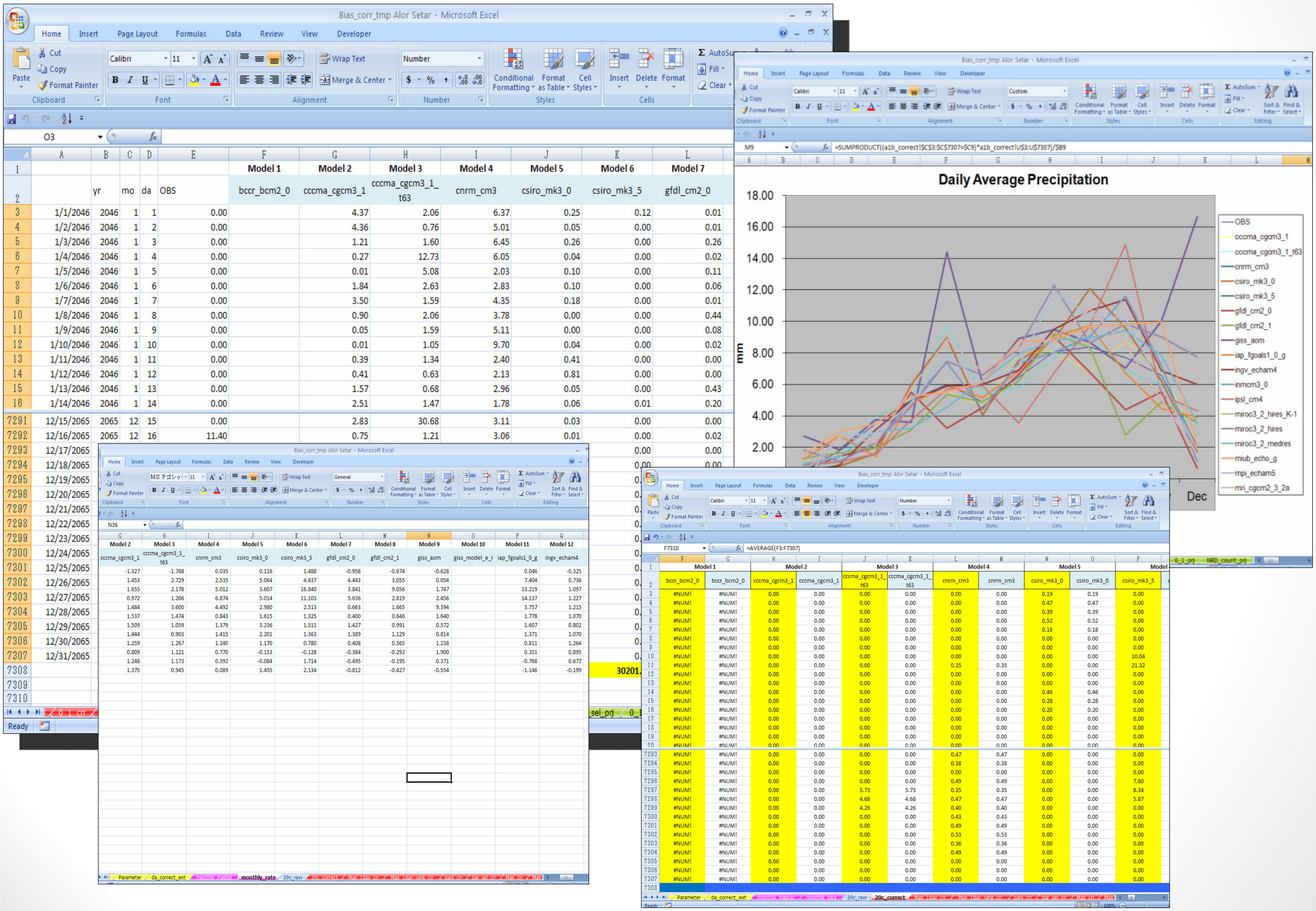
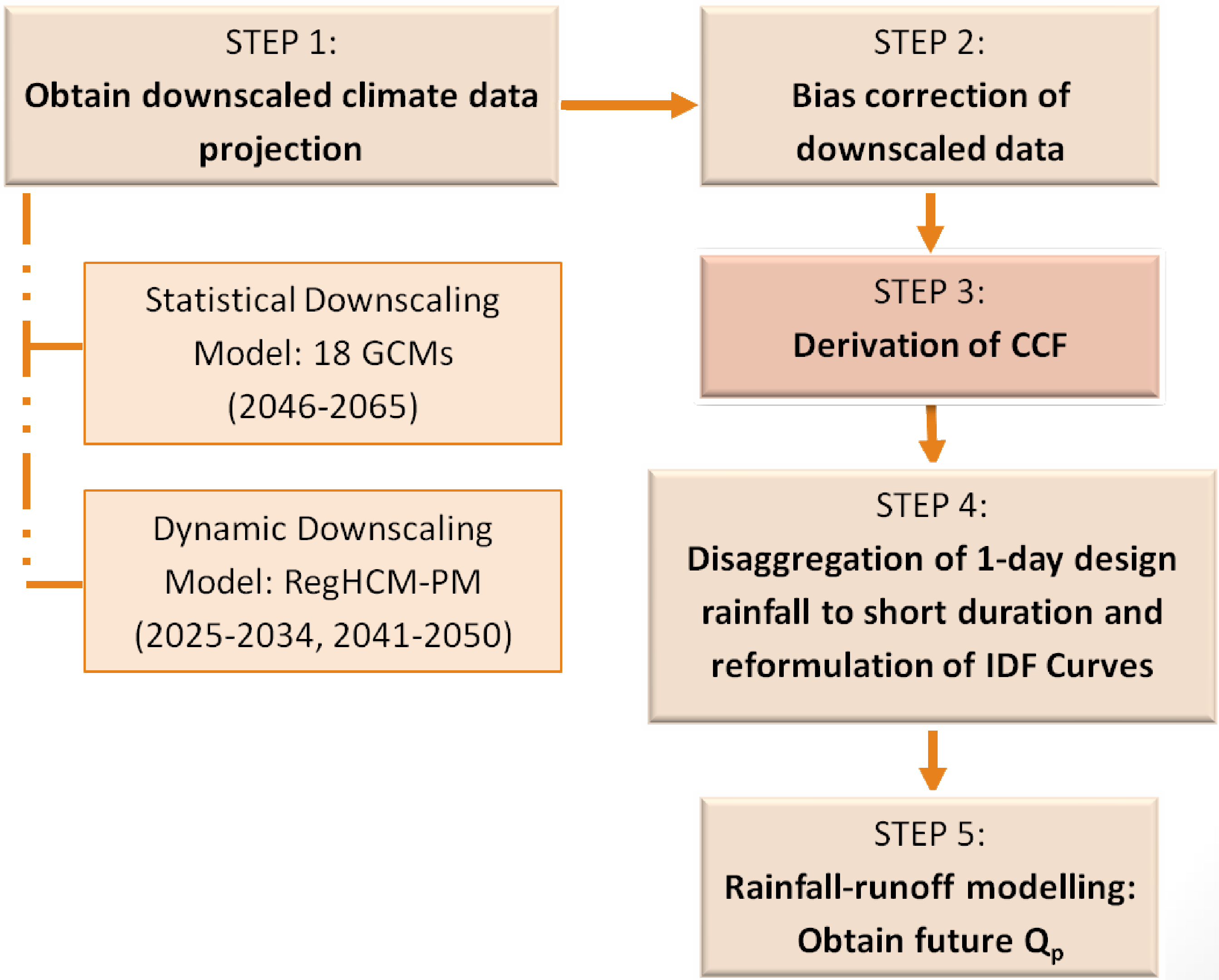
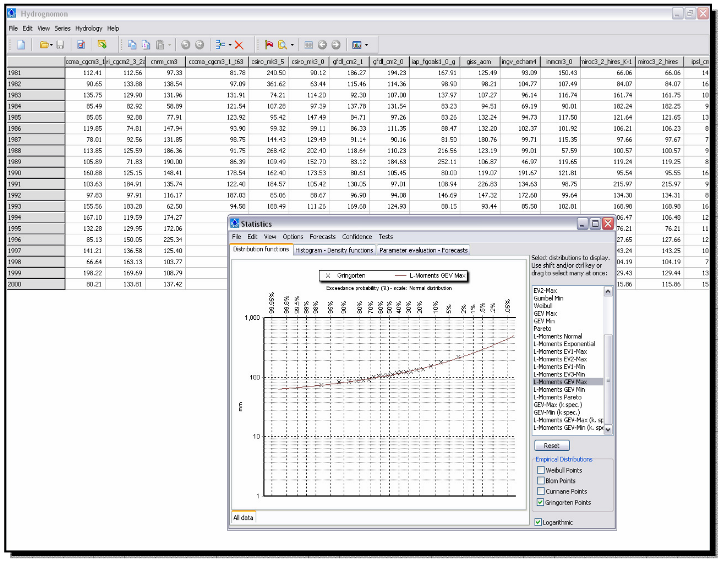
# BIAS CORRECTION

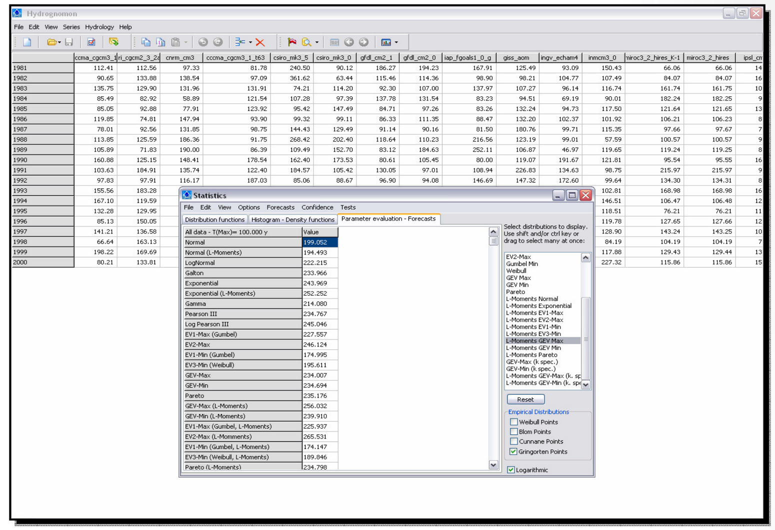


# Derivation of CCF



# CCF DERIVATION –
# Frequency Analysis / Design Rainstorm



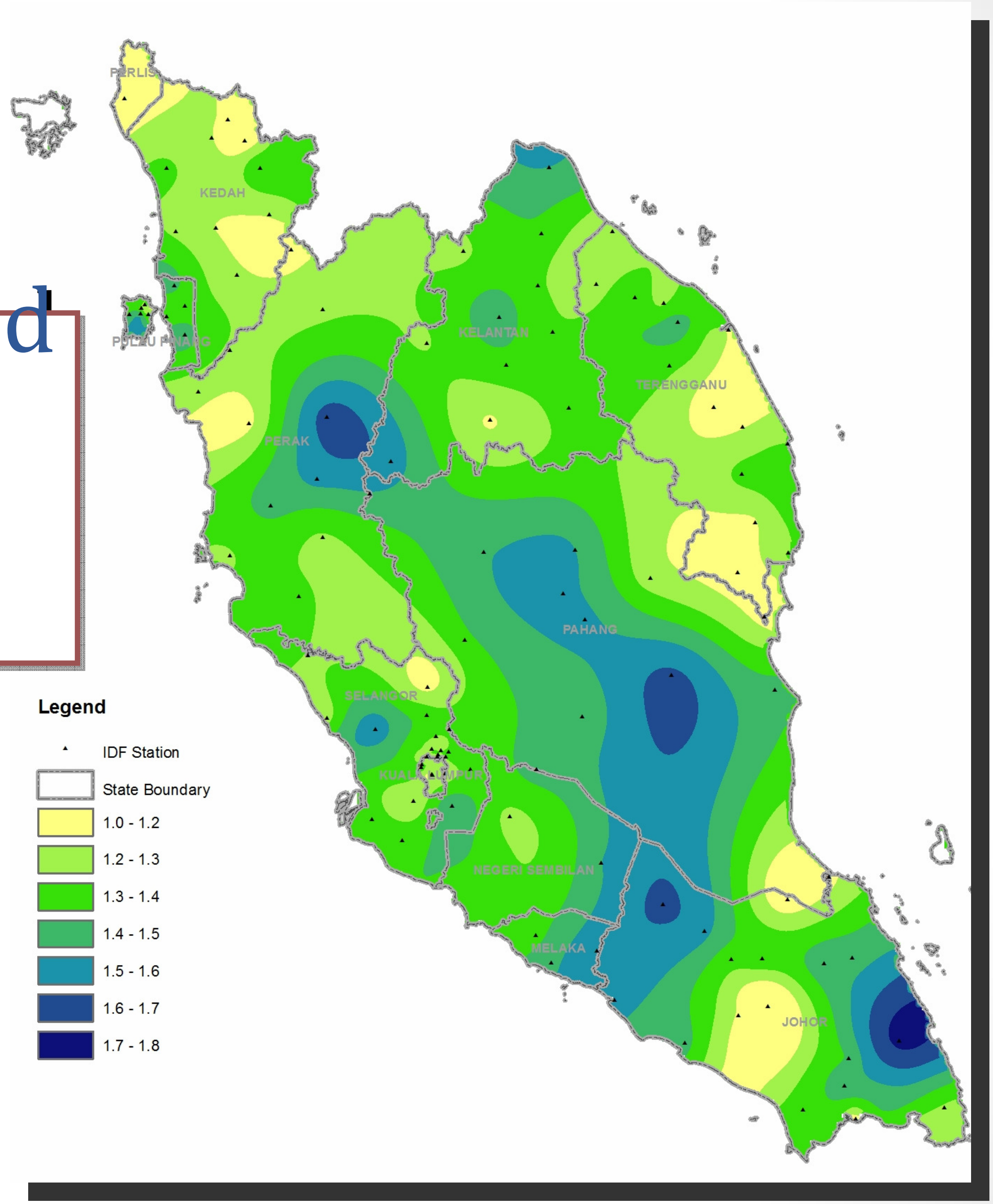


GEV-Max (L-Moments)

| Model | 2046-2055 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 20 | 25 | 50 | 100 | 1000 |
| cccma_cgcm3_1 | 95.74 | 114.54 | 121.95 | 126.73 | 127.89 | 130.70 | 132.61 | 135.57 |
| cccma_cgcm3_1_t63 | 89.06 | 131.96 | 162.37 | 193.13 | 203.23 | 235.42 | 269.03 | 393.04 |
| cnrm_cm3 | 97.58 | 113.27 | 124.71 | 136.53 | 140.47 | 153.20 | 166.77 | 219.17 |
| csiro_mk3_0 | 97.58 | 113.27 | 124.71 | 136.53 | 140.47 | 153.20 | 166.77 | 219.17 |
| csiro_mk3_5 | 112.92 | 123.34 | 130.26 | 136.93 | 139.05 | 145.60 | 152.11 | 173.79 |
| gfdl_cm2_0 | 86.05 | 103.21 | 116.67 | 131.41 | 136.50 | 153.57 | 172.80 | 256.67 |
| gfdl_cm2_1 | 108.71 | 132.36 | 140.20 | 144.63 | 145.62 | 147.82 | 149.15 | 150.79 |
| giss_aom | 112.92 | 123.34 | 130.26 | 136.93 | 139.05 | 145.60 | 152.11 | 173.79 |
| iap_fgoals1_0_g | 111.81 | 136.65 | 150.64 | 162.47 | 165.92 | 175.76 | 184.42 | 206.68 |
| ingv_echam4 | 113.08 | 166.52 | 205.39 | 245.53 | 258.87 | 301.96 | 347.84 | 524.41 |
| inmcm3_0 | 103.44 | 131.11 | 142.49 | 150.06 | 151.95 | 156.59 | 159.83 | 165.17 |
| ipsl_cm4 | 117.63 | 138.42 | 157.03 | 179.68 | 188.04 | 218.04 | 255.40 | 460.50 |
| miroc3_2_hires_K-1 | 135.06 | 194.19 | 241.30 | 293.54 | 311.73 | 373.20 | 443.28 | 757.38 |
| miroc3_2_hires | 135.07 | 194.20 | 241.30 | 293.55 | 311.73 | 373.20 | 443.28 | 757.35 |
| miroc3_2_medres | 108.74 | 148.23 | 182.75 | 223.95 | 238.98 | 292.25 | 357.40 | 700.20 |
| miub_echo_g | 121.13 | 161.95 | 193.18 | 226.75 | 238.20 | 276.13 | 318.08 | 493.78 |
| mpi_echam5 | 108.11 | 127.00 | 138.20 | 148.06 | 151.01 | 159.65 | 167.54 | 189.50 |
| mri_cgcm2_3_2a | 114.33 | 139.84 | 152.85 | 163.04 | 165.88 | 173.56 | 179.86 | 193.82 |

**CC FACTOR**

# Generalized 1 Day CCF for 50 yr ARI



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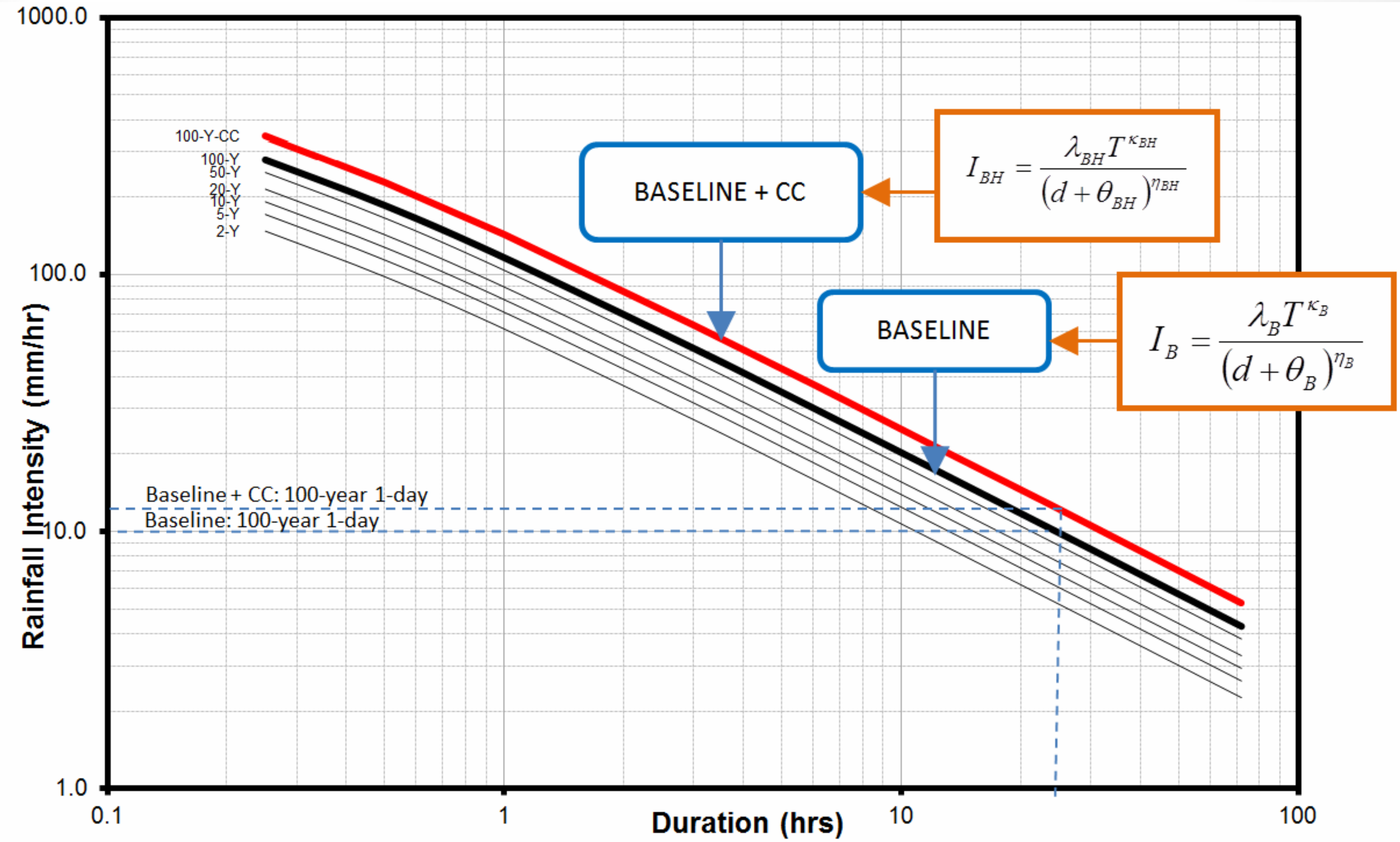


IDF mathematical formulation associated future rainfall intensity relationship (with climate change scenario)

# 1-day Future IDF Parameter ($\lambda_{BH}$) corresponding to Return Period in Kedah state

| State | No. | Station ID | Station Name | 1-day $\lambda_{BH}$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Return Period, T | | | | | | | |
| | | | | 2 | 5 | 10 | 20 | 25 | 50 | 100 | 200 |
| Kedah | 1 | 6207032 | Ampang Pedu | 69.47 | 71.27 | 72.22 | 73.00 | 73.22 | 73.86 | 74.41 | 74.90 |
| | 2 | 5507076 | Bt.27, Jln Baling | 58.55 | 60.64 | 61.84 | 62.86 | 63.16 | 64.04 | 64.84 | 65.56 |
| | 3 | 5808001 | Bt.61, Jln Baling | 51.41 | 53.74 | 55.00 | 56.06 | 56.37 | 57.24 | 58.02 | 58.71 |
| | 4 | 5704055 | Kedah Peak | 92.90 | 98.19 | 100.91 | 103.08 | 103.70 | 105.44 | 106.93 | 108.24 |
| | 5 | 5806066 | Klinik Jeniang | 68.59 | 69.98 | 70.71 | 71.30 | 71.47 | 71.95 | 72.37 | 72.73 |
| | 6 | 6108001 | Komp Rmh Muda | 60.25 | 64.83 | 67.41 | 69.61 | 70.27 | 72.14 | 73.83 | 75.37 |
| | 7 | 6206035 | Kuala Nerang | 53.34 | 58.78 | 61.68 | 64.07 | 64.76 | 66.71 | 68.42 | 69.94 |
| | 8 | 6306031 | Padang Sanai | 65.37 | 65.71 | 66.84 | 68.48 | 69.10 | 71.32 | 73.94 | 76.97 |
| | 9 | 6103047 | JPS Alor Setar | 69.44 | 75.61 | 79.04 | 81.94 | 82.79 | 85.23 | 87.41 | 89.38 |

# IDF Parameters

| State | Station ID | Station Name | Derived Parameters | | | | |
|---|---|---|---|---|---|---|---|
| | | | $\lambda$ | $\lambda_{BH}$ | $\kappa$ | $\theta$ | $\eta$ |
| Kedah | 5507076 | Bt. 27, Jalan Baling | 52.40 | 64.84 | 0.172 | 0.104 | 0.788 |
| | 5704055 | Kedah Peak | 81.58 | 106.93 | 0.200 | 0.437 | 0.719 |
| | 5806066 | Klinik Jeniang | 59.79 | 72.37 | 0.165 | 0.203 | 0.791 |
| | 5808001 | Bt. 61, Jalan Baling | 47.50 | 58.02 | 0.183 | 0.079 | 0.752 |
| | 6103047 | Setor JPS Alor Setar | 64.83 | 87.41 | 0.168 | 0.346 | 0.800 |
| | 6108001 | Kompleks Rumah Muda | 52.34 | 73.83 | 0.173 | 0.120 | 0.792 |
| | 6206035 | Kuala Nerang | 54.85 | 68.42 | 0.174 | 0.250 | 0.810 |
| | 6207032 | Ampang Padu | 66.10 | 74.41 | 0.177 | 0.284 | 0.842 |
| | 6306031 | Padang Sanai | 60.33 | 73.94 | 0.193 | 0.249 | 0.829 |

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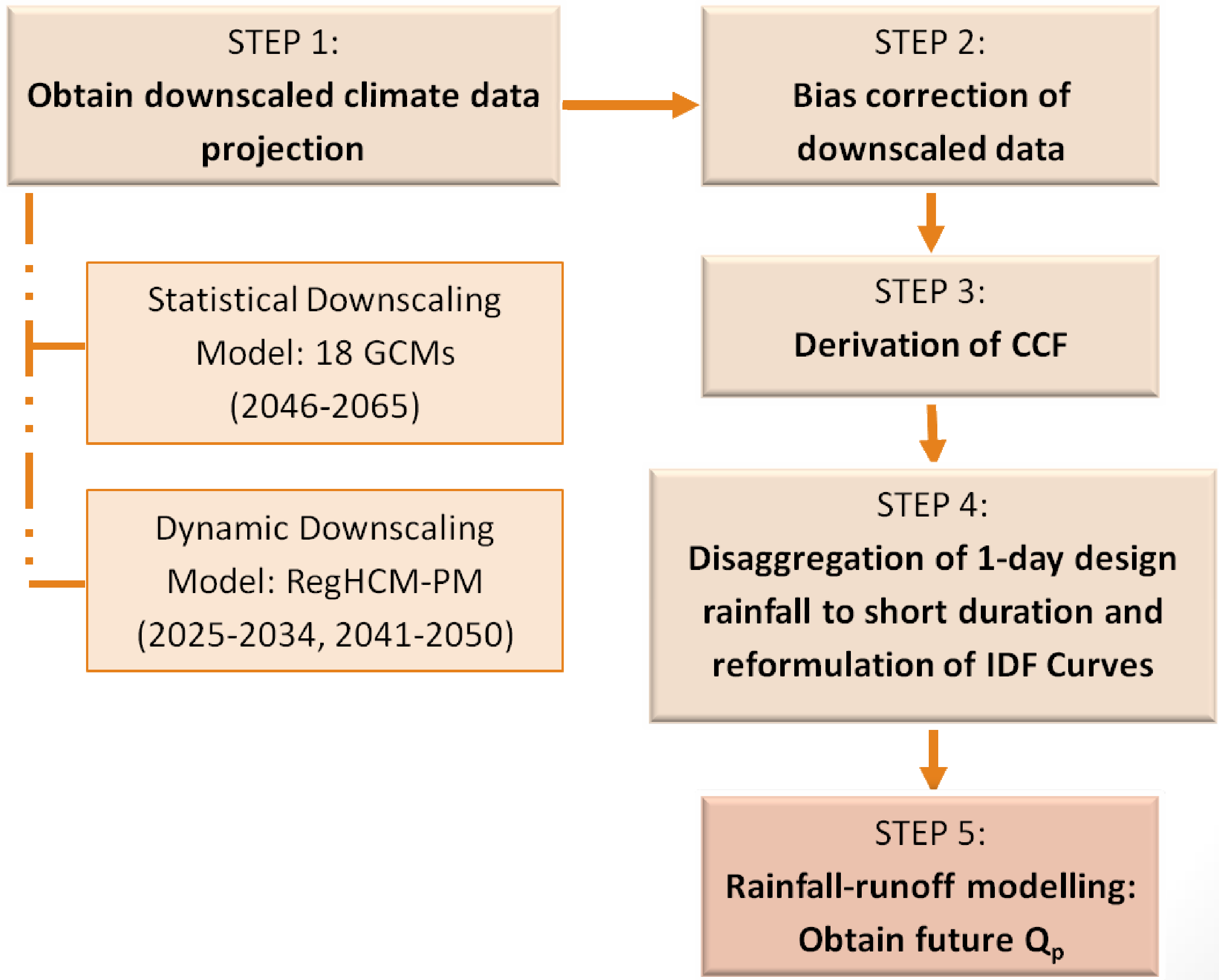
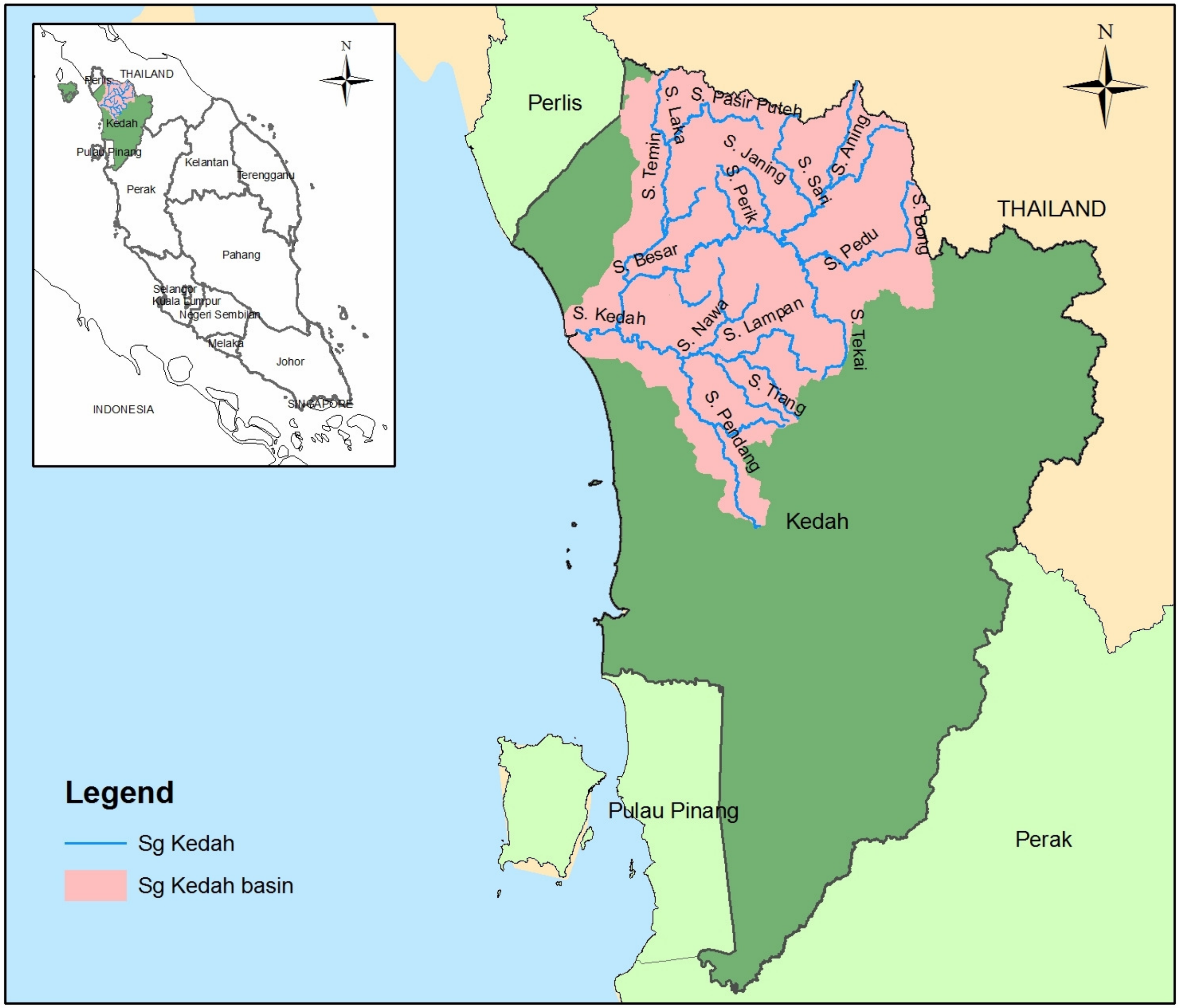
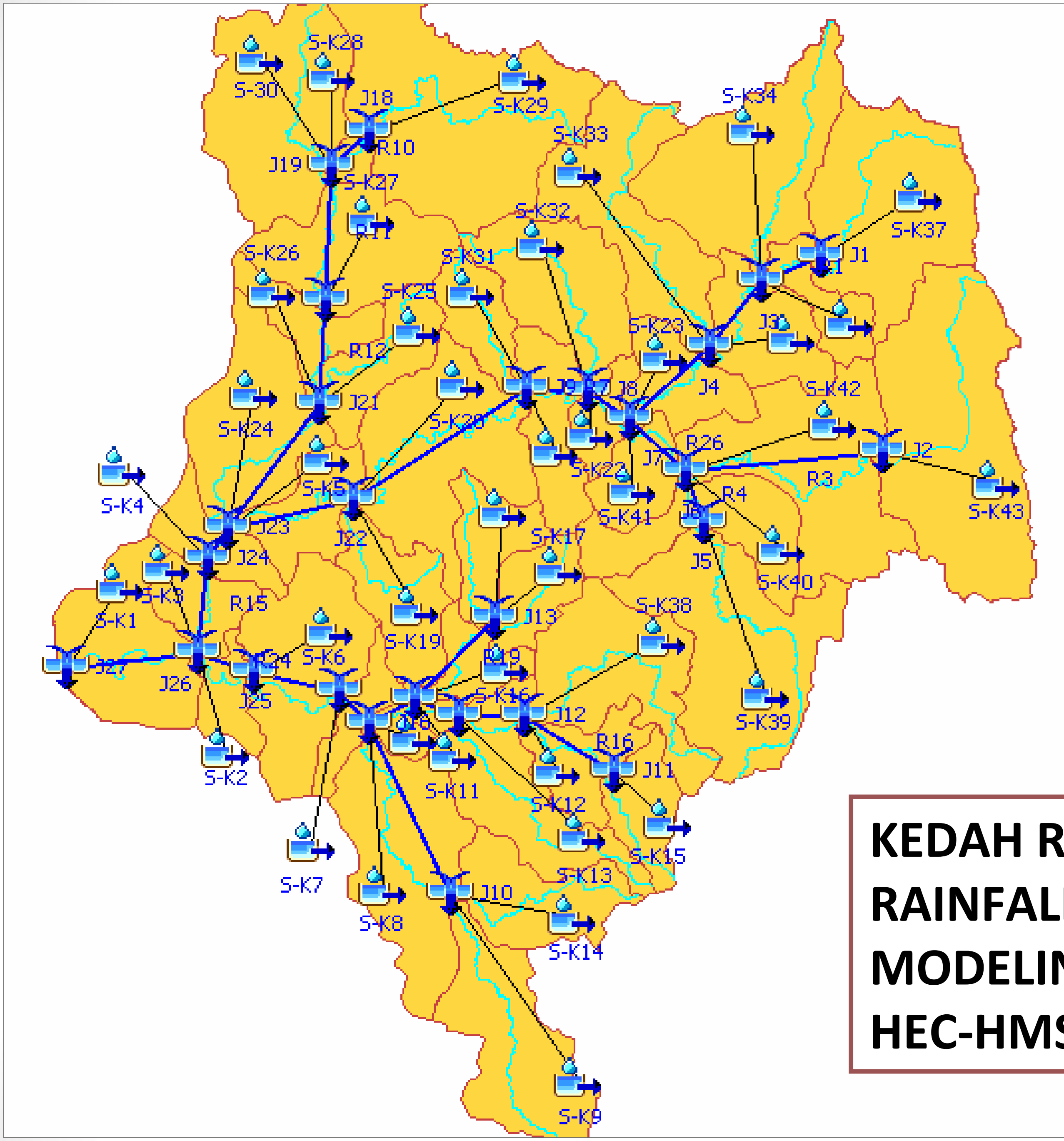
# Derivation of CCF



# Application: Kedah River Basin





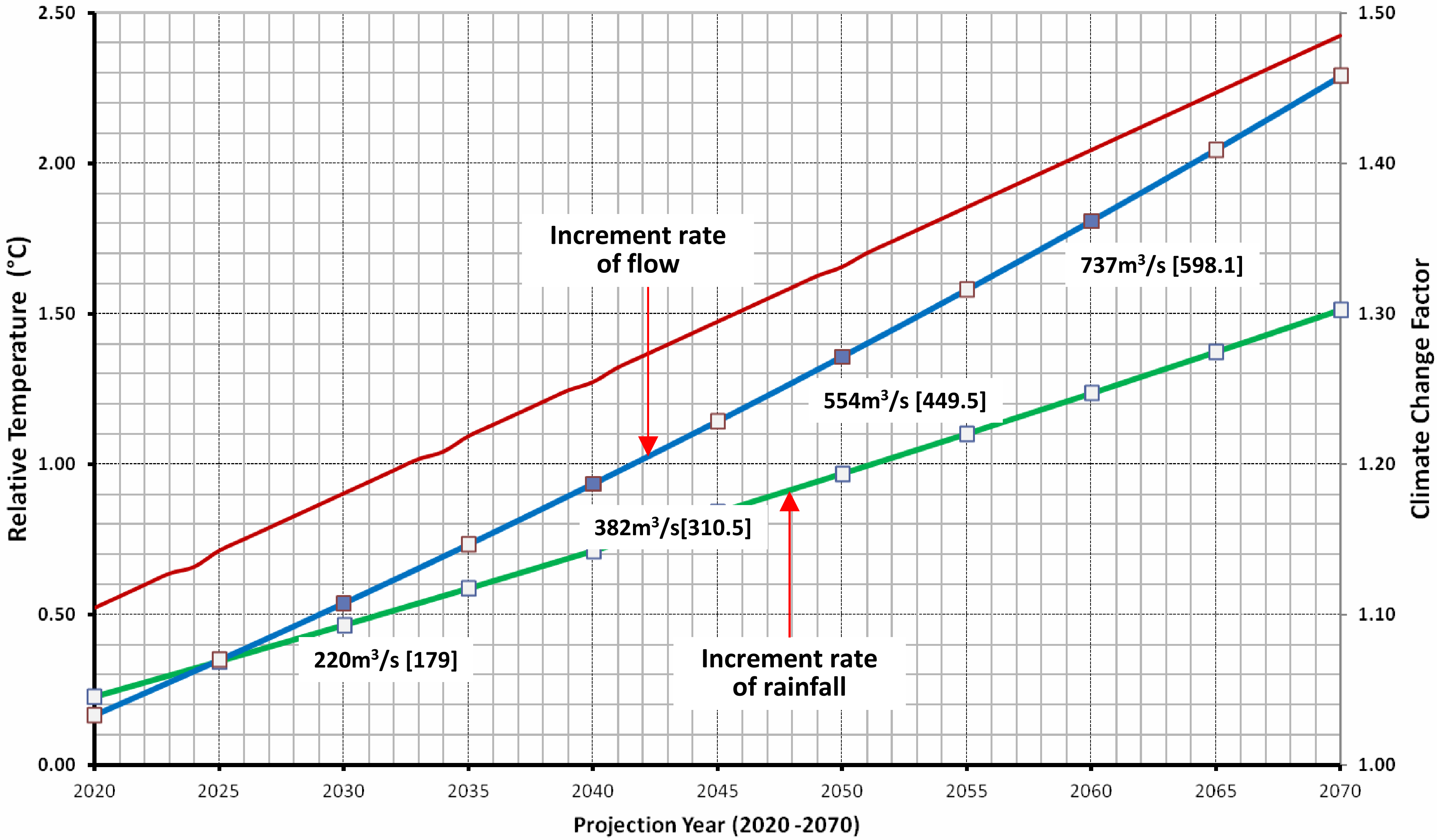

# KEDAH RIVER RAINFALL-RUNOFF MODELING USING HEC-HMS

**ANALYSIS OUTCOME**

# DESIGNED FLOOD PEAKS – KEDAH RIVER BASIN

| Item | Time Horizon | Climate Change Factor (CCF) | 1-Day Design Rainfall (mm) | Peak Discharges ($Q_p$) 100-years ARI | | Percentage Increase of Flood Magnitude (%) |
|---|---|---|---|---|---|---|
| | | | | Climate Change Scenario Flood Magnitude, $Q_p$ ($m^3/s$) | Climate Change Scenario Flood Magnitude Increment ($m^3/s$) | |
| **Baseline** | - | - | 241 | 2048 | - | - |
| **1** | 2020 | 1.05 | 245 | 2111 | 63 | 3.1 |
| **2** | 2030 | 1.09 | 257 | 2268 | 220 | 10.7 |
| **3** | 2040 | 1.14 | 268 | 2430 | 382 | 18.7 |
| **4** | 2050 | 1.19 | 280 | 2602 | 554 | 27.1 |
| **5** | 2060 | 1.25 | 293 | 2785 | 737 | 36.0 |

# Projected Daily Annual Mean Surface Temperature for Malaysia & Climate Change Factor of Kedah River Basin

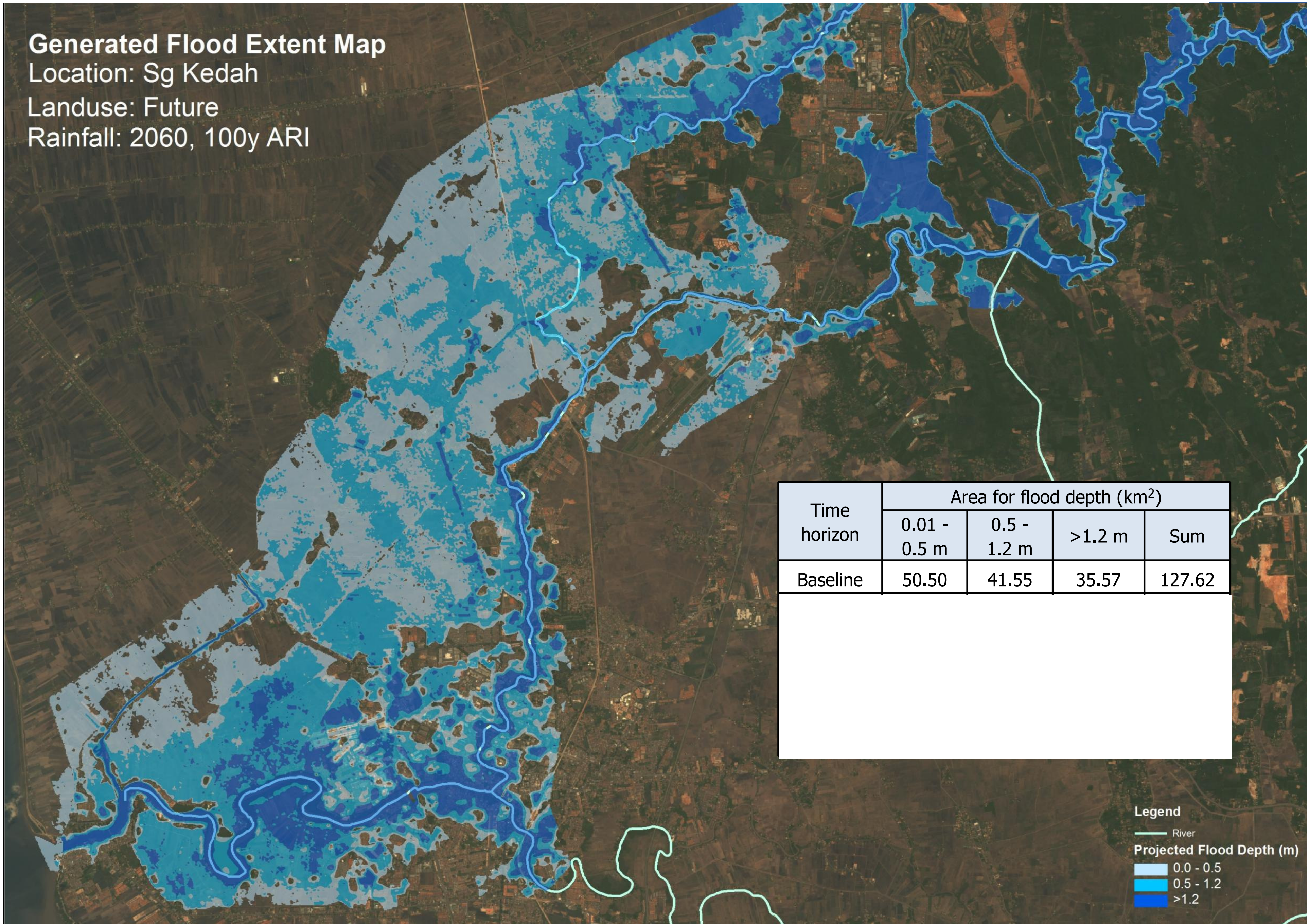


## Generated Flood Extent Map

Location: Sg Kedah

Landuse: Future

Rainfall: 2060, 100y ARI




| Time horizon | Area for flood depth ($km^2$) | | | |
|---|---|---|---|---|
| | 0.01 - 0.5 m | 0.5 - 1.2 m | >1.2 m | Sum |
| Baseline | 50.50 | 41.55 | 35.57 | 127.62 |

# CONCLUSION

- Current practice of strengthening and empowering the water related sectors through integration and sustainability approach strategies and policies are required to be improved.
- Water system designs, operations and managements – to be reviewed and re-established – incorporate CCF in strategic planning and development.
- Impacts of climate change on the country's water related hazards – projected and quantified through CCF.
- CCF – determine appropriate adaptation options, measures, and actions.