EXTREME EVENTS AFFECTING WATER RESOURCES IN THE HOPE RIVER WATERSHED IN JAMAICA: USE OF WETSPRO FOR BASEFLOW SEPARATION AND ITS LONG TERM TREND

•A.Mandal[1], P.Donk[2], J.Sidial[1] and M.Curtis[1]

•[1.] Department of Geography and Geology, University of the West Indies, Mona Campus, Kingston, Jamaica. Email: arpita.mandal@uwimona.edu.jm

•[2.] *N.V. Energiebedrijven*, Anton De Kom University of Suriname

Introduction: Jamaica

Jamaica has a tropical maritime (marine) climate. Mean daily temperature ranges from a seasonal low of 26 º C in February to a high of 28º C in August (33 º C in recent years).

Islandwide long term mean annual rainfall exhibits a characteristic pattern, with the primary maximum in October and the secondary in May. The main dry season lasts from December to April.

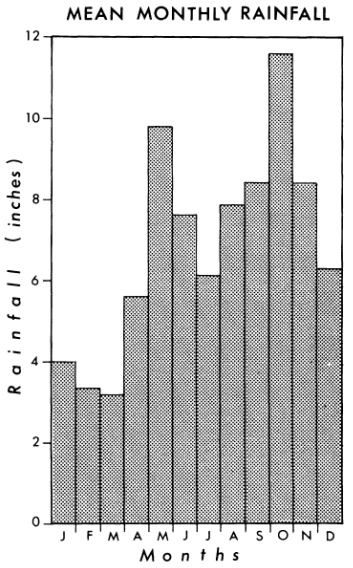
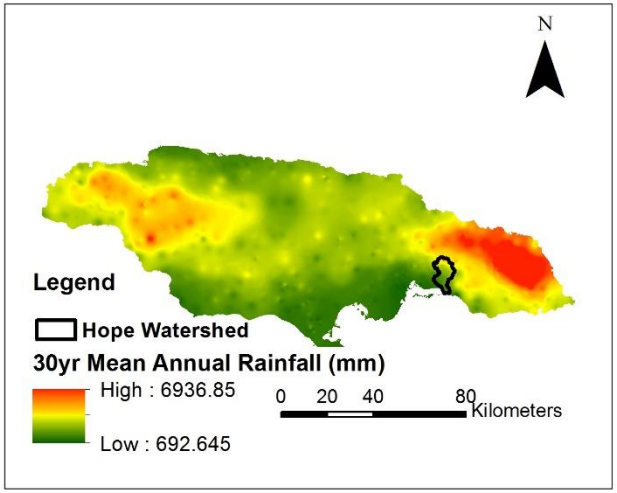
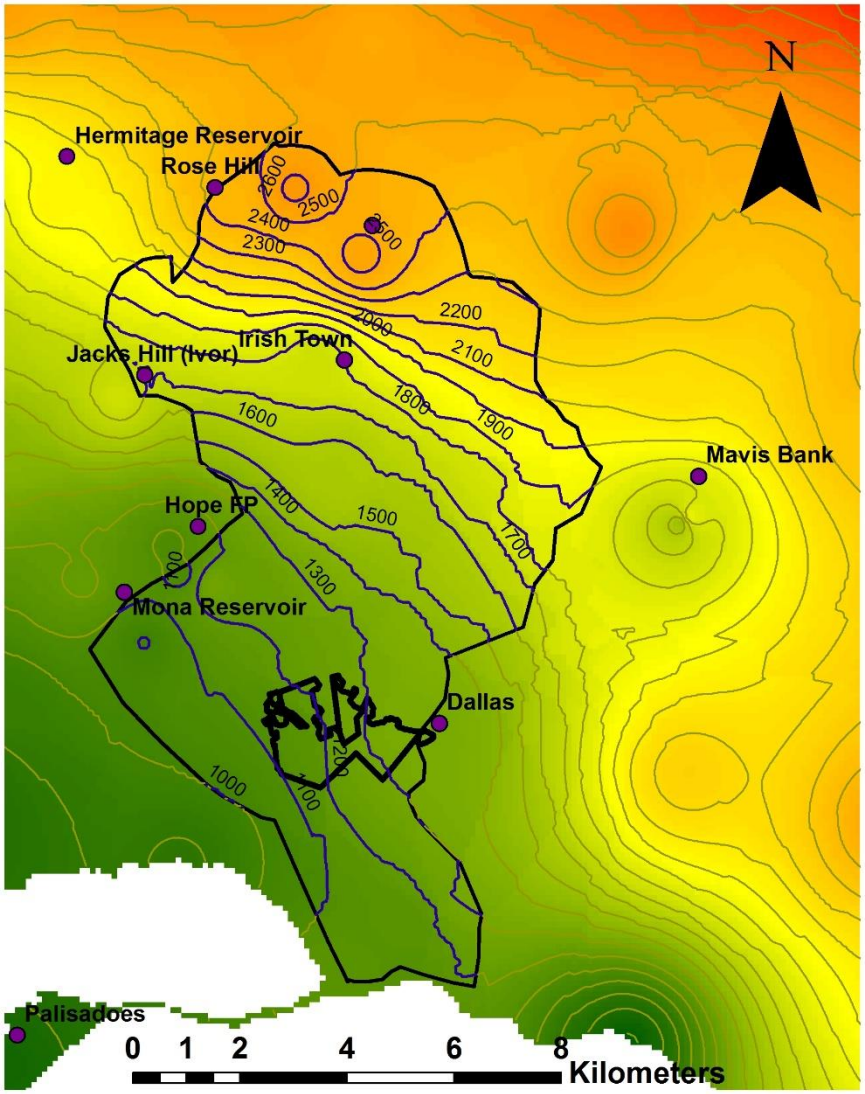


FIG. 4—Mean monthly rainfall. *Source:* Compiled from data obtained from Jamaica Meteorological Service.





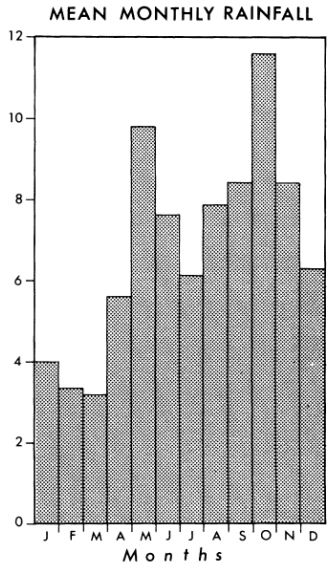


FIG. 4—Mean monthly rainfall. *Source:* Compiled from data ained from Jamaica Meteorological Service.

Legend

allyr1

Legend

Rain gages

Hope Watershed

30yr Mean Annual Rainfall (mm)

Value

High : 2681.67

Low : 692.645

Key Homes Plot

30yr mean annual rainfall for Jamaica and the Hope watershed. Hope watershed ranges in elevation from 1500m to ~2m at the mouth of the Hope River. Area : 85km2. Main source of surface water supply for the parish of Kingston and St Andrew.

Water supply sources that serve Kingston Basin

Water Input in Kingston Basin :

Mona Reservoir from Yallahs and Negro river : 14MGD.

Hope Water Treatment Plant : 5.5MGD

Constant Spring Treatment Plant : 15MGD

Alluvial wells : 12 MGD

Transfers : 5MGD

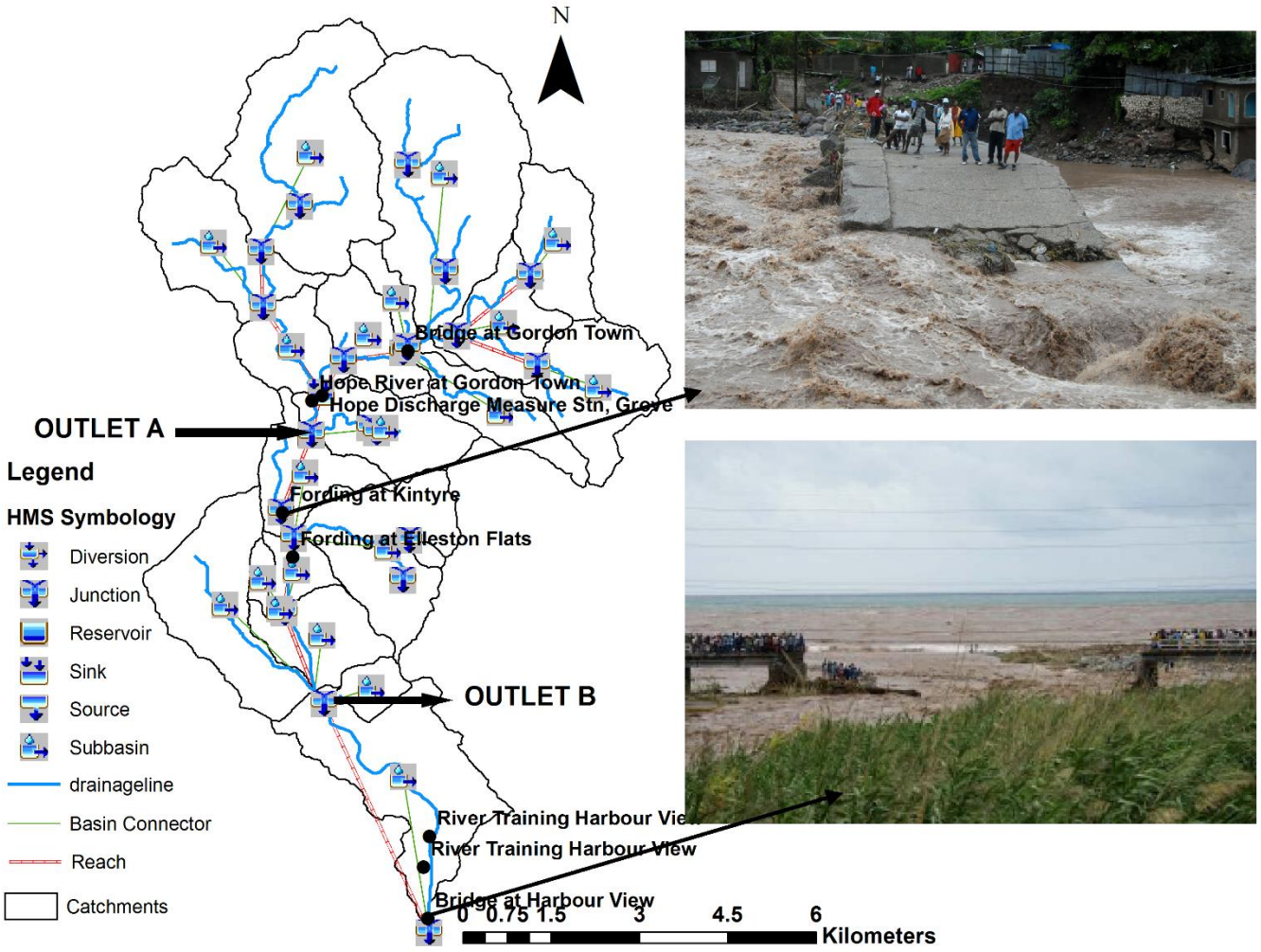
Capacity of the Mona and Hermitage Reservoir : 809 and 393 million gallon.

Source : Barne
Water Commis
(http://www.ceh
PERS/Parallel%2
s%20Management/Mark%20Barnett%20The%20Impact%20of%20the%20Present%20Drought.pdf

Low flow in the Hope River, at the gaging station.

Extreme events affecting the Hope watershed : Floods and Drought.

Most significant impact > Drought affecting potable water supply for the parish of Kingston and St Andrew.



Catchment model of the Hope watershed showing the two main areas of damage from flash flooding.

Mandal et al., 2016.

Figure 9: Map of Jamaica showing eastern parishes

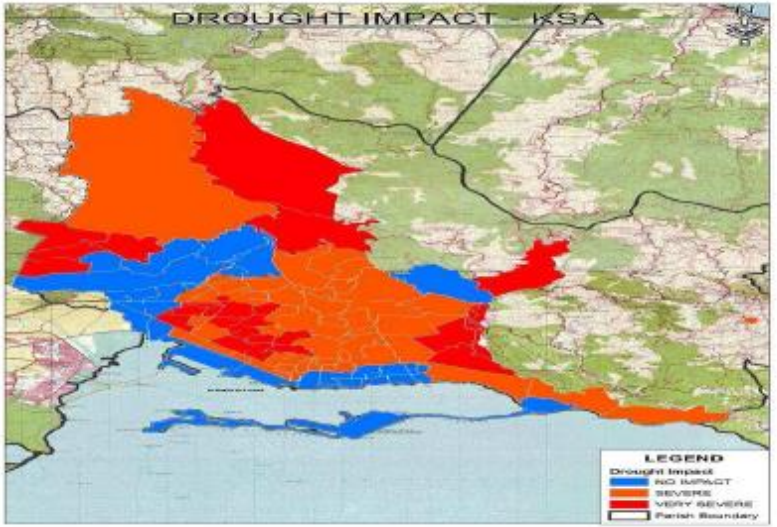


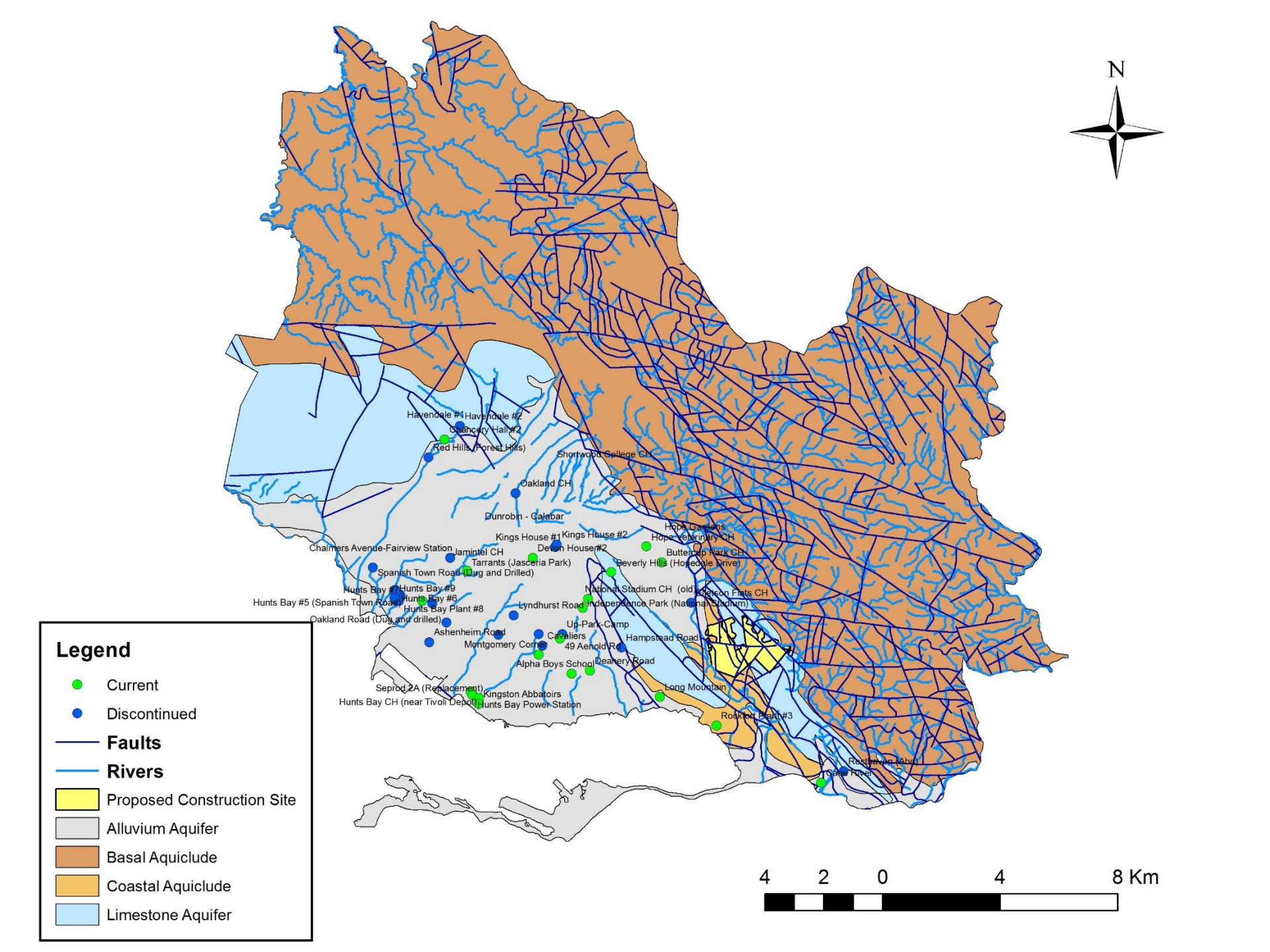
Figure 10: Impact of drought on KSA

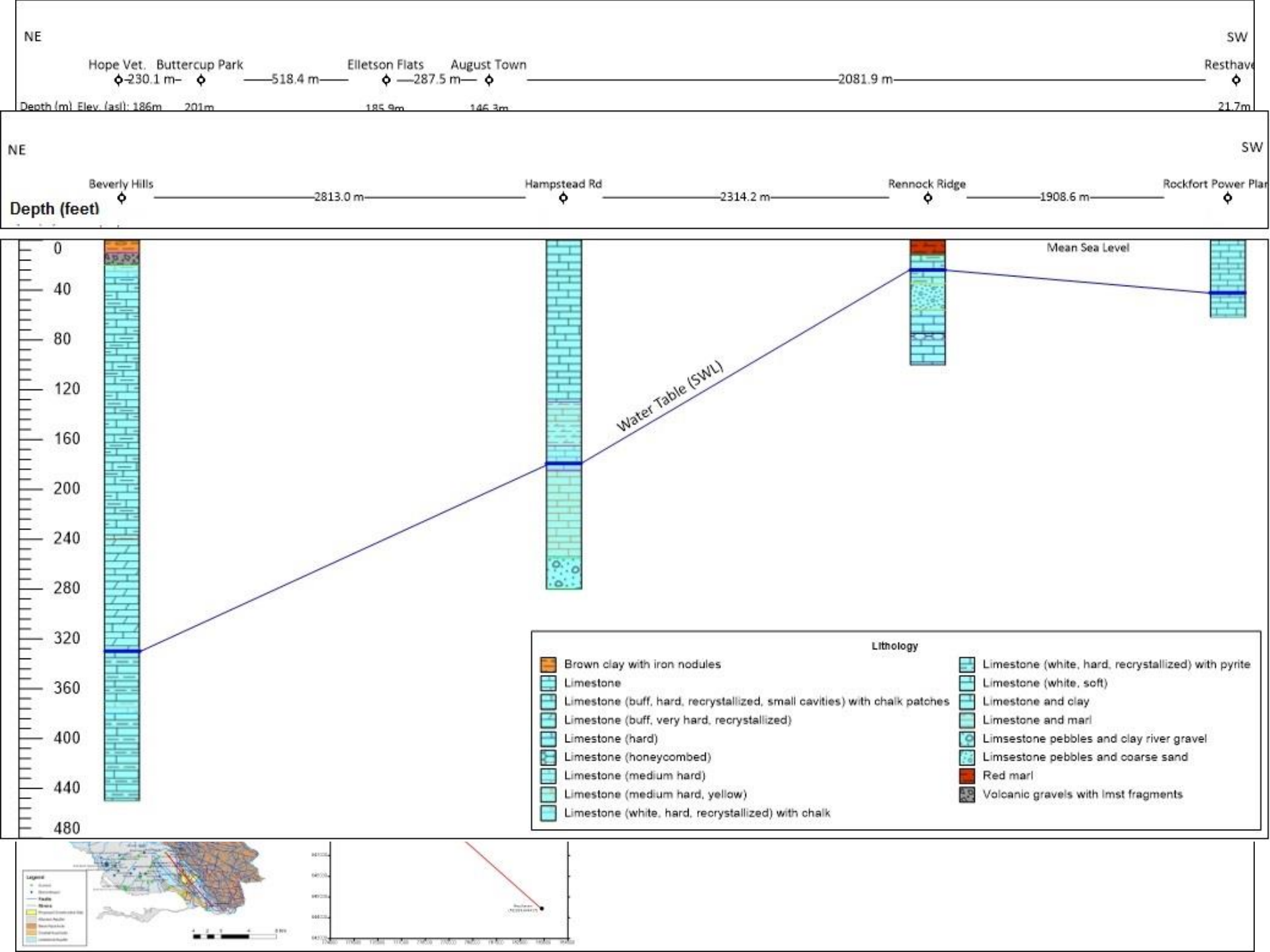
DROUGHT 2010 : EXTENT OF THE DROUGHT

Source : Barnett 2010 : The Impact of the Recent Drought on the National Water Commission (NWC) Water Supply Services to Kingston & St. Andrew
(http://www.cehi.org.lc/cef5/documents/CEF%20papers%20and%20presentations/PAPERS/Parallel%20Session%205%20Water%20Resources%20and%20Coastal%20Areas%20Management/Mark%20Barnett%20The%20Impact%20of%20the%20Present%20Drought.pdf

DROUGHT 2015 > CAUSE > EL NINO

Water levels fell to <28% in the Mona dam and to <38% for the Hermitage dam for the month of July 2015 which has led to severe water shortages and rationing for the urban population of Kingston, Portmore and Spanish Town. 85% of the Kingston Corporate area is directly affected water restrictions.

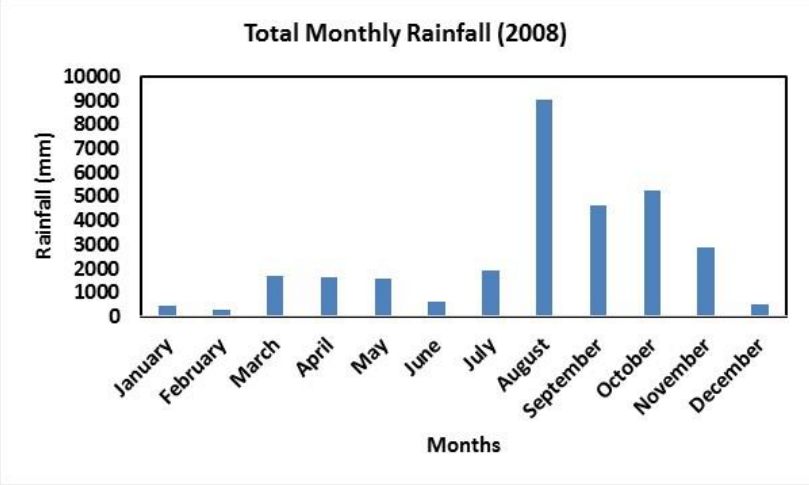

N
Havendale #1
Havendale #2
Chancery Hall #2
Red Hills (Forest Hills)
Shortwood College CH
Oakland CH
Dunrobin - Calabar
Kings House #1
Kings House #2
Devon House#2
Hope Gardens
Hope Veterinary CH
Buttercup Park CH
Beverly Hills (Honeydale Drive)
Chalmers Avenue-Fairview Station
Jamintel CH
Tarrants (Jasceria Park)
Spanish Town Road (Dug and Drilled)
Hunts Bay #7
Hunts Bay #9
Hunts Bay #6
Hunts Bay #5 (Spanish Town Road)
Hunts Bay Plant #8
Oakland Road (Dug and drilled)
Lyndhurst Road
National Stadium CH (old)
Independence Park (National Stadium)
Jetson Flats CH
Un-Park-Camp
Ashenheim Road
Cavaliers
Montgomery Corner
49 Arnold Rd
Hampstead Road
Alpha Boys School
Deanery Road
Seprod 2A (Replacement)
Kingston Abbatoirs
Hunts Bay CH (near Tivoli Depot)
Hunts Bay Power Station
Long Mountain
Rockfort Plant #3
Rest Haven (Mona)
Sandy River
Legend
Current
Discontinued
Faults
Rivers
Proposed Construction Site
Alluvium Aquifer
Basal Aquiclude
Coastal Aquiclude
Limestone Aquifer
4 2 0 4 8 Km

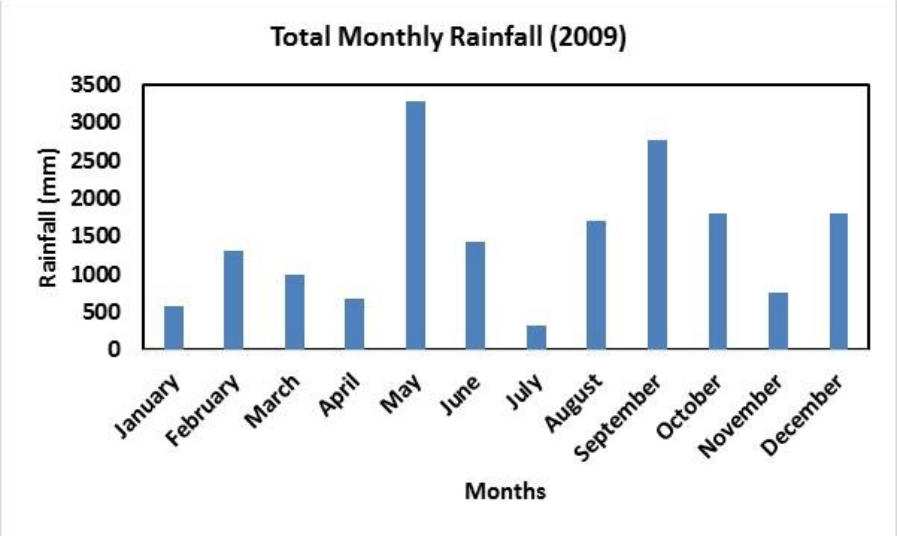

NE
SW
Hope Vet.
Buttercup Park
230.1 m
518.4 m
Elletson Flats
287.5 m
August Town
2081.9 m
Depth (m) Elev. (asl): 186m
201m
185.9m
146.3m
21.7m
NE
SW
Beverly Hills
2813.0 m
Hampstead Rd
2314.2 m
Rennock Ridge
1908.6 m
Rockfort Power Plan
Depth (feet)
0
40
80
120
160
200
240
280
320
360
400
440
480
Mean Sea Level
Water Table (SWL)
Lithology
Brown clay with iron nodules
Limestone
Limestone (buff, hard, recrystallized, small cavities) with chalk patches
Limestone (buff, very hard, recrystallized)
Limestone (hard)
Limestone (honeycombed)
Limestone (medium hard)
Limestone (medium hard, yellow)
Limestone (white, hard, recrystallized) with chalk
Limestone (white, hard, recrystallized) with pyrite
Limestone (white, soft)
Limestone and clay
Limestone and marl
Limsestone pebbles and clay river gravel
Limsestone pebbles and coarse sand
Red marl
Volcanic gravels with limst fragments

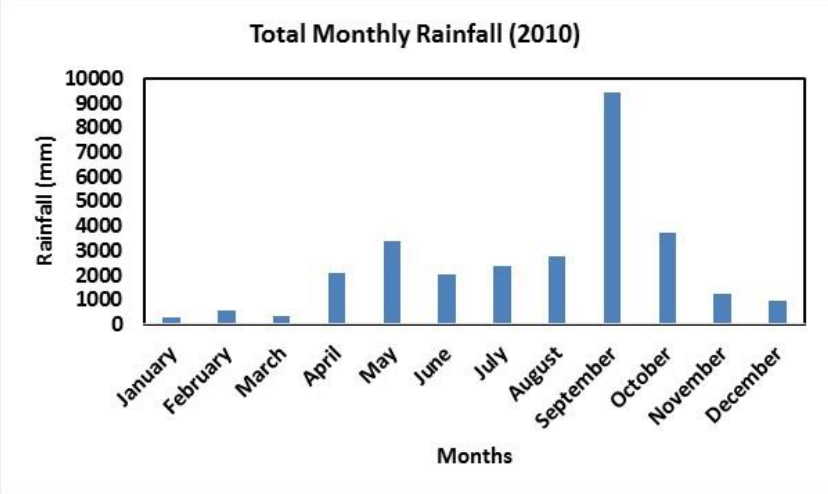
IMPACT OF DROUGHT ON KINGSTON AND ST ANDREW

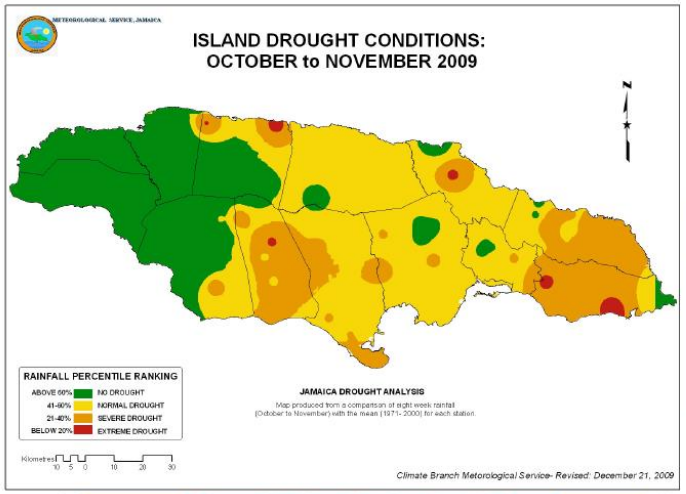
The year of 2009 and 2015 was an El-Nino year for the Caribbean which saw very less rainfall in the months of April-May and Oct-Nov with the Met office declaring a drought indices of 82 for Kingston in Dec 2009.

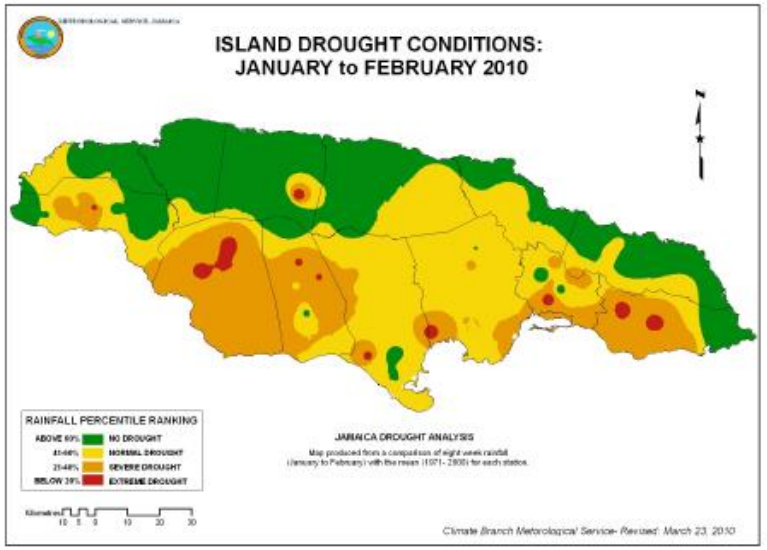
This led to severe drop in the water levels of the Hope , Yallahs and Wagwater rivers which supply the two reservoirs.

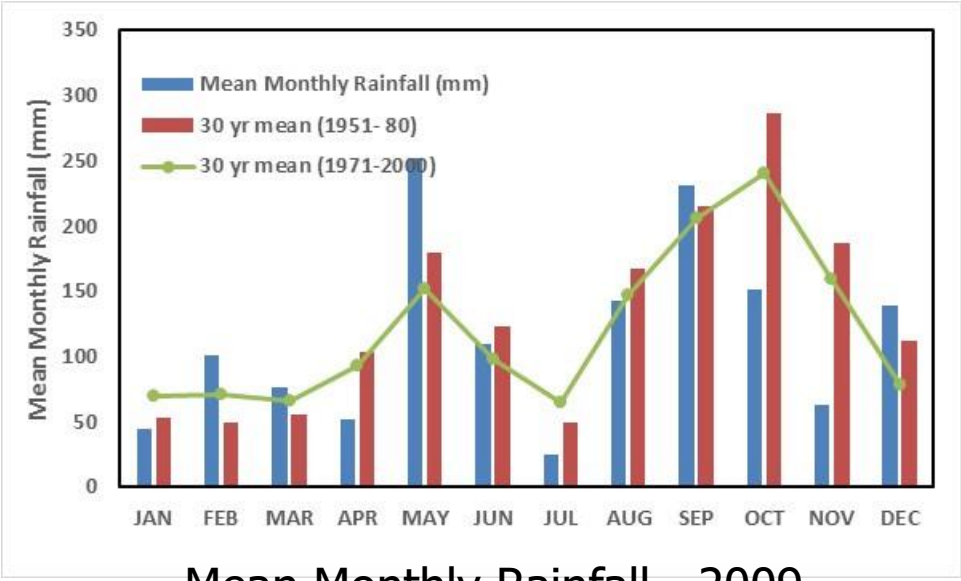




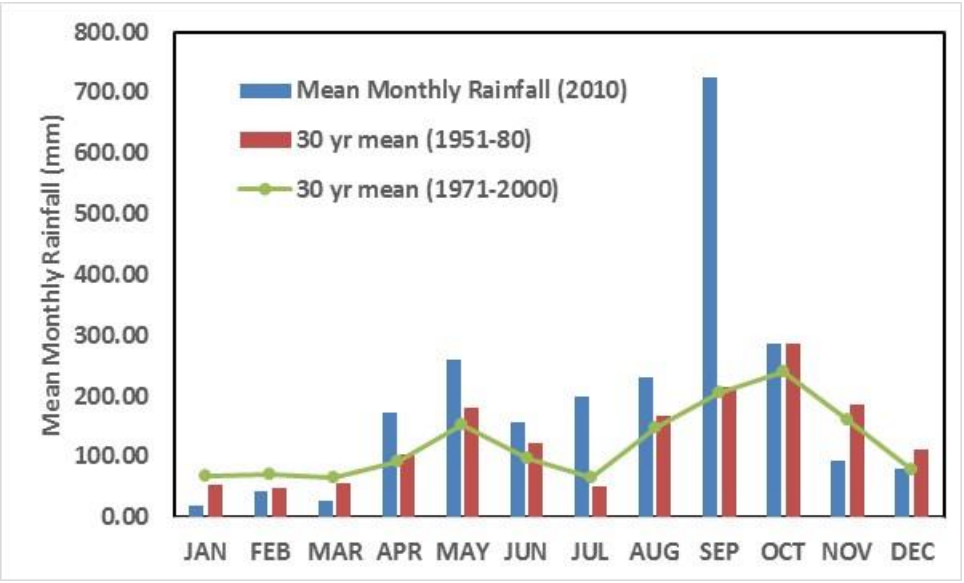




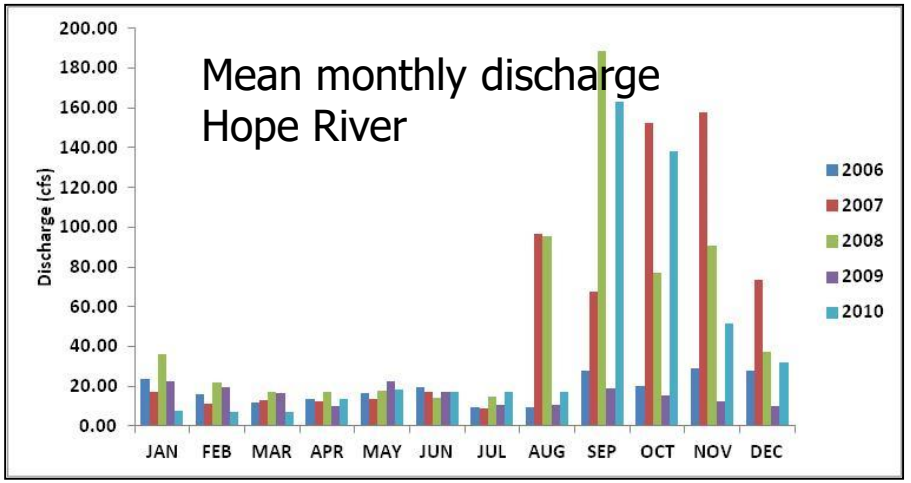




Mean Monthly Rainfall - 2009

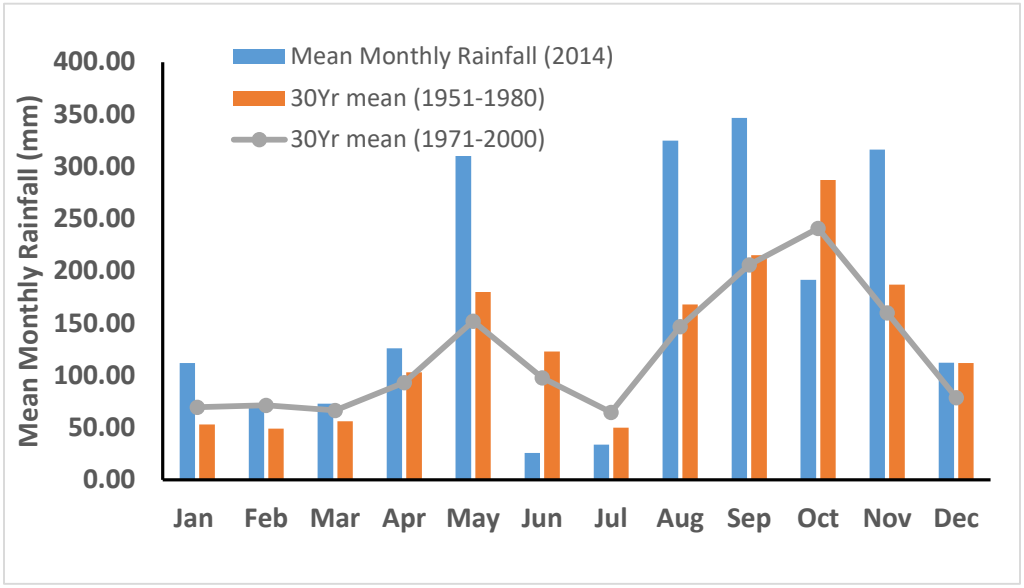


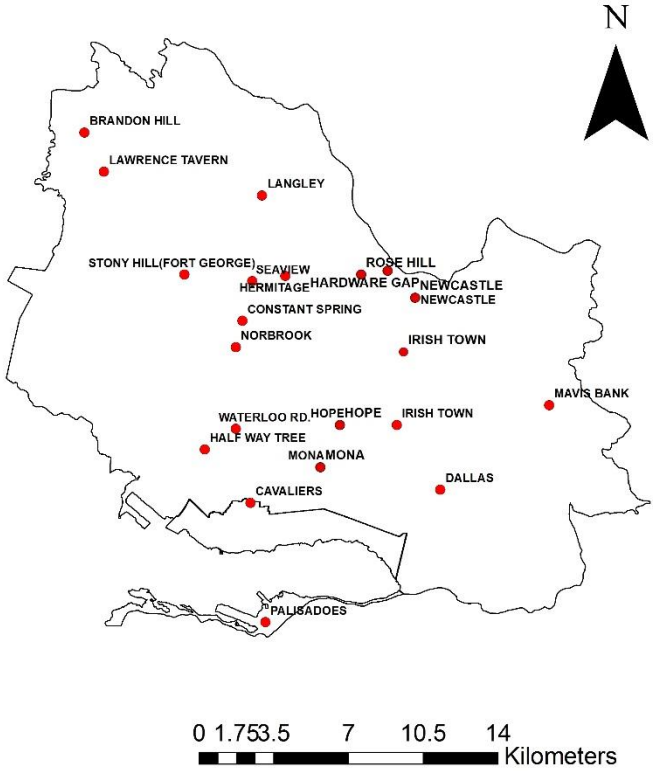
Mean Monthly Rainfall - 2010

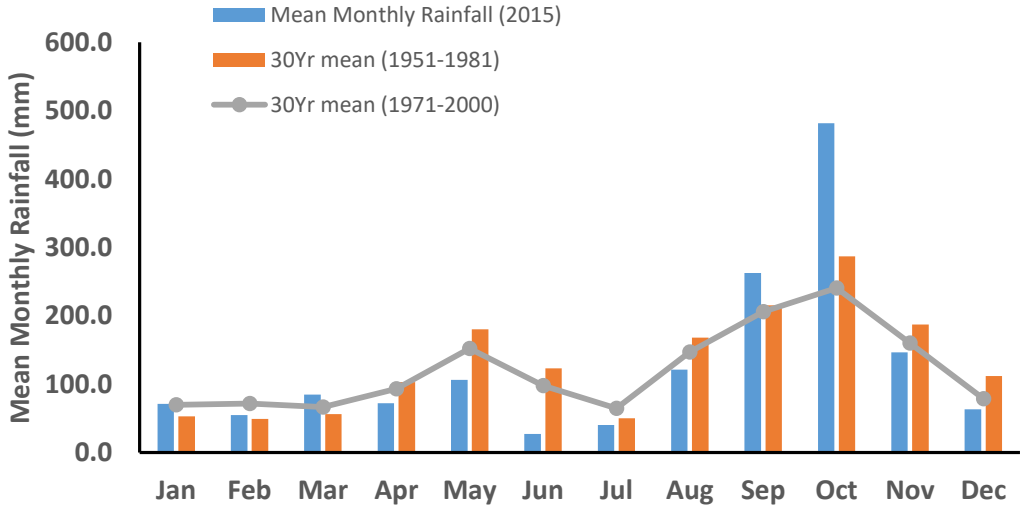


Streamflow data for the Hope River, Data from Water Resources Authority of Jamaica

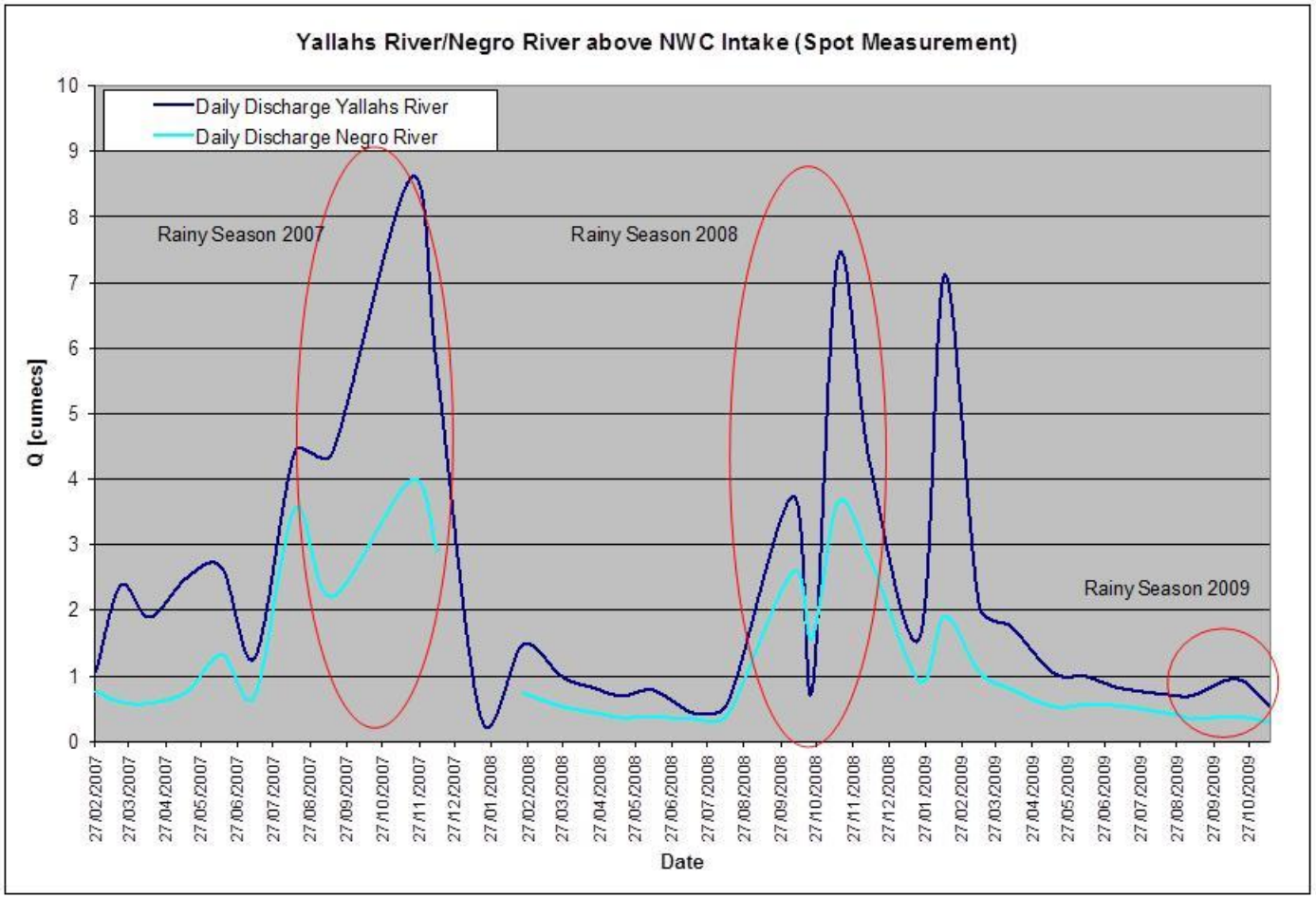
Mean Monthly Rainfall (mm) for Kingston Basin





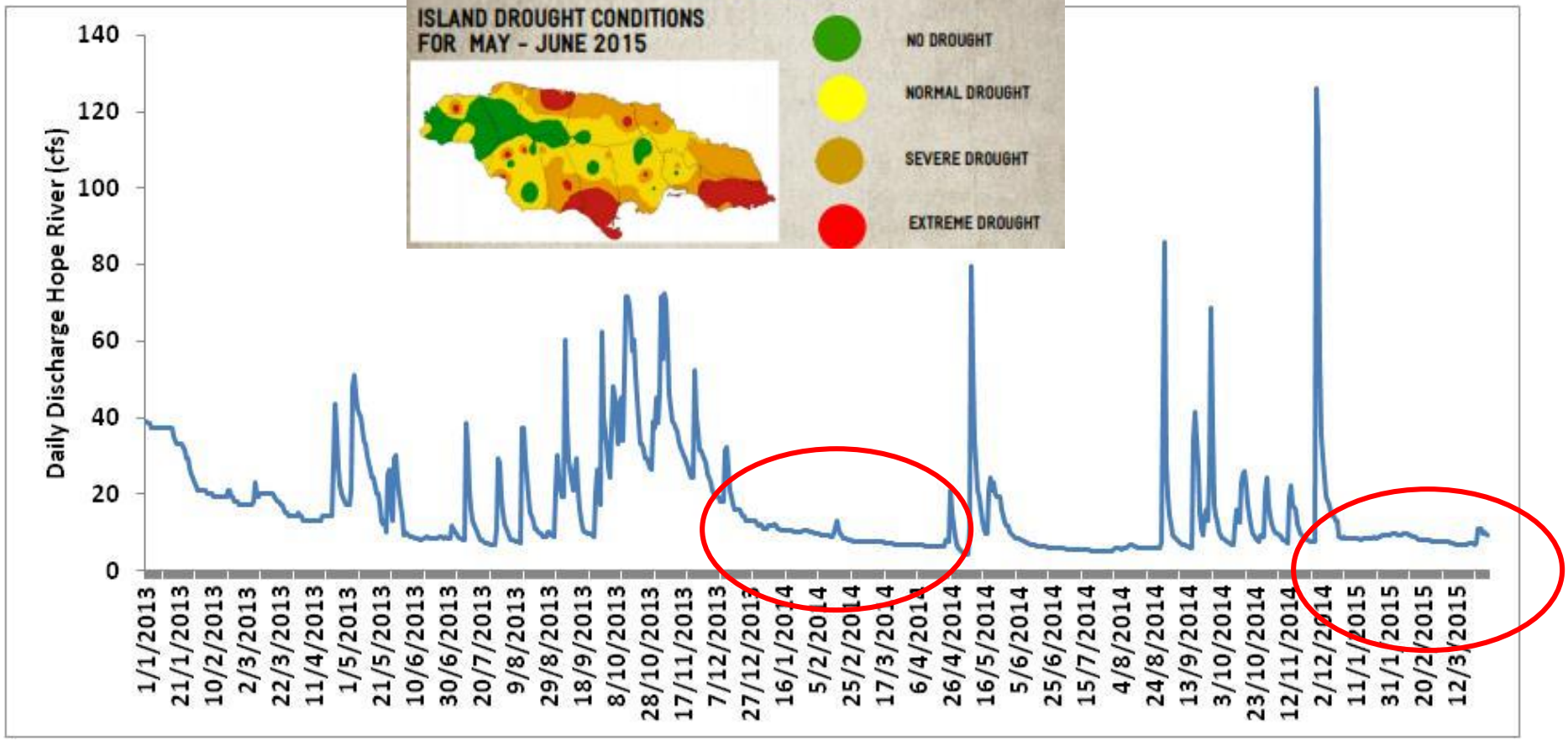


RAINGAGES IN KINGSTON AND ST ANDREW.

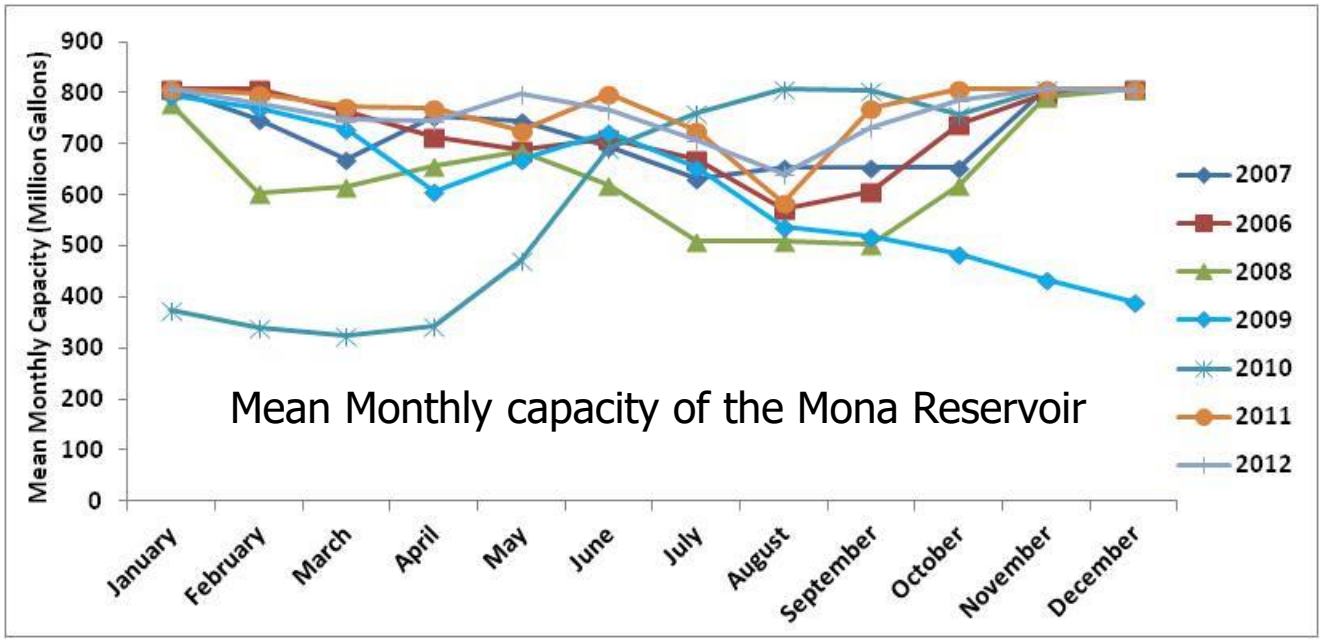


Flow in the Yallahs River, Data from Water Resources Authority of Jamaica

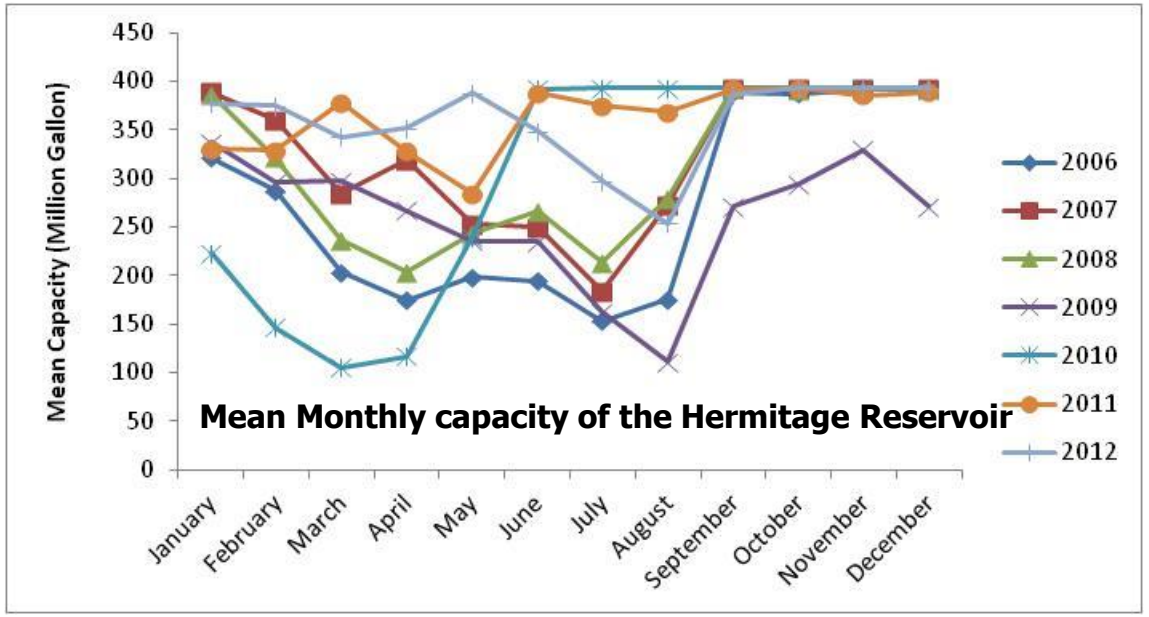
The Hope and the Mona Filter plant also showed a decline in their levels of input from 64% in early 2008 to 36% in 2010 (Mona) and almost nil for Hope FP due to almost negligible discharge in the Hope River (from 41% to 0%) in 2010. Source : Barnett 2010 : The Impact of the Recent Drought on the National Water Commission (NWC) Water Supply Services to Kingston & St. Andrew



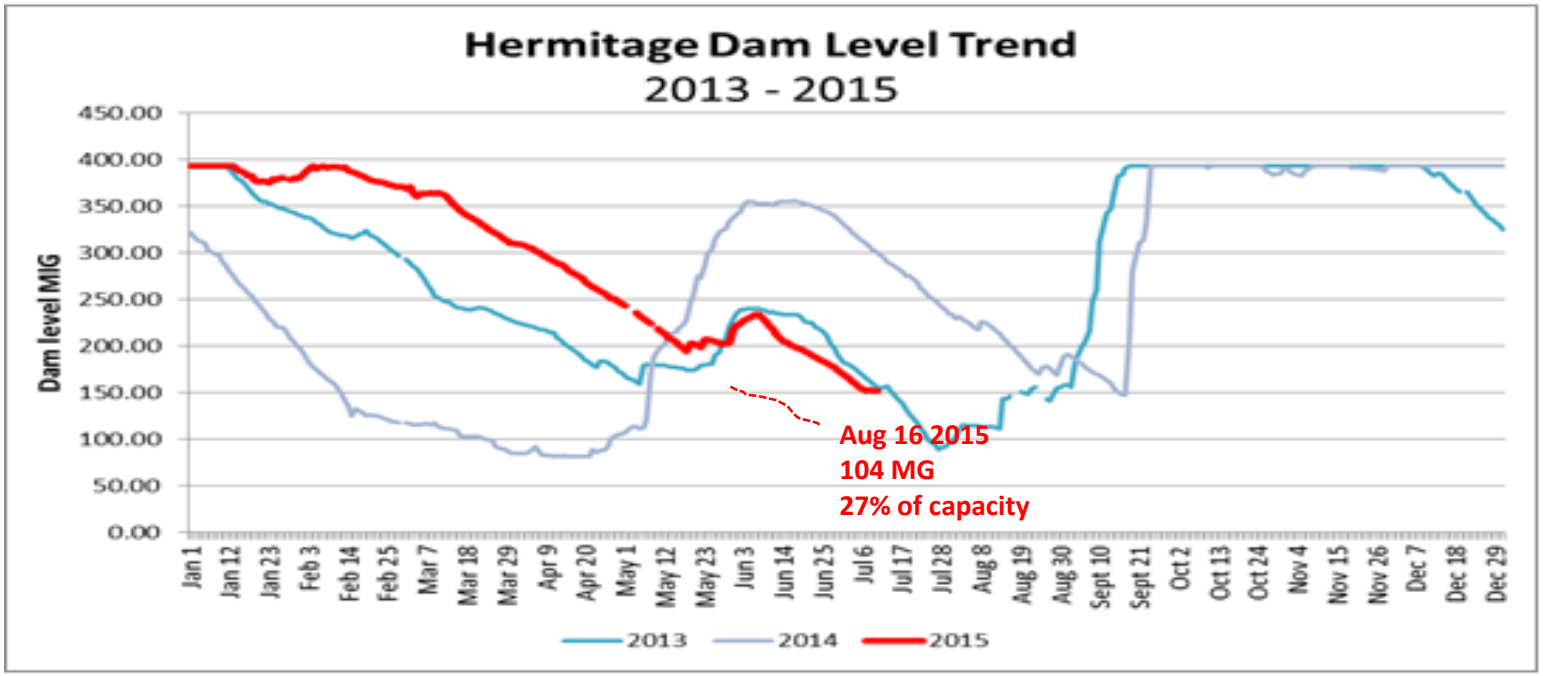
Daily discharge data measured at the gaging station at Grove, showing steep decline of the daily flow in 2014 and 2015.

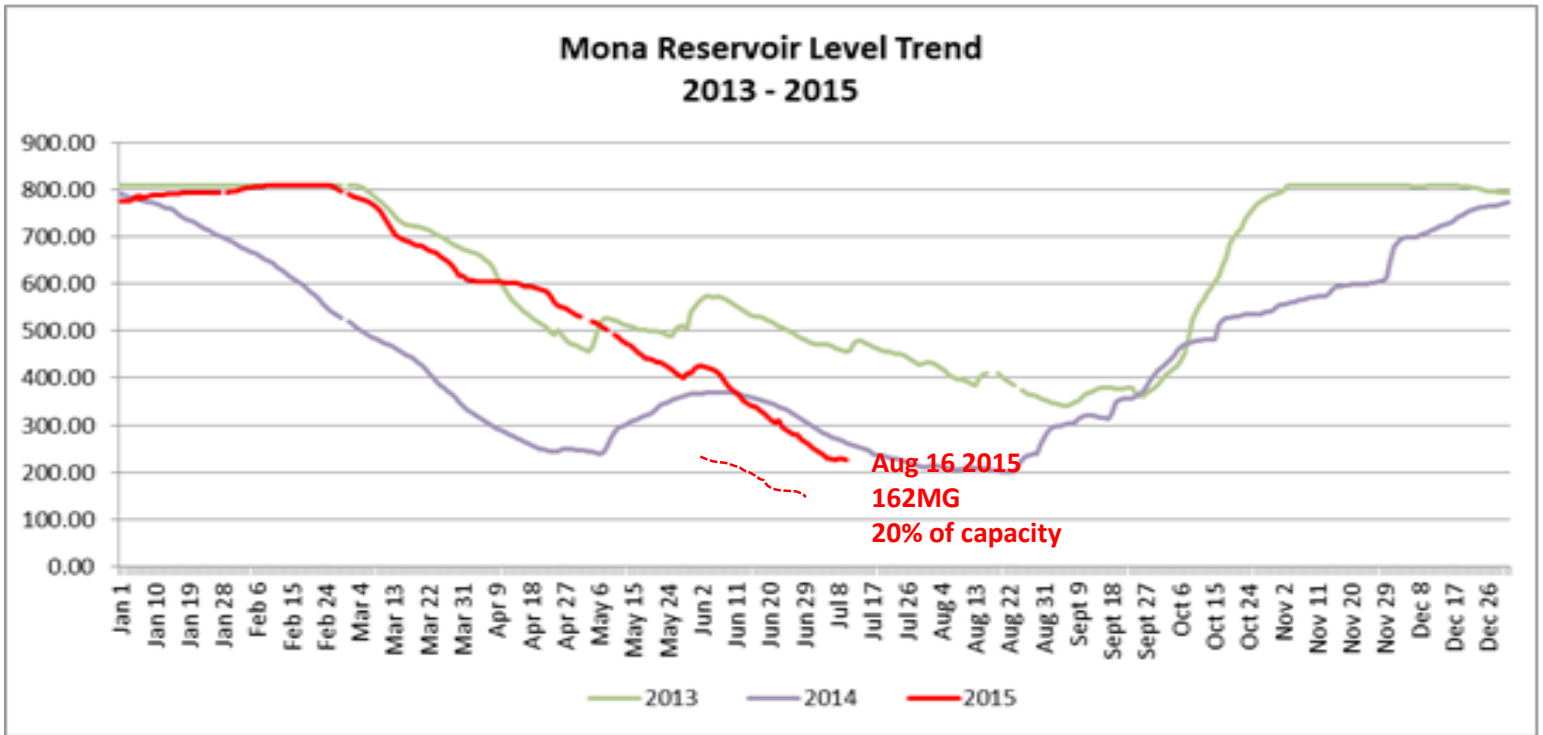


Mean Monthly capacity of the Mona Reservoir

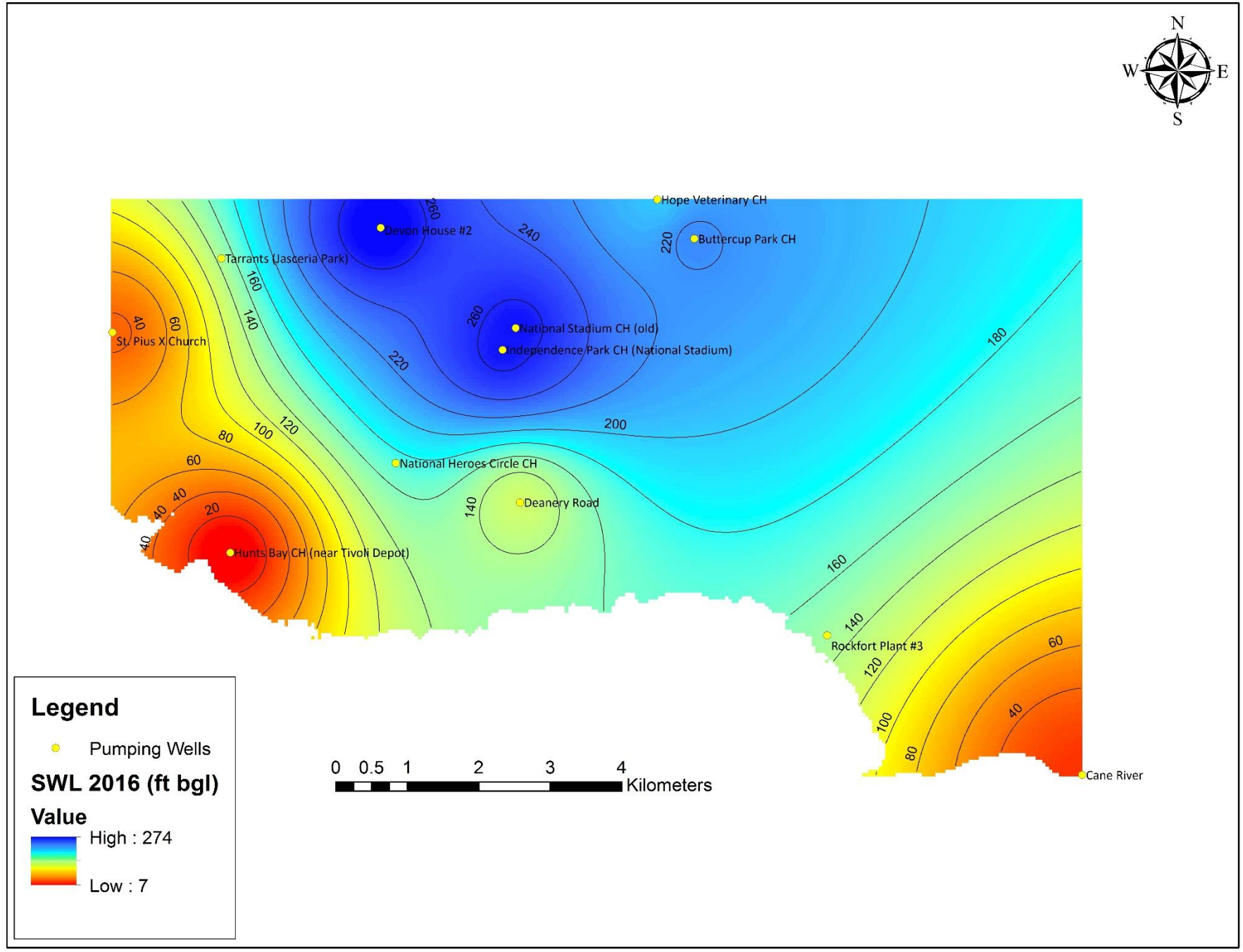


Mean Monthly capacity of the Hermitage Reservoir

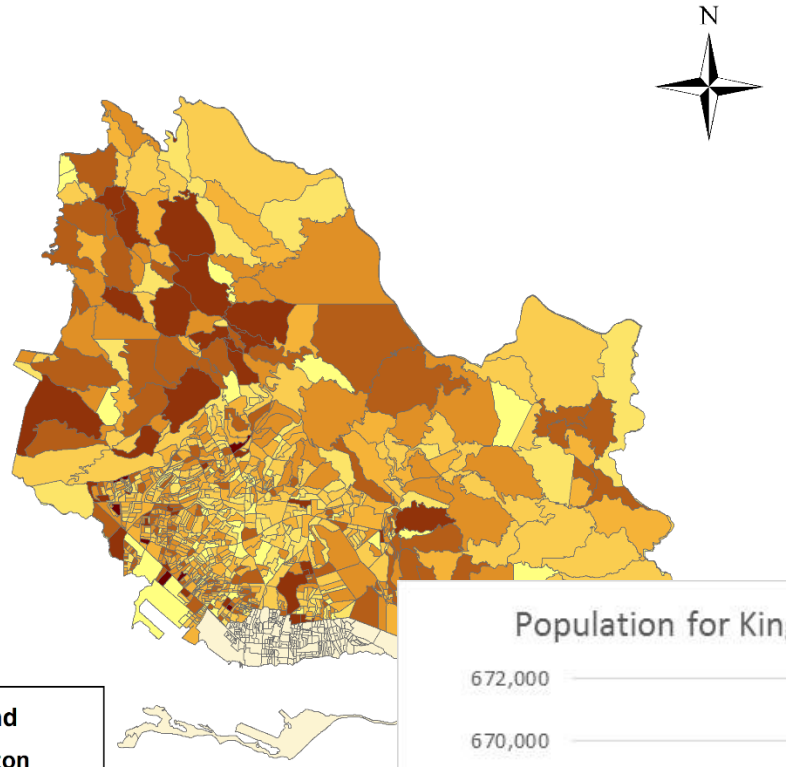




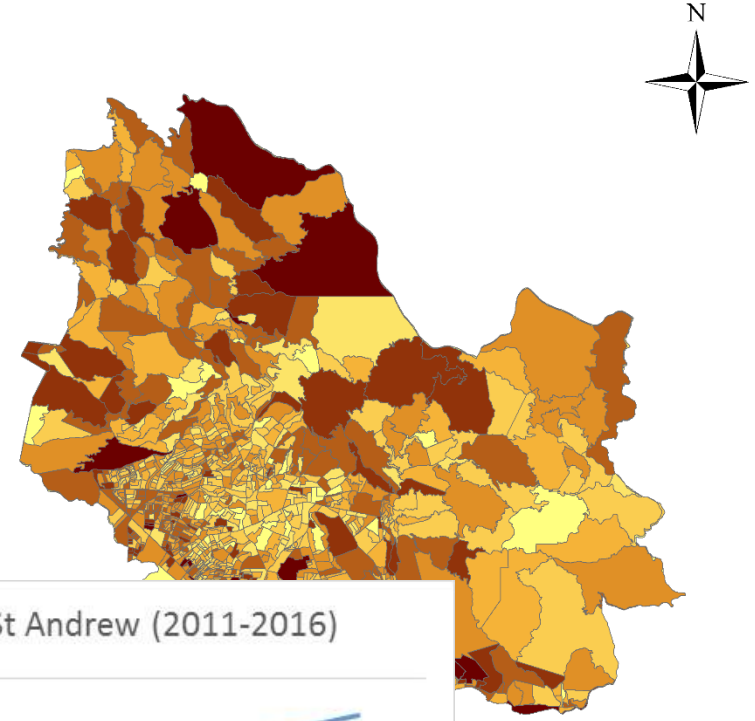
Impact of Drought on Raw Water Storage in KSA


N
W
E
S
Hope Veterinary CH
Devon House #2
Buttercup Park CH
Tarrants (Jasceria Park)
National Stadium CH (old)
Independence Park CH (National Stadium)
St. Pius X Church
National Heroes Circle CH
Deanery Road
Hunts Bay CH (near Tivoli Depot)
Rockfort Plant #3
Cane River
260
240
220
160
140
260
220
180
40
60
80
100
120
200
60
40
40
20
40
140
160
140
120
100
80
60
40
0 0.5 1 2 3 4
Kilometers
Legend
Pumping Wells
SWL 2016 (ft bgl)
Value
High : 274
Low : 7

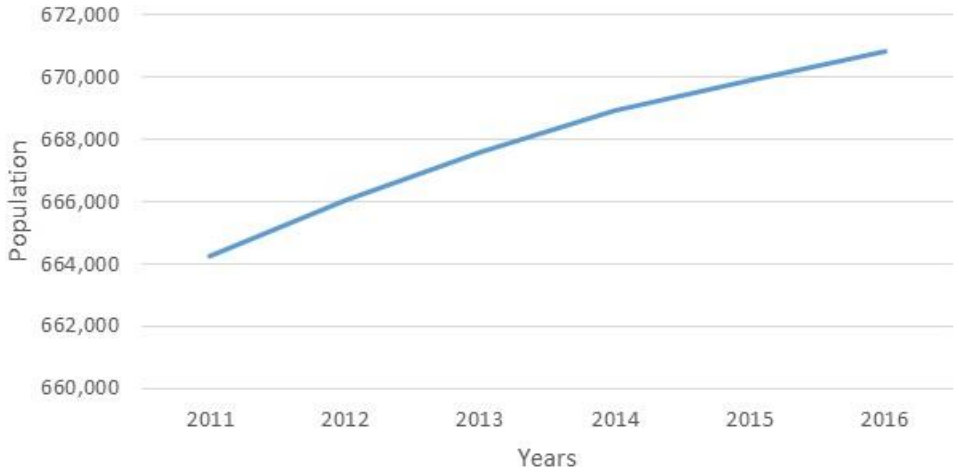
Population per Electoral Division in Kingston (2001)



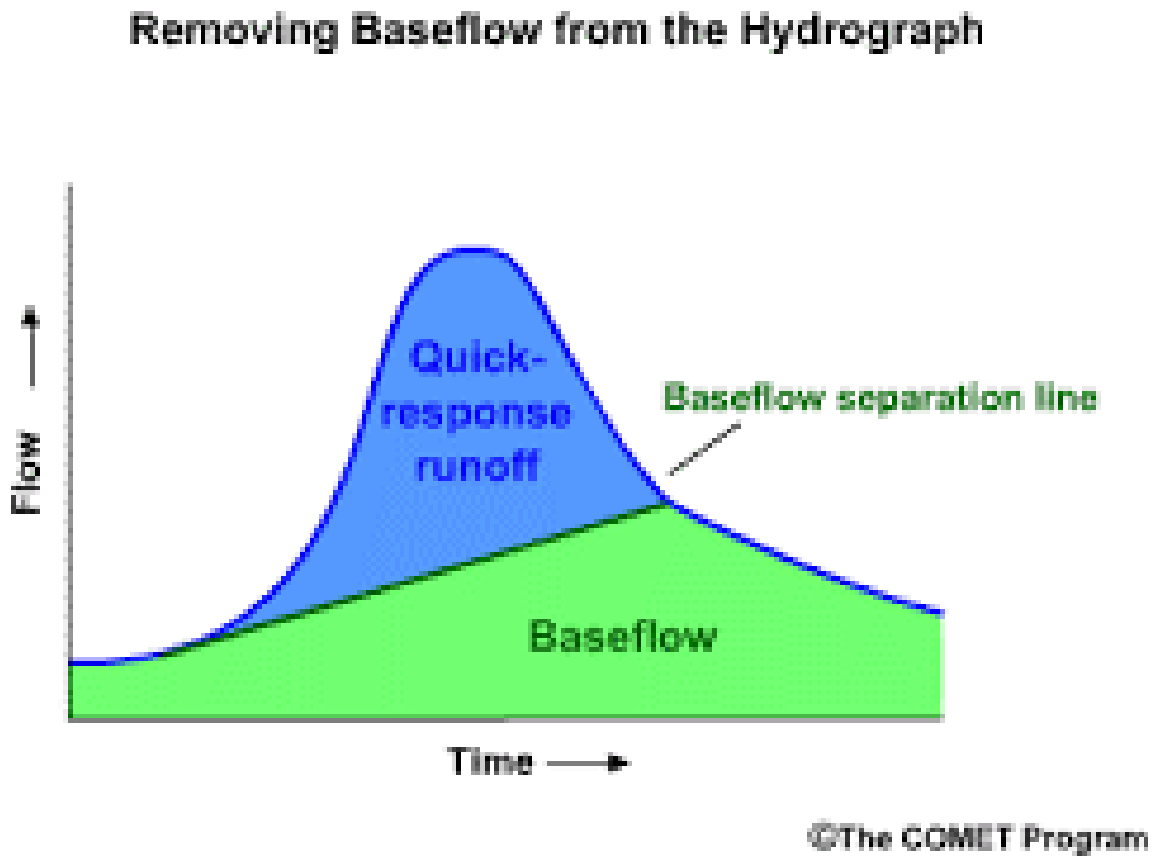
Population per Electoral Division in Kingston



Population for Kingston and St Andrew (2011-2016)



BASEFLOW FILTERING USING WETSPRO : LONG TERM TREND OF BASEFLOW.



Baseflow separation of the daily streamflow of Hope River carried out using WETSPRO . Data covering from 1955-2017 was used in the present work.
Baseflow: normal low flow in the river.

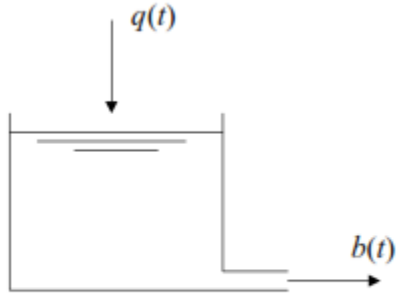
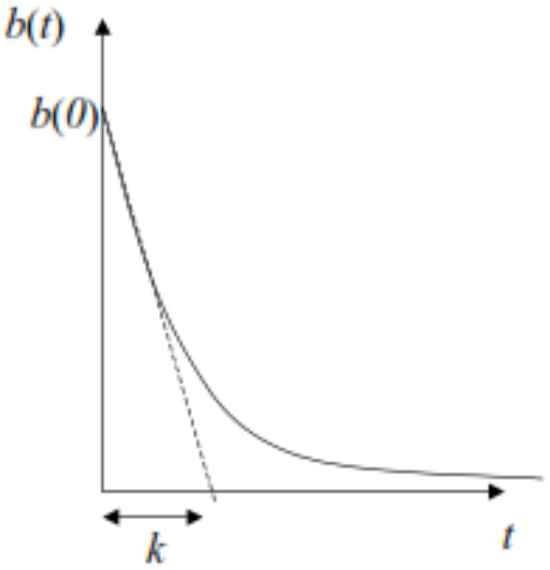


Figure 1. Input and output series of a reservoir model.



BASEFLOW SEPARATION USING THE RECESSION CONSTANT

WETSPRO : Tool designed for hydrological time series processing.

Actively used in Jamaica for the separation of daily flow into baseflow, overland and interflow.

Developed by Williams (2009) at KU LEUVEN.
Based on the principals of Chapman flitering. The filter aims to split the total flow time series in the subflow or slowflow component series and quickflow series.

WETSPRO results Hope River - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW

Cut Copy Format Painter Paste — Clipboard

Calibri 11 — Font

Wrap Text Merge & Center — Alignment

General — Number

Conditional Formatting Format as Table Cell Styles — Styles

Insert Delete Format — Cells

AutoSum Fill Clear Sort & Filter Find & Select — Editing

P5

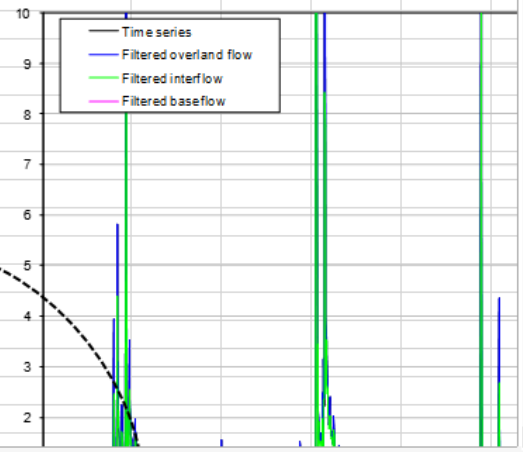
Subflow filter results: Hope River

Time	Total flow	Baseflow	Interflow	Overland flow
01/05/55	0.680	0.299	0.218	0.163
02/05/55	0.650	0.299	0.325	0.026
03/05/55	0.620	0.299	0.245	0.077
04/05/55	0.570	0.299	0.235	0.038
05/05/55	0.510	0.298	0.177	0.036
06/05/55	0.510	0.297	0.169	0.046
07/05/55	0.510	0.296	0.173	0.042
08/05/55	0.540	0.296	0.189	0.057
09/05/55	0.620	0.295	0.246	0.080
10/05/55	0.620	0.295	0.268	0.059
11/05/55	0.420	0.294	0.145	0.000
12/05/55	0.370	0.293	0.056	0.023
13/5/1955	0.340	0.292	0.050	0.001
14/5/1955	0.340	0.290	0.038	0.015
15/5/1955	0.340	0.289	0.045	0.009
16/5/1955	0.340	0.287	0.044	0.012
17/5/1955	0.340	0.285	0.046	0.011
18/5/1955	0.340	0.284	0.047	0.012
19/5/1955	0.310	0.282	0.031	0.000

To conclude on recession constants: Probably very steep/ mountainous area resulting in very small over and interland flow recession constants (less than 1 day discharges). Events contribute to high peak (greater than 10 m3/s) discharges on some occasions, which are discharged directly as overland and interflow for the greater part (during events). The greater fraction of total flow is contributed by baseflow with a great recession constant (160 days/ w = 0.55). Average total flow close to baseflow (mostly under 1m3/s).

Time	Total flow	Baseflow	Interflow	Overland flow
Max	99.25	1.578175924	65.00914133	33.76635478
Min	0.08	0.055089153	0.0001	6.55711E-06
Average	0.727120864	0.327860014	0.353077209	0.098845896

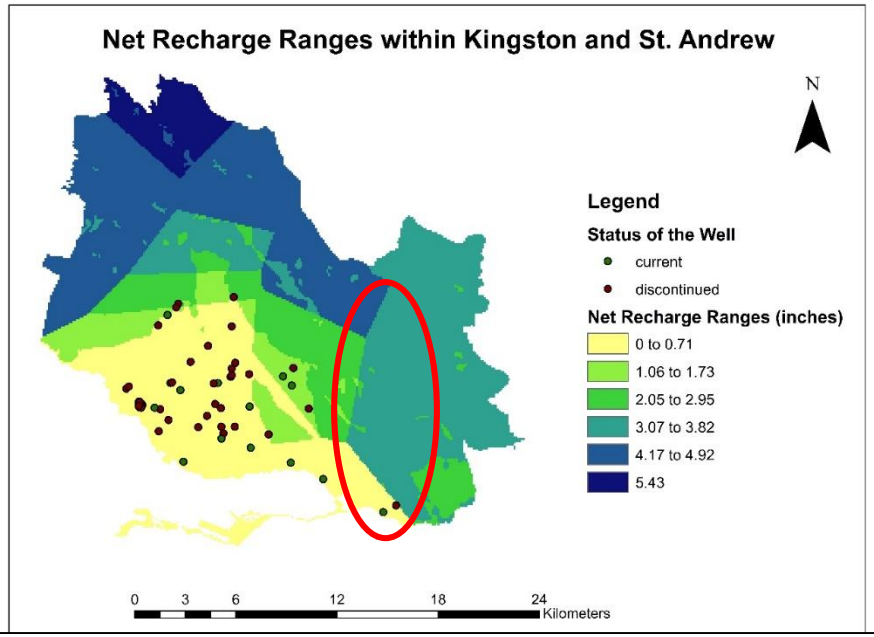
	BASEFLOW	INTERFLOW	OVERLAND FLOW
Filter parameters:			
unit of series]:	0		
mit of series]:	0.3	0	
of filter steps:	1	1	
of time steps]:	160	0.9	0.4
heter filter [-]:	0.55	0.2	
			0
			0
Graphical parameters:			
distance lines graph [number of time steps]:	100	50	50
first time step lines:	0	0	0

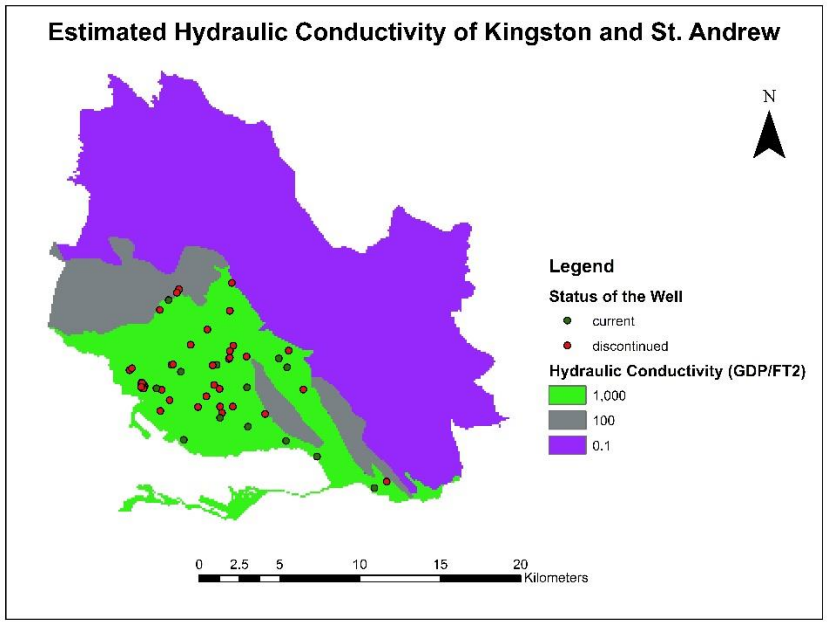


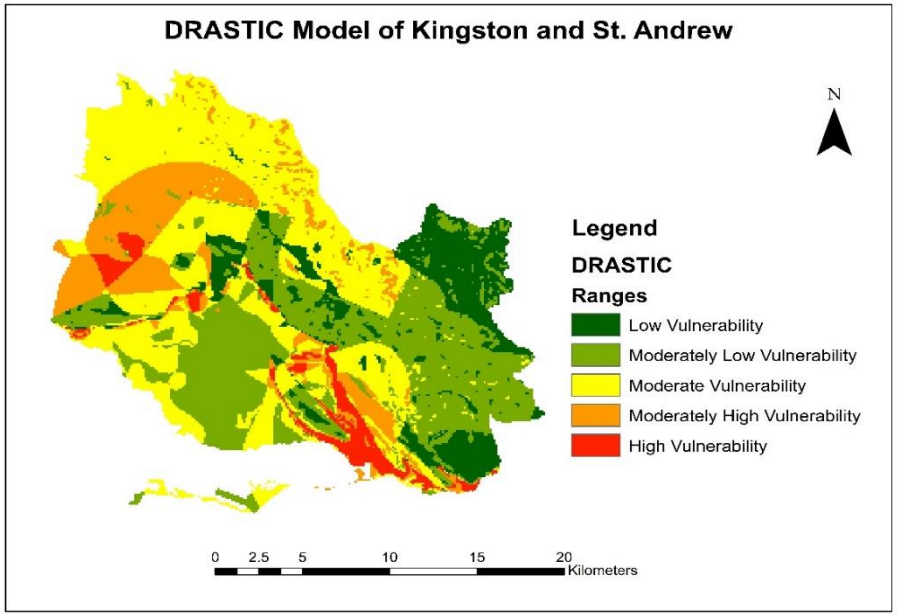
Hope River General Sheet2 Sheet3

READY 100%

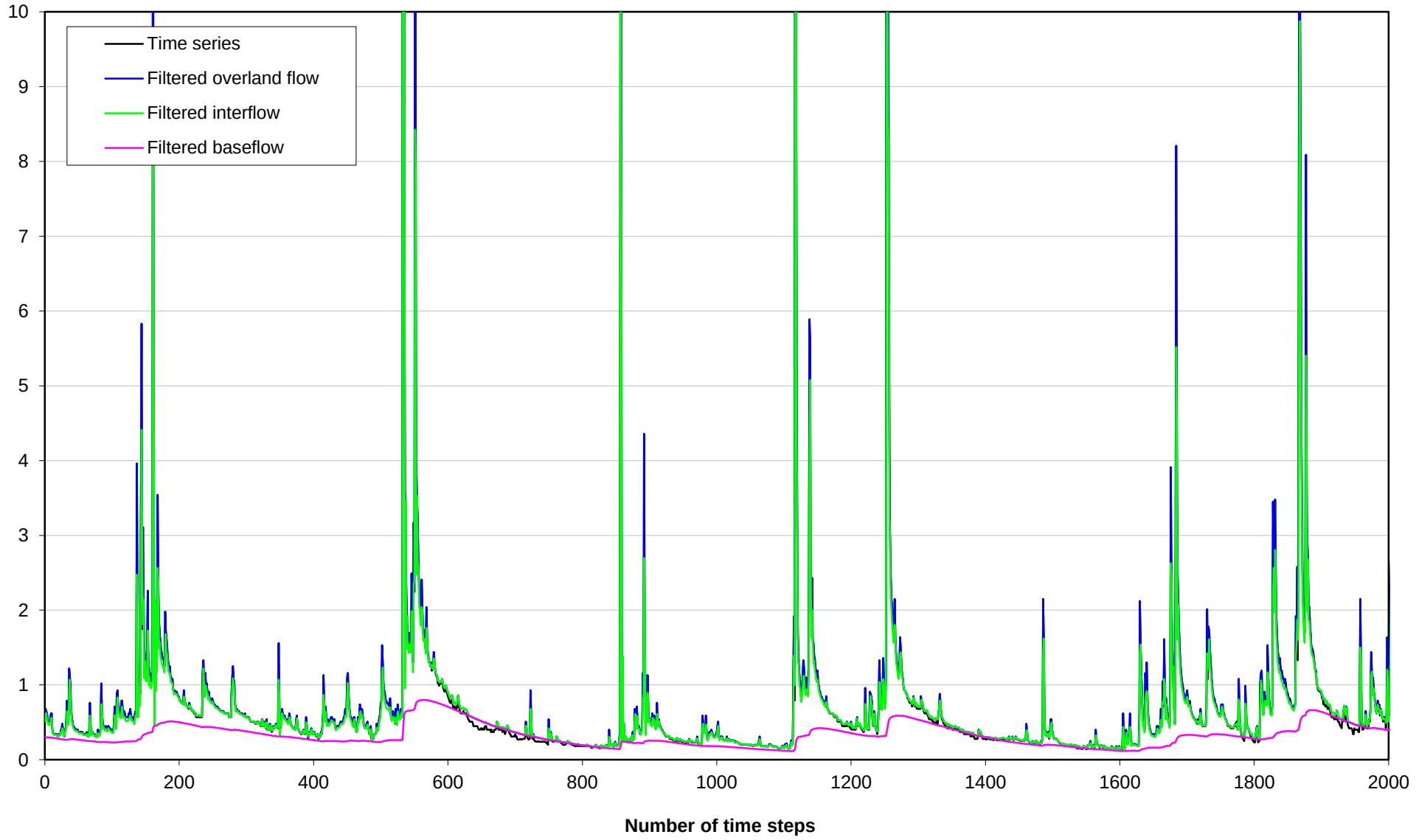
1:37 AM 10/23/2017

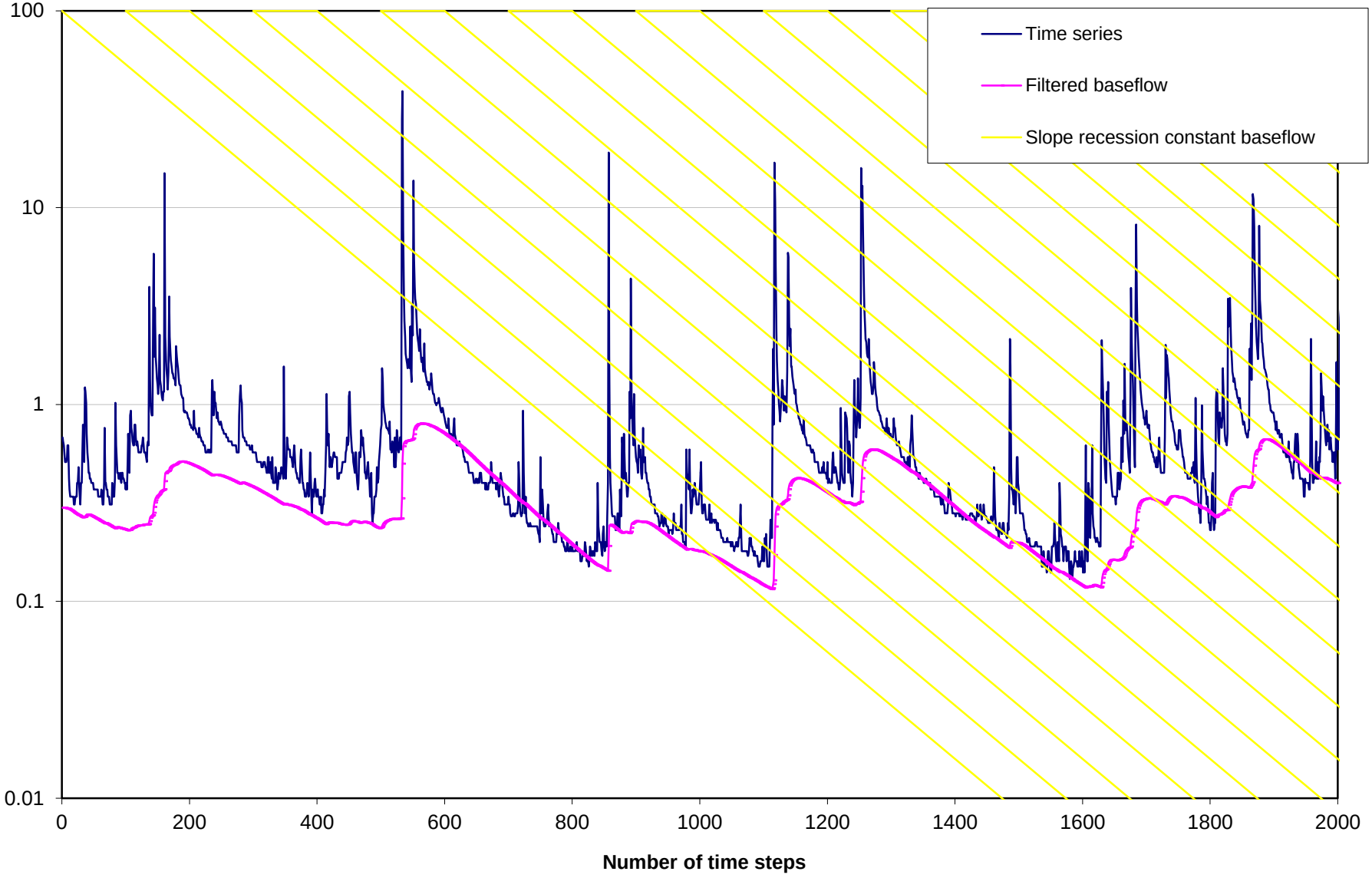






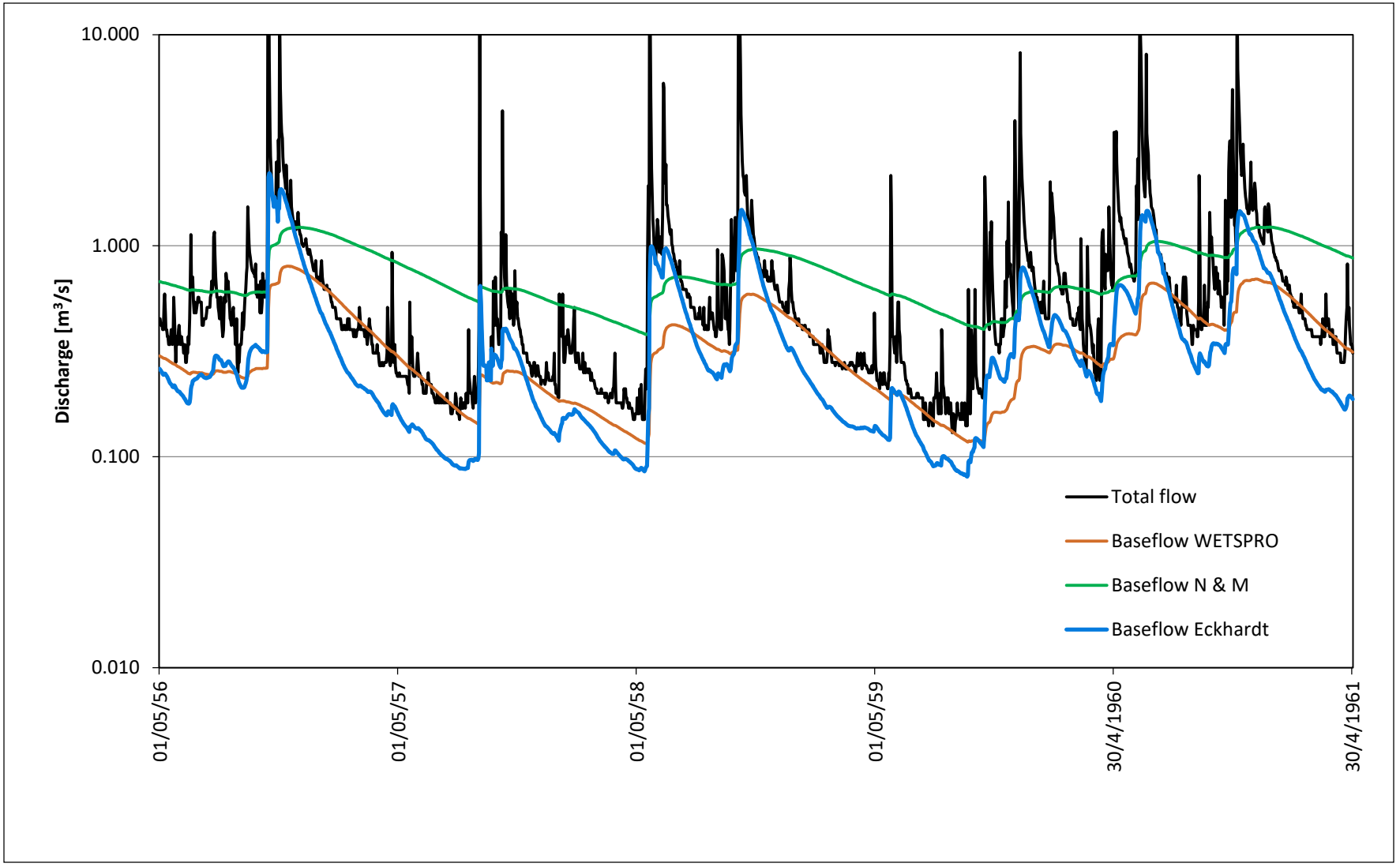
DRASTIC model runs for the Kingston Basin (CCRIF Internship, Kristinia Dougherty, 2017)
Vulnerability of the aquifer to contamination. Parameters used : Slope, Soil Types, Hydraulic Conductivity, Geology


Time series
Filtered overland flow
Filtered interflow
Filtered baseflow
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Number of time steps

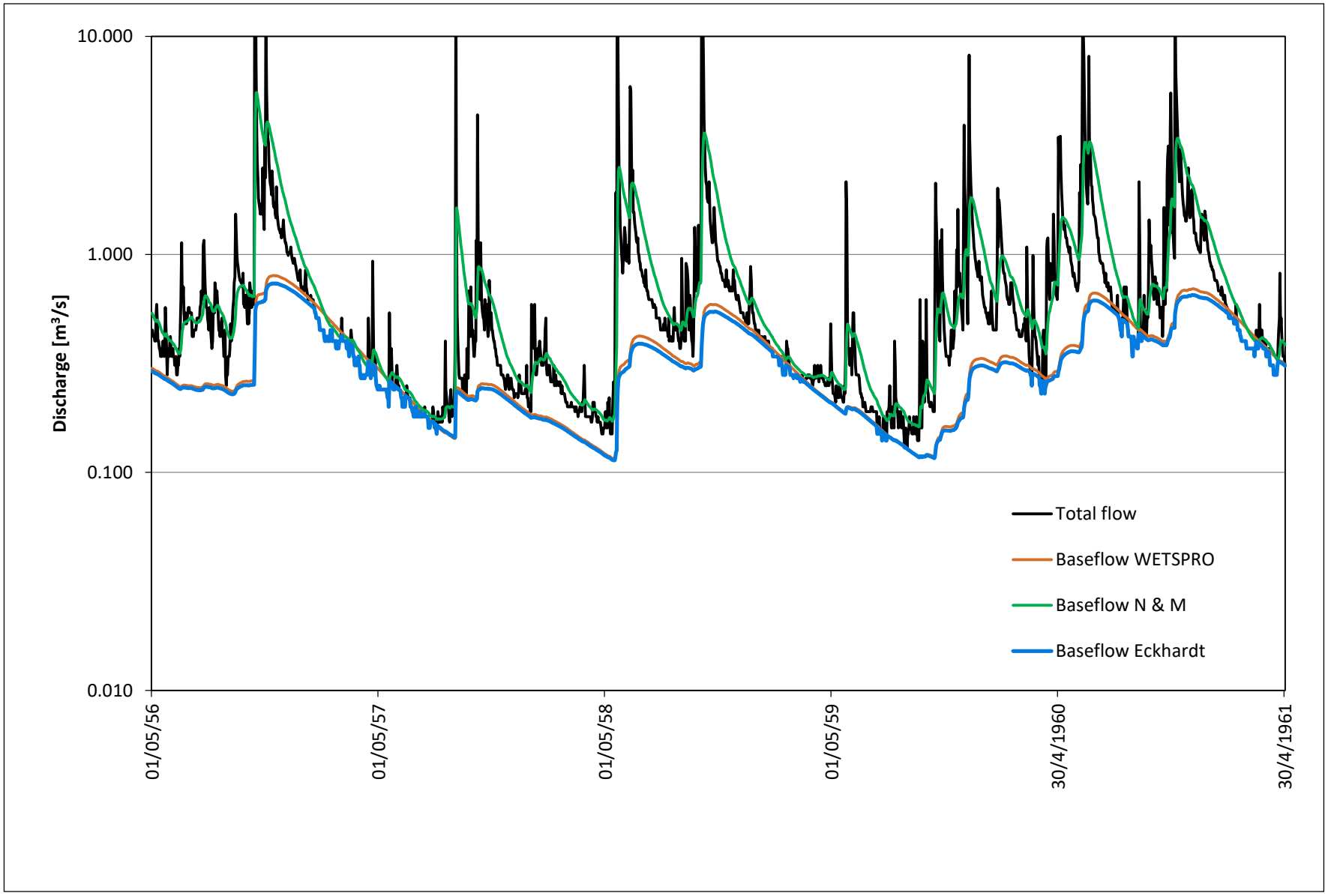


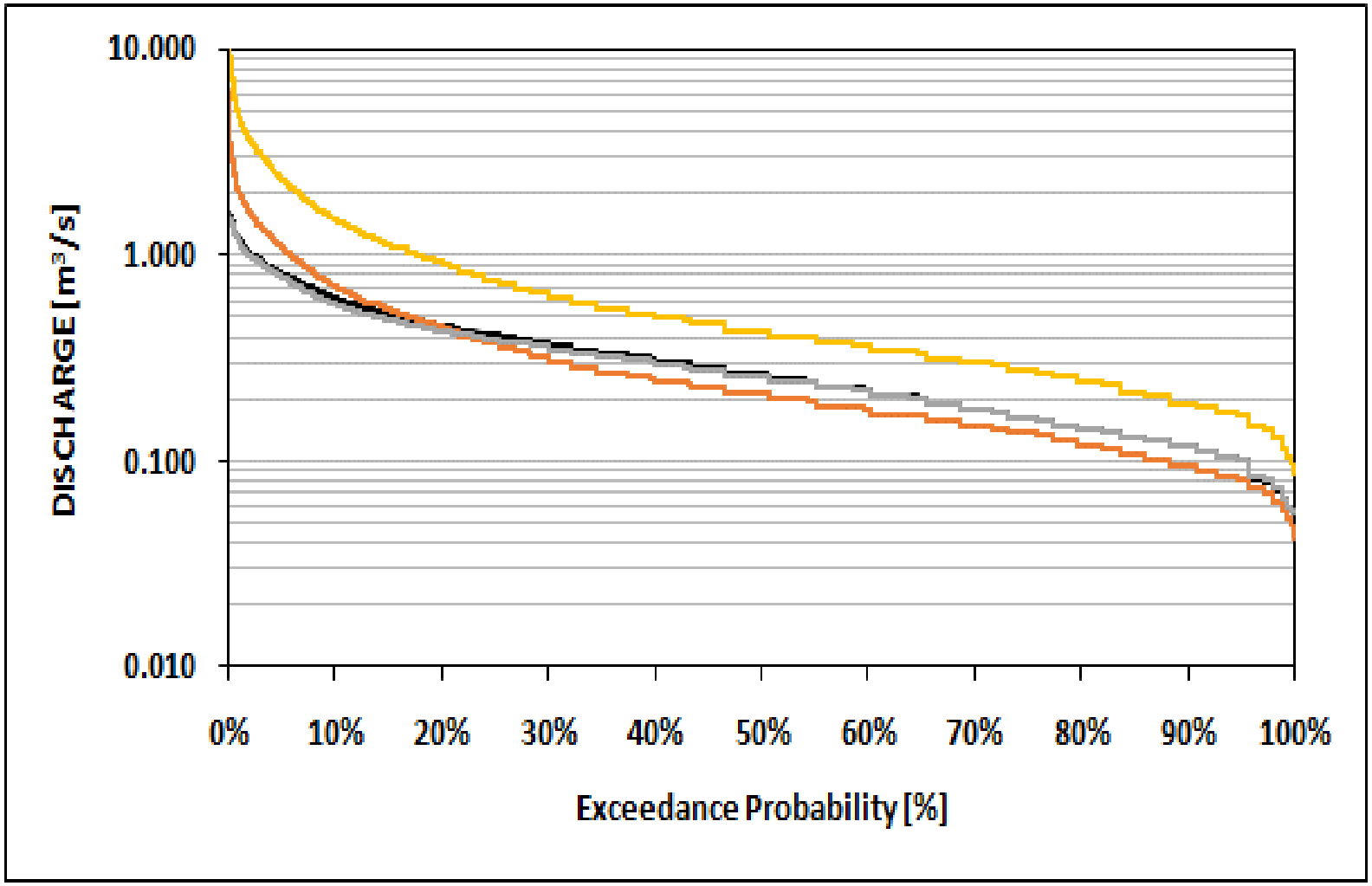
Long Term data shows a relatively low flow in the river.

Filtered baseflow for different filtering methods

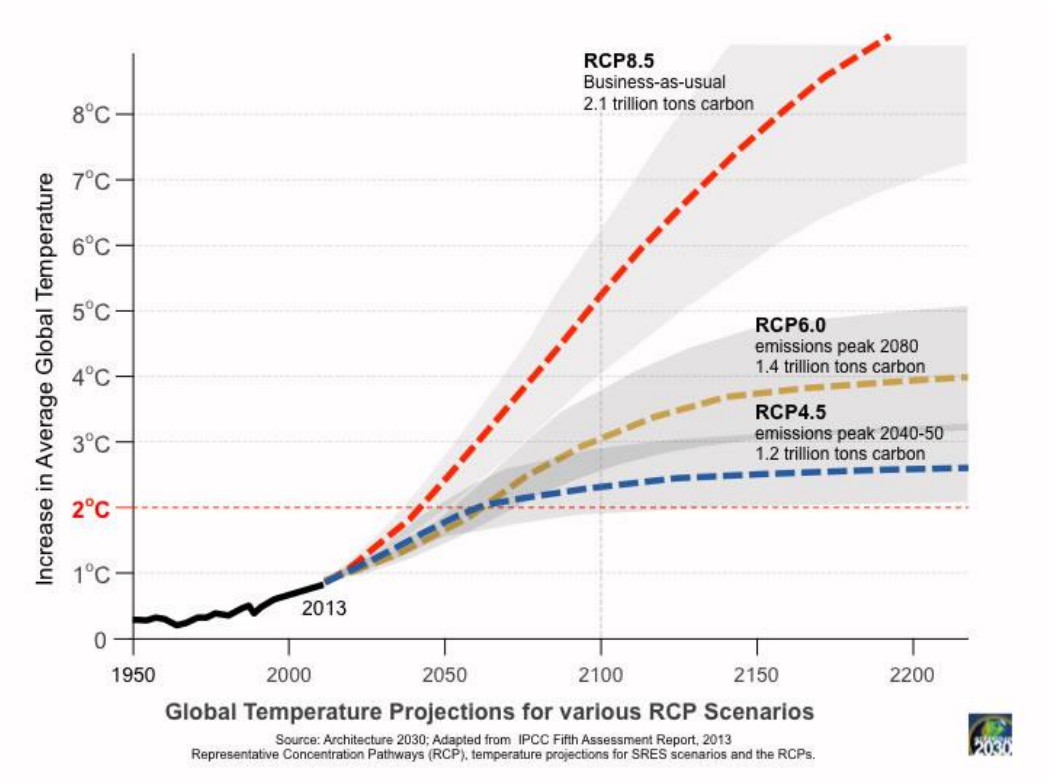


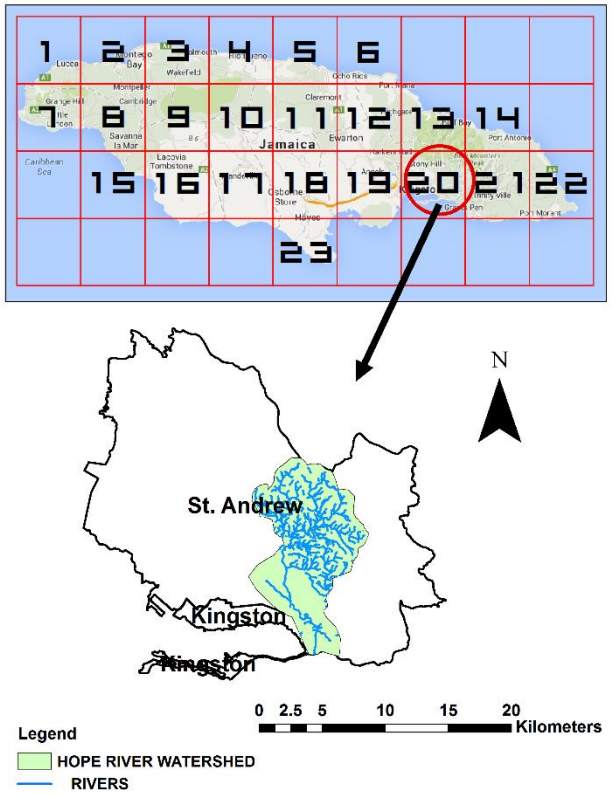
Filtered baseflow for different filtering methods (optimized parameter settings)





Flow Duration Curves (FDCs) for filtered baseflow: Black line: WETSPRO baseflow FDC: *k* = 160, *w* = 0.55// Grey line: Echardt baseflow FDC: *a* = 0.994, BFImax = 0.45 (optimized)// Orange line: Echardt baseflow FDC: *a* = 0.97, BFImax = 0.48// Yellow line: N &M baseflow FDC: *a* = 0.925 (best performance for N & M)





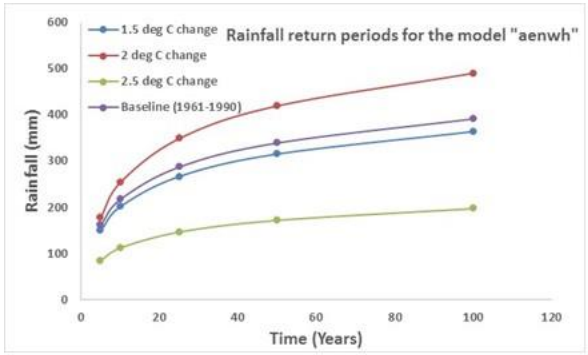
ONGOING WORK :

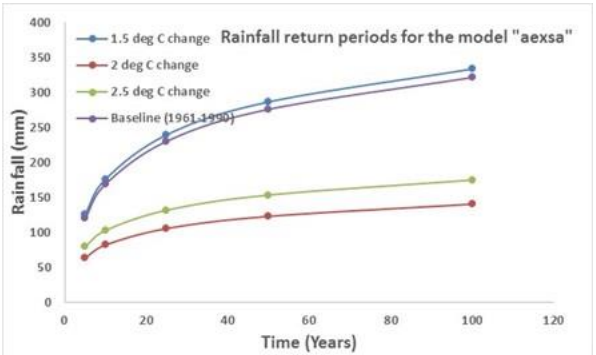
Impact of climate models conditioned over present model : Using RCP 4.5 Climate model results and its impact on the water resources. Impact of the 1.5 , 2.0 and 2.5 deg C change in temperature with respect to preindustrial levels.

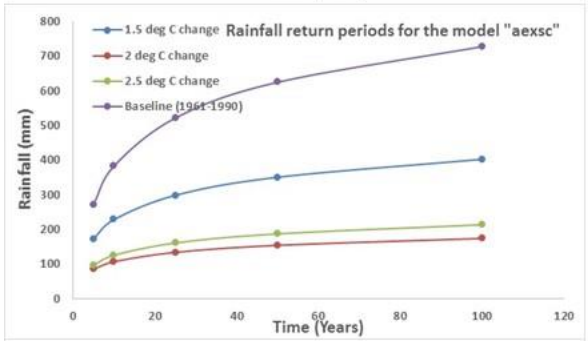
Development of a groundwater model for the upper Rio Cobre Limestone Aquifer using MODFLOW.

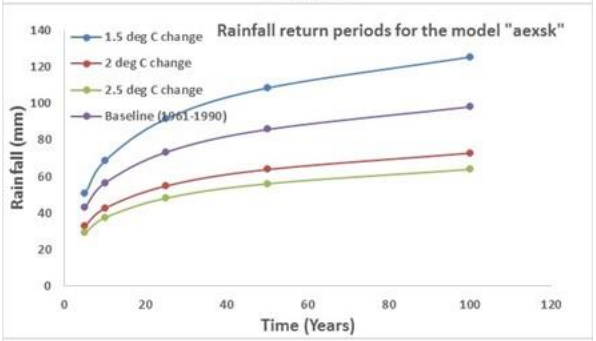
Estimation of resources from the limestone vs alluvium aquifer.

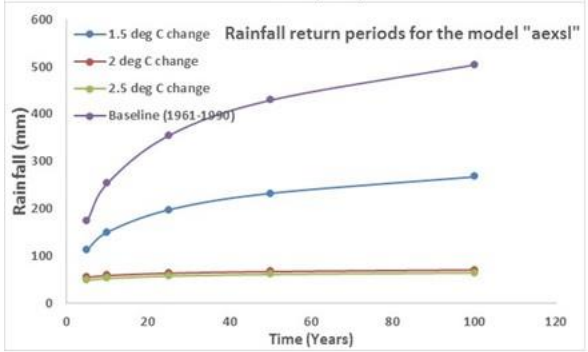
Demand and supply model for KMA (Kingston Metropolitan Area) using WEAP.

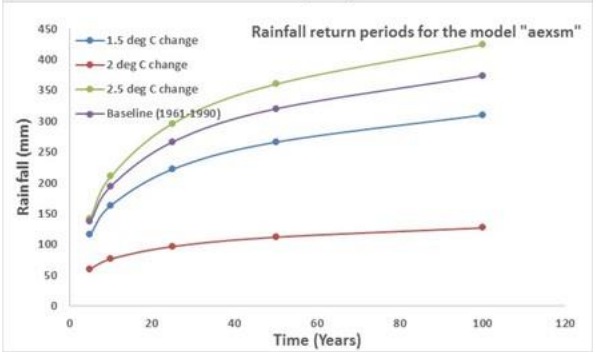


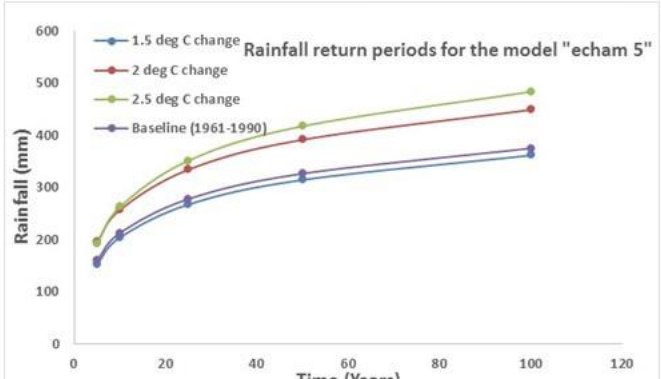












Rainfall return periods variation for different climate model runs.

Data based on the 25km climate model runs for the seven QUMP model simulations for the Hope watershed.

Majority of the models showing the drying trend.

Acknowledgements

- Water Resources Authority of Jamaica
- National Water Commission, Jamaica
- Meteorological Service of Jamaica