The Ministry of Transport, Works and Housing

National Works Agency (NWA)

Ministry of Local Government and Community Development

GUIDELINES FOR PREPARING HYDROLOGIC AND HYDRAULIC DESIGN REPORTS FOR DRAINAGE SYSTEMS OF PROPOSED DEVELOPMENTS

Revised June 2015

FOREWORD

This guide outlines a set of procedures and makes reference to a number of standards and/or requirements that are relevant and applicable to the subdivision and development of land across the island. As it stands, the design and calculation procedures applied in most of the hydraulic reports only consider the project site and not the entire watershed. Additionally, some of the existing guidelines are not suitable as they do not account for increased frequency and intensity of meteorological weather systems as forecasted by climate change projections.

The following guidelines will therefore set out the minimum information to be included in the preparation of hydrologic and hydraulic design reports on drainage systems for proposed sub-divisions. It is expected that the incorporation of these guidelines in the preparation of development proposal documents will allow for more accurate designs and the ease of application evaluation and approval. Furthermore, the guidelines will also advance the mainstreaming of Disaster Risk Reduction considerations into the project planning phase to reduce future impacts from hazards and economic losses from disasters; contributing to the achievement of goals under the Vision 2030 National Development Plan.

The NWA, WRA and ODPEM under their respective ministries contributed towards the development of these guidelines in their capacity as stakeholders in the national housing development process, pursuant to Section 14 of The Local Improvement Act 1914 and Section 5 (2) of the Disaster Risk Management Act 2015.

These guidelines were adopted by the Internal Review Committee (IRC) at the NWA and Sub-committee and Technical Review Committee at the National Environment and Planning Agency (NEPA) and will take effect as of July 1, 2015 for the approval of all development applications.

Special mention must be made to Mr. Howard Prendergast for NWA, Mr. Christopher Gayle for ODPEM, Mr. Herbert Thomas for WRA and Mr. Haruo Kubo, JICA Senior Volunteer for ODPEM.

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Ⅰ. Minimum Requirements for Hydrologic and Hydraulic Design Reports

1. Design Philosophy

All reports shall outline the design philosophy on which the drainage proposal is premised and shall include all assumptions made in the compilation of the report. This should include the watershed influencing the development as well as the final outfall.

These basic points should be taken into consideration in the designs.

1.1 Development site

No site/lot will be recommended for development which is vulnerable to flooding, erosion, storm surge, land slippage or might pose danger to property and/ or life, unless the counter measures proposed are proven to be sufficient.

1.2 Future development within catchment area

If there are future development plans within a specified catchment area, the developer(s) must take this into consideration when calculating the design flows for dimensioning the drainage and storage systems. The developer must consult with NWA, NEPA and WRA to be advised of the extent of build out of the watershed. This will inform the runoff coefficient determination.

1.3 Peak discharge and runoff volume

Peak discharge and runoff volumes should be determined based on up-to-date rainfall intensities issued by the Meteorological Service of Jamaica.

1.4 Margin for culvert and open channel

Box culverts, pipe culverts and open channels shall be designed with a freeboard not less than 25% of design flow depth.

1.5 Discharging offsite

1.5.1 No proposed road or lot will be allowed to drain storm water **directly** unto an existing road or property, without the specific permission from NWA.

1.5.2 The design should incorporate water detention or retention features to reduce the increase of run-off from the development. Pre and post development peak discharges must be determined based on an appropriate method for designing the required storage.

- Post-development peak flow should not exceed pre-development peak flow.
- Formulas used to calculate the required detention volume must also be given.

- Method to release stored runoff must also be given.

1.6 Depressions and sinkholes (refer to the Notes 1 & 2)

Geological factors can promote formation of sinkholes, slope failures, erosion and high level of sediment load. These can pose serious challenges and risk for construction activities in depressed areas. Flooding is often associated with depression during intense and continuous rainfall.

1.6.1 Development in closed depressions as defined or delineated by *****1:12,500 topographical maps shall be restricted. Developments of types other than housing may however be allowed by the relevant authorities under circumstances subject to special conditions.

1.6.2 **No residential development shall take place in areas of depression and sinkholes with a history of flooding or ponding.** (refer to the Note 3)**.**

1.6.3 **No residential development shall take place in 100 year floodplain of depressions and sinkholes.**

1.6.4 The 100 - year floodplain shall be determined by rainfall volume and flood line generated by the 24hour - 1 in 100year storm event assuming zero outflow by internal drainage. A minimum setback from the 24hour - 1 in 100year flood elevation shall be maintained in depressed areas as follows. This is to be submitted and approved by the relevant authorities (NWA & WRA).

Slope	Setback
1 : 20	30m
1 : 4 – 1 : 20	15m
1 : 1 and steeper	7.5m

1.6.5 The design storage volume of depressions must have a minimum 10% margin in consideration of accumulation of silt.

Note 1 : Definitions

Depression : A depression is a landform that is completely surrounded by higher ground.

Sinkhole : A type of depression or hole formed in soluble rock (especially in limestone) by the action of water, serving to conduct surface water underground.

Note 2 : *****1: 12,500 topographical maps available at the Survey Department.

Note 3: Carry out relevant research through credible databases such as the Gleaner, ODPEM, WRA, NWA and DesInventar Online catalogue. Additionally, field assessments may be done to include interviews with residents of the relevant community.

1.6.6 Where depressions and sinkholes are used as final outfall within a subdivision the pre and post development rate of discharge to the sinkholes and the capacity of the depression should be determined by a professional engineer (hydrological/hydro-geological studies). Measures for preventing any significant increase in the post development levels should be designed and submitted for approval by the relevant authorities (NWA & WRA).

No grading or altering of depressions will be allowed.

1.6.7 Depressions and sinkholes which are to be used for storm water discharge shall be kept in their natural state. Measures shall be put in place to prevent or minimize sedimentation before final discharge. Sinkholes shall be prevented from blockage using trash rack or other appropriate devices.

1.6.8 Sinkholes within a subdivision shall be fenced and be protected for safety and security reasons.

1.6.9 No development shall be permitted above underground features (caverns etc.).
Developments above or in close proximity to caverns etc. should only proceed after detailed exploration to ascertain their characteristics and site suitability approval by the relevant authority (Mines and Geology Division).

1.6.10 During site preparation for development, cavities or sinkholes shall not be covered, filled or buried. Developments, both when completed and during construction, should not block access to cavities or sinkholes. As a temporary measure, a storm drain inlet protection or sediment barrier shall be constructed to prevent sediment laden run-off from entering the sinkhole area(s) during construction activities.

1.6.11 During construction, sediments shall be captured on site using sediment control fences (berms, silt fences, sumps, swales, sediment/siltation control basins etc.) that will prevent sediments from entering or clogging sinkholes and depression areas. Waterways with high flow discharge rates which drain surrounding lands within areas to be disturbed for construction purposes shall be provided with check dams, erosion control aprons etc. for reducing high flows and trapping and retaining sediments. Upon removal, sediments must be properly disposed of at an approved disposal site.

2. Submission of Drawings and Photos

2.1 Location map

The following points are to be taken into consideration:

- Indicate azimuth direction
- Annotate roads, rivers, landmarks, other important features.
- Submit electronic copy of maps to be geo-referenced (jpeg, or similar format).
- Project area should be highlighted by red lines.
- Watershed should be highlighted by blue lines.

2.2 Conceptual drawing (example Fig. 1)

Conceptual drawings are very important to clarify the overall picture of the design.

The following points are to be taken into consideration.

- Display entire watershed area including project area.
(to be shown on the 1:12,500 scale topographic map.)
- If the proposed site is located in an area where the 1:12,500 scale will not supply sufficient topographic detail, then the developer will be requested to provide a topographic survey at a higher resolution.
- Identify significant drainage features upslope and downslope of project area (rivers, gullies, bridges, sinkholes etc.)
- The drainage area in km^2 or hectares should be stated.

2.3 Grading plan

Where existing topography is proposed to be significantly altered, a grading plan showing revised contours and elevations must be submitted. See “Hillside Development Manual” (Mines & Geology Department).

2.4 Photographs

Photographs (in color) identifying pre development site conditions including existing drainage features and topography. All special features outlined in proposal or relevant to development must also be submitted.

2.5 Design drawings

Design drawings for plan, longitudinal and cross sections of the project area and typical cross sections of main structures must be submitted. Contour lines with appropriate intervals should be included.

3. Calculation Procedure (refer to the Fig.2)

3.1 Submission of drainage calculation report

Submission of drainage calculation report is required for all developments that:

a) are vulnerable to flooding i.e. in close proximity to waterways or depressions.

b) Can aggravate flooding in other areas by encroachment of floodway or increased run-off.

3.2 Units

The International System of Units (SI) (cm, m, km, m^2, km^2, m^3, second) should be used.

3.3 Return period

In principle, the following design return periods are applicable:

Type of Drainage System	**Return Period**
The **minor drainage system** consists of inlets, street and roadway gutters, roadside ditches, small channels and swales, and small underground pipe **systems** which collect stormwater runoff and transport it to structural control facilities, pervious areas and/or the major drainage system (i.e., natural waterways, large impoundments, gullies, rivers etc.).	Up to 1 in 10yr
The **major drainage system** is defined by flow paths for runoff from less frequent storms, up to the 100-yr frequency. It consists of natural waterways, rivers, large man-made conduits, depression storage areas and large water impoundments. If the minor system is exceeded during a storm event, the **major system** is then utilized.	Up to 1 in 100yr

3.4 Average runoff coefficient (refer to the Table 1)

Where the watershed consists of areas with differing values of runoff coefficients, a composite runoff coefficient for the total area is computed as :

C= (a1c1+a2c2+a3c3……ancn) / (a1+a2+a3……an)

where a1,a2,a3 ··· an : the area of the various sub-catchments

c1,c2,c3 ····· cn : the runoff coefficients for the respective sub-catchments

a1+a2+a3+····+ an : total watershed area

3.5 Rainfall intensity (refer to the AppendixⅢand the Fig.3-8)

The rainfall intensity can be calculated based on the methodology in the Flood Plain Mapping Project; Rainfall Frequency Analysis report.

3.6 Calculation of inlet time (Time of Concentration, Tc)

All Tc formulae have limitations considering the development features. Inlet time calculation by W.S. Kerby's formula is one that is widely used:

$$\mathbf{ti = 1.445(N \cdot L/\sqrt{S})^{0.467}}$$

where ti : Inlet time (min)

L : Flow length (m)

S : Slope gradient

N : Coefficient of roughness for Kerby's formula(refer to the Table 2)

Other appropriate methods can also be used.

3.7 Calculation of peak discharge (refer to the Note 4)

The rational method is appropriate for estimating peak discharges for small drainage areas, of up to about 1km^2 (100 hectares), where there is no significant flood storage. The method provides the designer with a peak discharge value.

$$\mathbf{Q = 1/3.6 \times 10^6\ C \cdot I \cdot A \qquad A \leqq 100ha}$$

where Q : Peak discharge (m^3/s)

C : Runoff coefficient

I : Rainfall intensity (mm/hr)

A : Catchment area (km^2)

3.8 Calculation of flow velocity

The Manning's formula is to be used to calculate flow velocity.

$$\mathbf{V = 1/n \cdot R^{2/3} \cdot i^{1/2}}$$

where V : Flow velocity (m/sec)

n : Manning roughness coefficient (refer to the Table 3)

R : Hydraulic radius =Area(wet)/Perimeter(wet)

i : Channel gradient

Note 4: Use of the rational method includes the following assumptions and limitations:

-Due to significant margin of error associated with the modelled intensity the minimum duration to be used for computation of rainfall intensity is 10 minutes. If the time of concentration computed for the drainage area is less than 10 minutes, then 10 minutes should be adopted for rainfall intensity computations.

-The rational method does not account for storage in the drainage area. NB. If detention ponds are to be designed the rational method should not be used. Where the assumptions of the rational method are not fulfilled the use of hydro- numerical modelling; the Tr55, Jamaica II and Hec-hms are advised.

-Anecdotal data should be included in the report if available.

3.9 Calculation of gutter flow time

The average fluid velocity's formula is used to calculate flow time.

$$t = 1/60 \cdot L / V$$

where t : Gutter flow time (min)

L : Gutter length (m)

V : Flow velocity (m/sec)

3.10 Hydro numerical modelling

Where numerical models are used:

- State name of program and description
- Boundary conditions should also be given
- Model outputs should be represented graphically

4. Other Design Considerations

4.1 Flood protection for houses

The setting of floor levels should be 0.40m above the 100 year flood level for the development in order to allow the road and other finished surfaces to convey the storm water flows for major storm events without affecting the buildings. No Floor Level should be set lower than 0.40m above any road level adjacent to the building.

If roadways are used for conveyance of runoff to drains (storm sewer or gullies), the flood level for each building should be based on the conveyance capacity of the cross section through the building and the road(s) adjacent to the building.

Roof guttering to downpipes into suitable storage facilities (where allowable) should be considered. Where run-off is directed into dry wells, soak-aways or absorption pits a proper assessment of groundwater level and infiltration capacity should be done. A minimum setback of 3m shall be maintained from any permanent structure. (Refer to International Plumbing Code and International Building Code & Hillside Development Manual, Mines and Geology Division).

4.2 Detention basin

4.2.1 ***Inflow*** - The relationship between the size of the watershed and the design storm frequency is as follows:

Watershed area <250ha	10 year frequency
Watershed area ≥250ha	25 year frequency

The duration of a storm is critical in determining inflow. Generally, the high intensity- short duration storm tends to determine basin size. However basin performance must be checked for low intensity- long duration storm as these latter storms generate a higher flow volume over a longer time.

4.2.2 ***Outflow*** - The allowable outflow from a basin is determined from the conveyance capacity of the existing drainage facilities downstream. A larger basin might be required to reduce outflows to pre development flow rates.

4.2.3 ***Freeboard requirements*** - Regardless of the size of watershed upstream of a basin, the 100 year storm must be routed through the basin and the basin sized so that the maximum water surface elevation (100 year) is at least 0.60m below the lowest point along the top of the basin. It is preferred that the basin fully contains inflows from the design storm without spillage over the emergency spillway (100 year).

***4.2.4 Provisions for dewatering* -** The sizing of the outfall must allow for emptying of the basin within 48 - 72 hours so that enough storage is available to adequately mitigate a subsequent storm.

***4.2.5 Provision for sedimentation* -** The design volume of the basin must take into consideration the possible sediment load from the upper watershed of the development and should be at least 10% above the design volume. .

***4.2.6 Basin side slopes* -** Side slopes in detention basins shall be a minimum 3:1 (horizontal to vertical) below the design water surface and 2:1 above. The soil type will influence the side slope. If the basin has a secondary use such as a park, then side slopes should preferably be flatter than 4:1 for ease of mowing and maintenance.

4.3 Roads (refer to Note 5)

Maximum recommended road slope shall be 15% for distances not exceeding 50m.

Road alignment and grading should be guided by the existing contours.

Refer to the Hillside Development Manual (Mines and Geology Division).

4.4 Storm drains/ sewer

4.4.1 For drainage appurtenances being transferred to the Parish Council the minimum recommended size of open channel storm drains/ sewers is 450mm in width/ diameter and underground culverts/pipes is 600mm.

For drainage appurtenances on individual lots and small development areas not exceeding 0.10ha the minimum recommended size of open channel drains is 450mm in width and underground culverts/pipes is 300mm in diameter.

Note 5: It is the designer's responsibility to ensure that proper geometrics (alignment, cross sections, profile) are considered in the road designs. Roads should be aligned in a manner to avoid sudden bends and cutting across contours. In hilly terrain, it is important to select road alignments which do not require steep road gradients. Roads with steep gradients are often troubled with excessive erosion of the road surface and drains. By reducing the road gradients, the water can be drained away from the road more efficiently and at lower speeds, thereby reducing the erosion caused by the water.

4.4.2 Allowable minimum and maximum velocity in storm drains/ sewers

Material of drains/ sewers	**Velocity (m/sec)**
Concrete	1.0～3.5
Asphalt	0.9～1.5
Stone pitching/ block	0.6～1.9
High-density polyethylene	1.0～3.5

4.4.3 Minimum gradient of storm sewers shall be as set out below.

Pipe diameter (mm)	**Minimum gradient (%)**
450	0.5
600	0.5
900	0.35
1200	0.35

4.4.4 Maximum allowable length of underground storm sewer between manholes shall be 80m (D≥600) and 50m (600> D≥ 300). D: Pipe diameter (mm)

4.5 Sediment trap

All street inlets which are to be connected to storm water channels/ pipes, should provide mud reservoir (sump) with minimum 300mm depth. A section of the sump invert should be left open and pervious to allow for drawdown of stagnant water and vector control.

4.6 Scour protection

Design of drainage facilities located on steep slopes should incorporate mechanisms to counter scouring of drainage surfaces especially at the inlet and outlet and along main channels. Examples of scour protection mechanisms include the use of stepped drainage design on steep slopes, weirs, rip rap to reduce flow velocity and, baffle walls at the intersection of sub-channels and main channel.

5. Environmental Considerations

5.1 Change in floodplain elevations

Consideration shall be given to post development flows and final discharge point(s) to ensure that properties and structures that had not previously been subjected to flooding are not exposed to any additional risk. It should be noted that a shift in a floodplain's hydrology can possibly lead to the degradation of wetland and forest habitats. Where the Local Authority determines that a particular area is vulnerable to flooding due to historical flooding problems or downstream floodplain development and where the conveyance system design cannot be expanded to accommodate the flows; special stormwater management practice should be incorporated.

5.2 Stormwater management

Hydraulic structures which may be considered include but are not limited to: catch basin inserts, dry extended detention ponds, water quality inlets and oil/ grit separators, hydro-dynamic structures, grass channels, bio-retention, deep sump catch basins and dry wells.

5.3 Stormwater filtering systems

Design variants may include but not be limited to: infiltration trenches and basins, surface sand filter, underground sand filter, perimeter sand filter, organic filter, pocket sand filter strips.

5.4 Detention/ Retention pond buffers and setbacks

A pond buffer should be provided that extends outward from the maximum water surface elevation of the pond. The pond buffer should be contiguous with other buffer areas where practicable. An additional setback may be provided for permanent structures. Existing trees should be preserved in the buffer area during construction. It is also desirable to establish forest conservation areas adjacent to such ponds.

Refer to Buffers and Setback Guidelines (NEPA)
Refer Revised Policy on Setback from Drains and Gullies (NWA)

5.5 Site and resource mapping

The developer shall identify significant natural resources and demonstrate that these areas will be protected and preserved. Additionally, options should be evaluated to enhance important hydrologic functions. Specific areas that should be mapped by the project designer include: wetland, wetland buffers, stream buffers, perennial streams, forests, forest buffers, highly erodible soils, intermittent streams, major waterways, floodplains, fish sanctuaries, areas prescribed for endangered/protected species, protected areas, and heritage sites.

5.6 Landscaping plan

A landscaping plan for stormwater pond(s) and its buffer shall be prepared to indicate how aquatic and terrestrial areas will be vegetated, stabilized and established.

5.7 Other design considerations

5.7.1 For a more integrated approach, guidelines should extend to:

- protect water sources from possible adverse impacts of urban stormwater runoff
- drainage improvements with the intention to achieve long term performance, safety, ease of maintenance, community acceptance and environmental benefit.

5.7.2 Consideration should also be given to improvement in water quality treatment, maintenance and reduction in environmental impact. As such the following set of performance standards should be incorporated in the design philosophy:

- Site designs shall minimize the generation of stormwater and maximize pervious areas to facilitate maximum stormwater infiltration.
  However, in landslide risk areas, the infiltration of stormwater will increase soil pore pressures which may induce landslides. In these areas, site designs should be considered in order to minimize filtration stormwater by intercepting and channeling away from the slope.
- If the proposed development entails the direct discharge of stormwater runoff into functional wetlands, pre-treatment is required as a part of the proposal.
- Stormwater discharge to critical areas with sensitive resources such as fish sanctuaries, recreational beaches, recharge areas and water supply reservoirs, should be subject to additional performance criteria.
- Drainage design for development shall consider reduction in pollution loads to minimize the impact on water quality. Allowance for routine monitoring and maintenance shall also be made.

II. References

[1] The Local Improvement Act 1914

[2] The Flood-Water Control Act 1958

[3] Guidelines for Design & Construction of Housing Infrastructure
Vol. 1 Storm Water Drainage 1984 J.I.E. Recommended

[4] Vol. 3 Section 1 Roads, Infrastructure, Drainage and Traffic Management
National Works Agency 2007

[5] Guidelines for Drainage Review of Subdivisions and Development Applications
(Draft) Ministry of Transport and Works September 2000

[6] Intensity Duration Frequency Curves Norman Manley & Sangster International
Airports, Underground Water Authority February 1995

[7] Seminar for the Transfer of Technology, Flood Plain Mapping Project Rainfall
Frequency Analysis November 27, 1989

[8] Japan Road Association 2009

Fig. 1 Conceptual Drawing (Example)

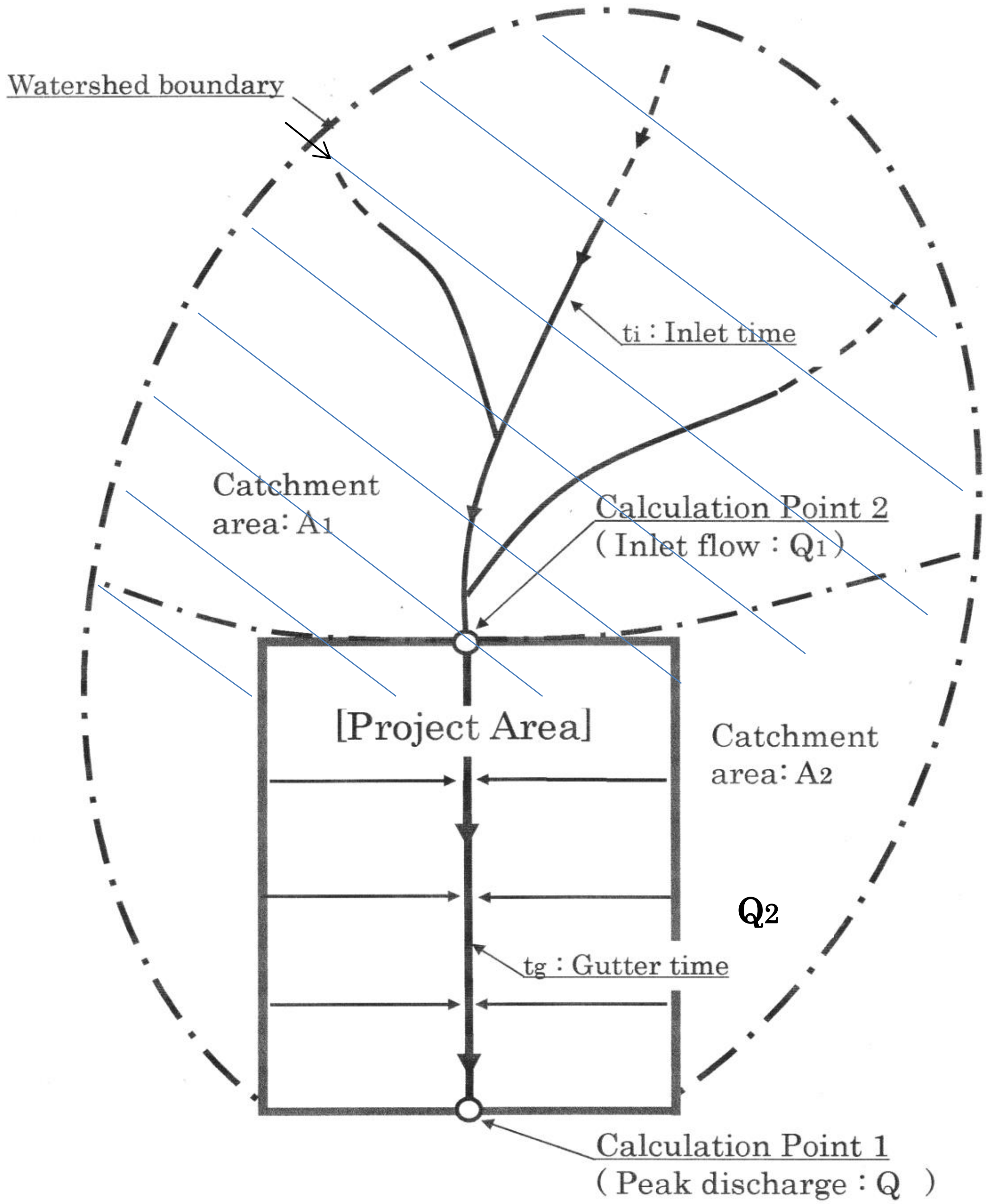

Fig. 2 Calculation Procedure

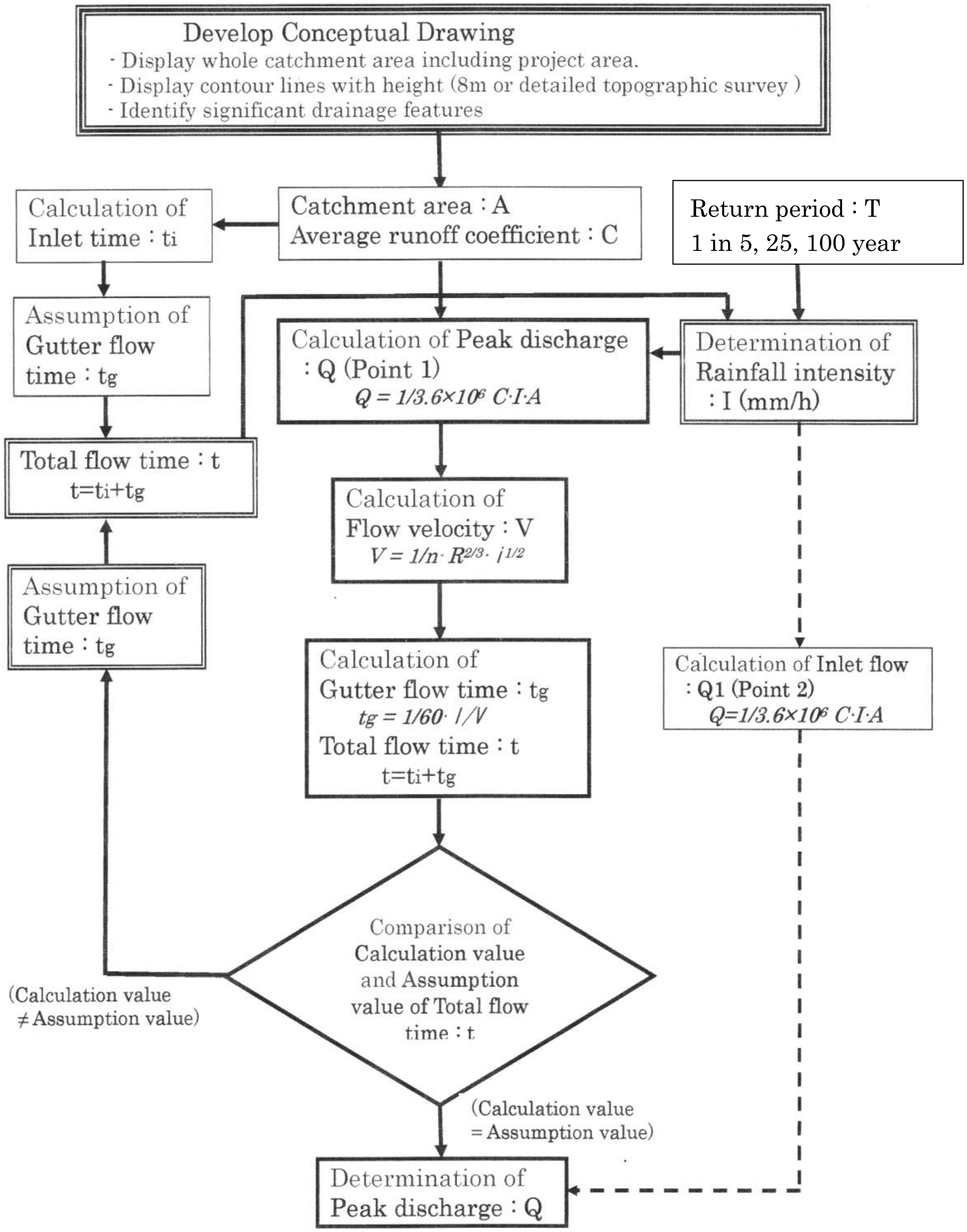

Table 1 Runoff Coefficient : C

Land Use	C
A. Commercial	
-Densely developed	0.9
-Shopping plazas	0.8
B. Residential	
-Single family	0.4
-Multi-units-detached	0.5
-Multi-units-attached	0.6
-Suburban	0.3
-Apartments	0.6
C. Industrial	
-Heavy industry	0.75
-Light industry	0.8
D. Park	0.2
E. Playing fields	0.3
F. Undeveloped	0.2
G. Hill district	
-Low-pitched	0.3
-Steep slope	0.5
H. Forest	0.3
I. Agricultural land	
-Paddy field	0.75
-Croft (small farm)	0.2
J. Road	
-Pavement	0.9
-Gravel road	0.5

Table 2 Kerby Coefficient of Roughness : N

Land Use	N
-Asphalt/ Concrete surface	0.013
-Smooth impervious surface	0.02
-Smooth compacted land	0.10
-Low density lawn	0.20
-Agricultural land	0.20
-Bawn (meadow), lawn	0.40
-Deciduous woodland	0.60
-Coniferous forest	0.80

Table 3 Manning Roughness Coefficient : n

Type of Channel	Condition of Channel	n
Culvert/ Pipe	-Cast-in-place concrete	0.015
	-Concrete pipe	0.013
	-Concrete secondary product	0.013
	-High-density polyethylene	0.012
Channel with lining	-Stone masonry	0.032
	-Stone masonry with mortar joint	0.025
	-Concrete with smoothing plane	0.015
	-Mortal	0.013
	-Wood with smoothing plane	0.015
	-Steel	0.012
Channel without lining	-Soil	0.022
	-Soil with weed	0.027
	-Gravel	0.025
	-Rock	0.035
Natural channel	-Fairing (smooth) channel	0.030
	-Non-fairing (rough) channel	0.100

Appendix List

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Appendix I

THE LOCAL IMPROVEMENTS ACT 1914

THE LOCAL IMPROVEMENTS ACT

ARRANGEMENT OF SECTIONS

[The inclusion of this page is authorized by L.N. 42/1995]

14.—(1) Every Council shall submit all maps, specifications, plans, sections and estimates deposited with the Council to the Chief Technical Director and the Chief Technical Director shall give the Council such advice and assistance with respect to the same as may appear to him

Council for parishes other than Kingston to submit maps, etc., to Chief Technical

11/1959 S. 6 (b).

(2) Where the Council proposes to reject the advice given or overrule any objections made by the Chief Technical Director the Council shall before making a final decision afford the Chief Technical Director an opportunity to be heard.

11/1959 S. 6 (b).

(3) For the purposes of this section any reference to the Chief Technical Director shall be deemed to include a reference to the Government Town Planner and the section shall be construed accordingly.

Appendix II

THE FLOOD-WATER CONTROL ACT 1958

THE FLOOD-WATER CONTROL ACT

ARRANGEMENT OF SECTIONS

[The inclusion of this page is authorized by L.N. 96/1998]

Powers of the undertakers of a scheme.

10.—(1) The undertakers of a scheme shall have power, for the purpose of carrying out any of their duties under section 4—

(*a*) to enter by their servants or agents upon any land within the relevant flood-water control area and there make surveys, take measurements and levels and do such work as may be necessary or expedient for securing proper control of, or defence against, flood-water in the relevant flood-water control area or for effecting any purpose ancillary to such control or defence, and for such purposes the undertakers of the scheme may— 4/1961 S. 2.

(i) alter or regulate the course of any watercourse by widening or straightening any portion of such watercourse or by making new channels for water, whether by pipes, drains, sluice-ways or any other means;

(ii) bring upon, make or maintain on, any part of such lands any appliances, plant, tools and other things required for the works;

(*b*) to clean any watercourse and clear or remove from any such watercourse or from the banks thereof any vegetation or tree (whether growing or not) and any log, refuse, soil or any obstruction whatsoever which obstructs or impedes, or which may obstruct or impede, the natural flow of water in the watercourse, and to place or deposit any matter or thing so removed on any land adjacent to the watercourse, but not beyond a distance of one chain measured from the top of the bank of the watercourse which such land adjoins;

(c) to do all such other acts as may be necessary for the proper and efficient construction, completion, improvement, repair and maintenance of any flood-water control works or for the assumption of responsibility for, or control over, any such works.

(2) Save in the case of an emergency the power of entry conferred by this section shall not be exercised unless—

(a) the prior consent of the occupier of the land has been obtained; or

(b) notice of intention to enter is given in writing to such occupier at least seven days before the date of entry.

(3) For the purposes of this section "emergency" means any emergency caused by flood, hurricane, or any other *vis major* or act of God.

(4) The undertakers of a scheme shall, while carrying out any works of construction, improvement, repair or maintenance, at their own expense take such reasonable steps, whether by fencing or otherwise, as may be necessary to prevent accidents to persons using the land or to any animals upon the land.

Appendix Ⅲ

Flood Plain Mapping Project Rainfall Frequency Analysis

1. Ratio and constant

Duration(D)	Cn	Ratios for Return Period(Tyr) and duration(D)				
		5yr	10 yr	25yr	50yr	100yr
10min	-	0.40	0.40	0.40	0.40	0.40
15min	-	0.52	0.52	0.52	0.52	0.52
30min	-	0.76	0.76	0.76	0.76	0.76
1hour	-	0.41	0.40	0.38	0.37	0.35
2hour	0.25	-	-	-	-	-
6hour	0.50	-	-	-	-	-
12hour	0.69	-	-	-	-	-
24hour	-	1.00	1.00	1.00	1.00	1.00

2. Calculation procedures

For 10 to 30 min rainfall duration(D) $Rain_{(Tyr,Dmin)} = ratio_{(Tyr,Dmin)} * ratio_{(Tyr,1hr)} * Rain_{(Tyr,24hr)}$

e.g. $Rain_{(5yr,10min)} = ratio_{(5yr,10min)} * ratio_{(5yr,1hr)} * Rain_{(5yr,24hr)}$

$=0.4*0.41*Rain(5yr,24hr)$

For 1hr duration $Rain_{(Tyr,1hr)} = ratio_{(Tyr,1hr)} * Rain_{(Tyr,24hr)}$

e.g. $Rain_{(5yr,1hr)} = 0.41 * Rain_{(5yr,24hr)}$

For 2hr, 6hr, 12hr duration (D) $Rain_{(Tyr,Dhr)} = Cn * Rain_{(Tyr,24hr)} + (1-Cn) * Rain_{(Tyr,1hr)}$

$= Cn * Rain_{(Tyr,24hr)} + (1-Cn) * ratio_{(Tyr,1hr)} * Rain_{(Tyr,24hr)}$

e.g. $Rain_{(100yr,12hr)} = 0.69 * Rain_{(100yr,24hr)} + (1-0.69) * 0.35 * Rain_{(100yr,24hr)}$

NB: the Tyr -24hr rainfall over the drainage is derived from the Tyr rainfall isohyets maps

Adopted from: Flood Plain Mapping Project

Seminar on Transfer of Technology

Rainfall Frequency Analysis

Organizations : Office of Disaster Preparedness and Emergency Relief Coordination

Meteorological Office (November 27-30 1989)

Fig. 3 2 Year – 24 Hour Map

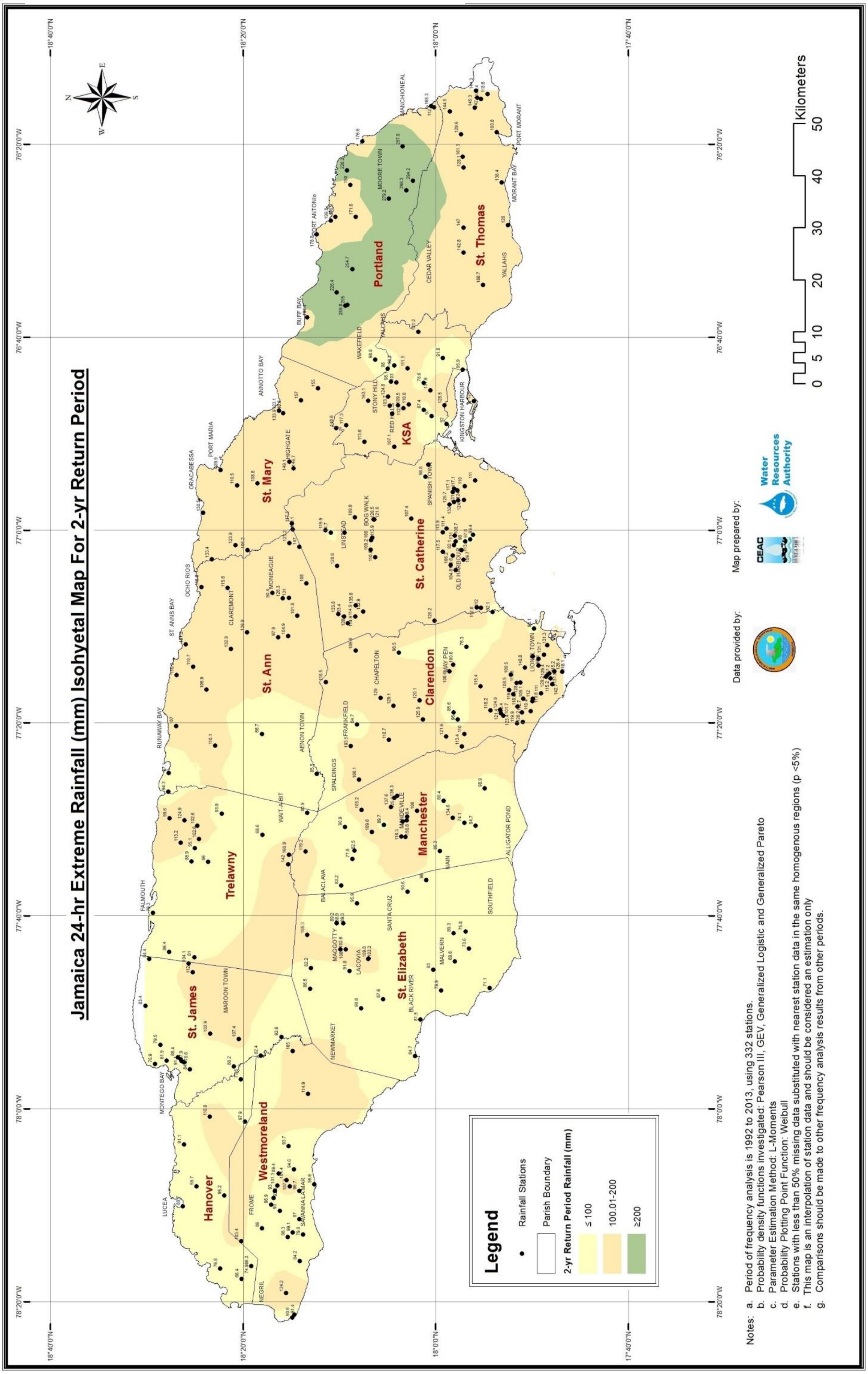


Fig. 4 5 Year – 24 Hour Map

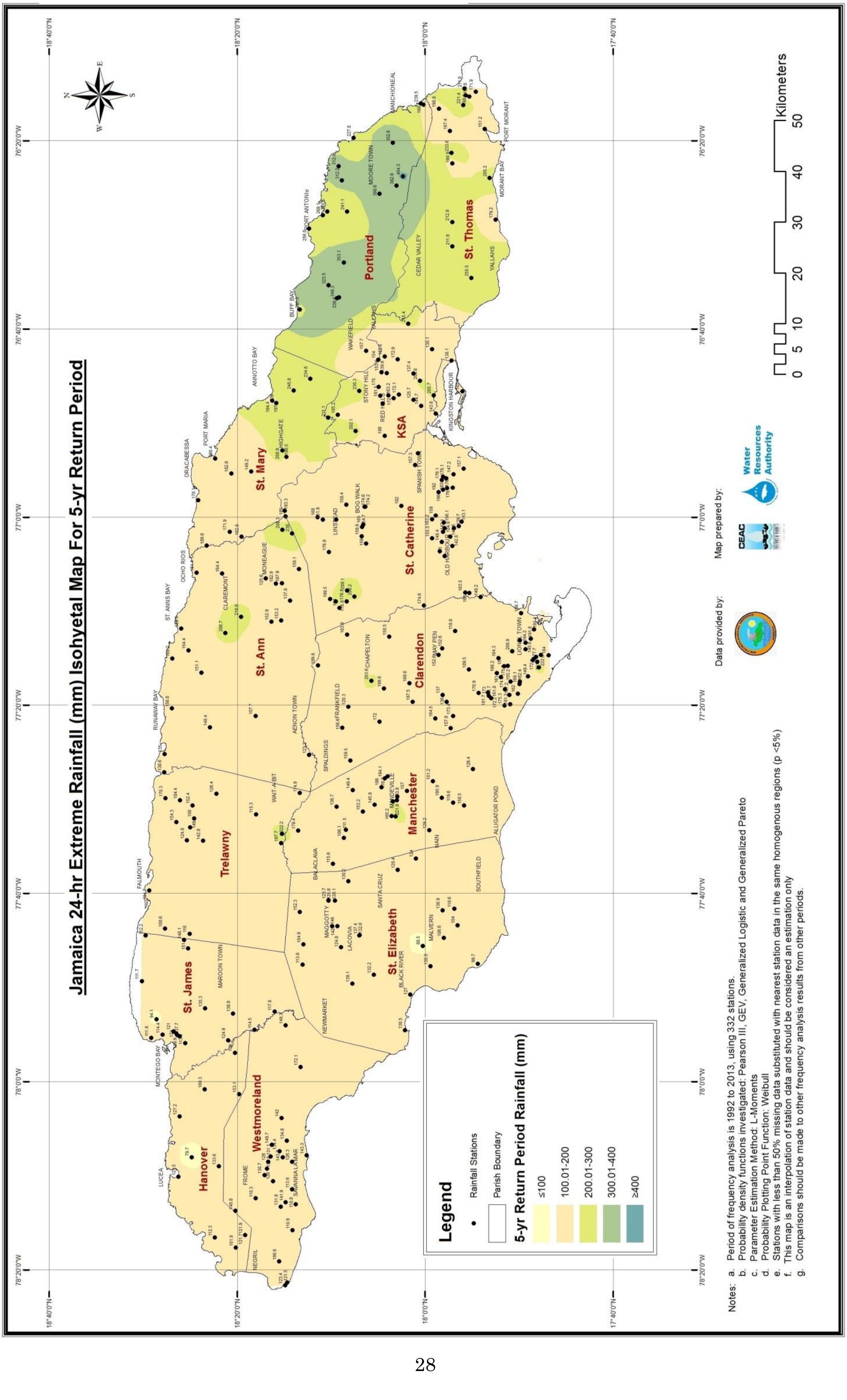


Fig. 5 10 Year – 24 Hour Map

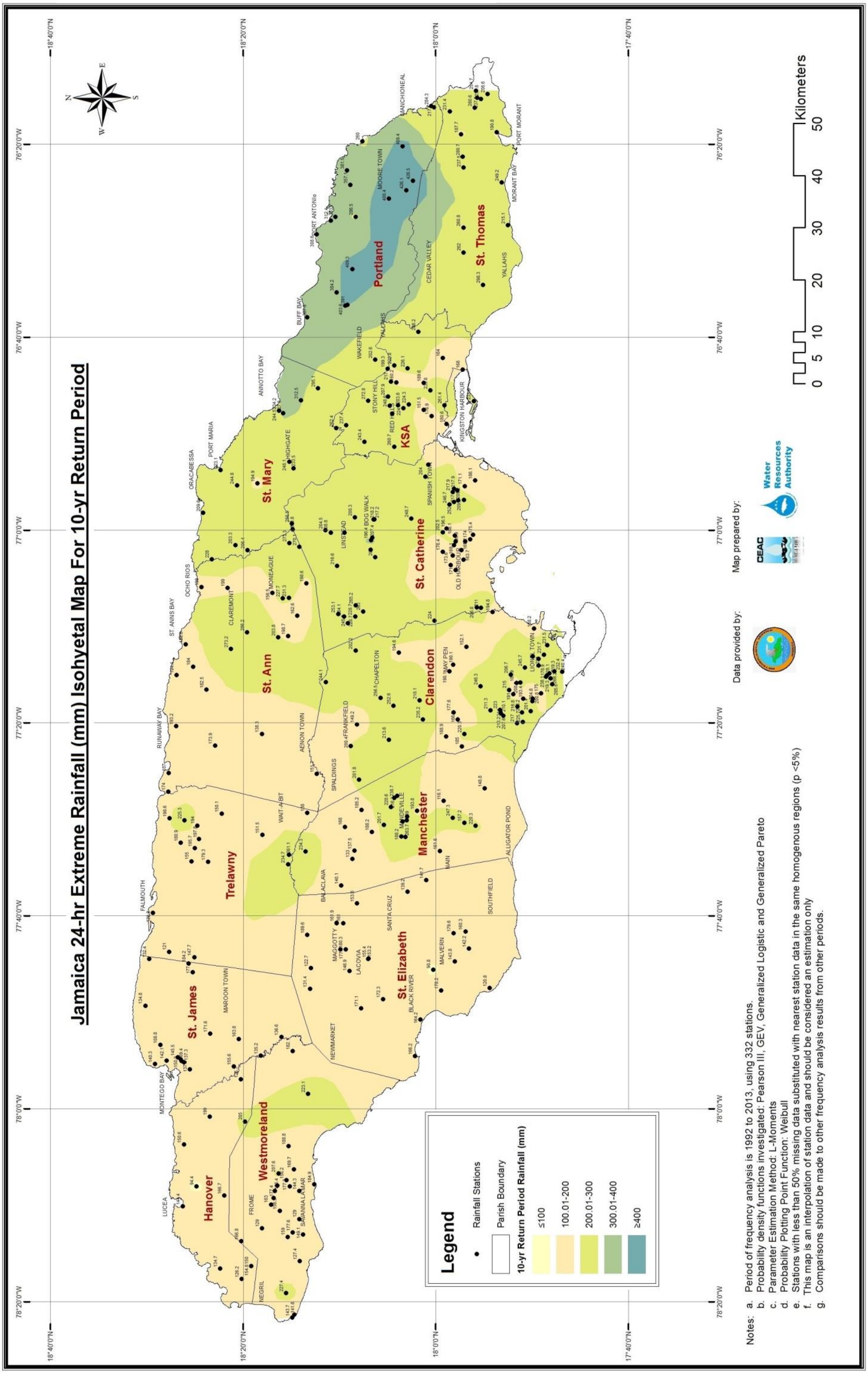


Fig. 6 25 Year – 24 Hour Map

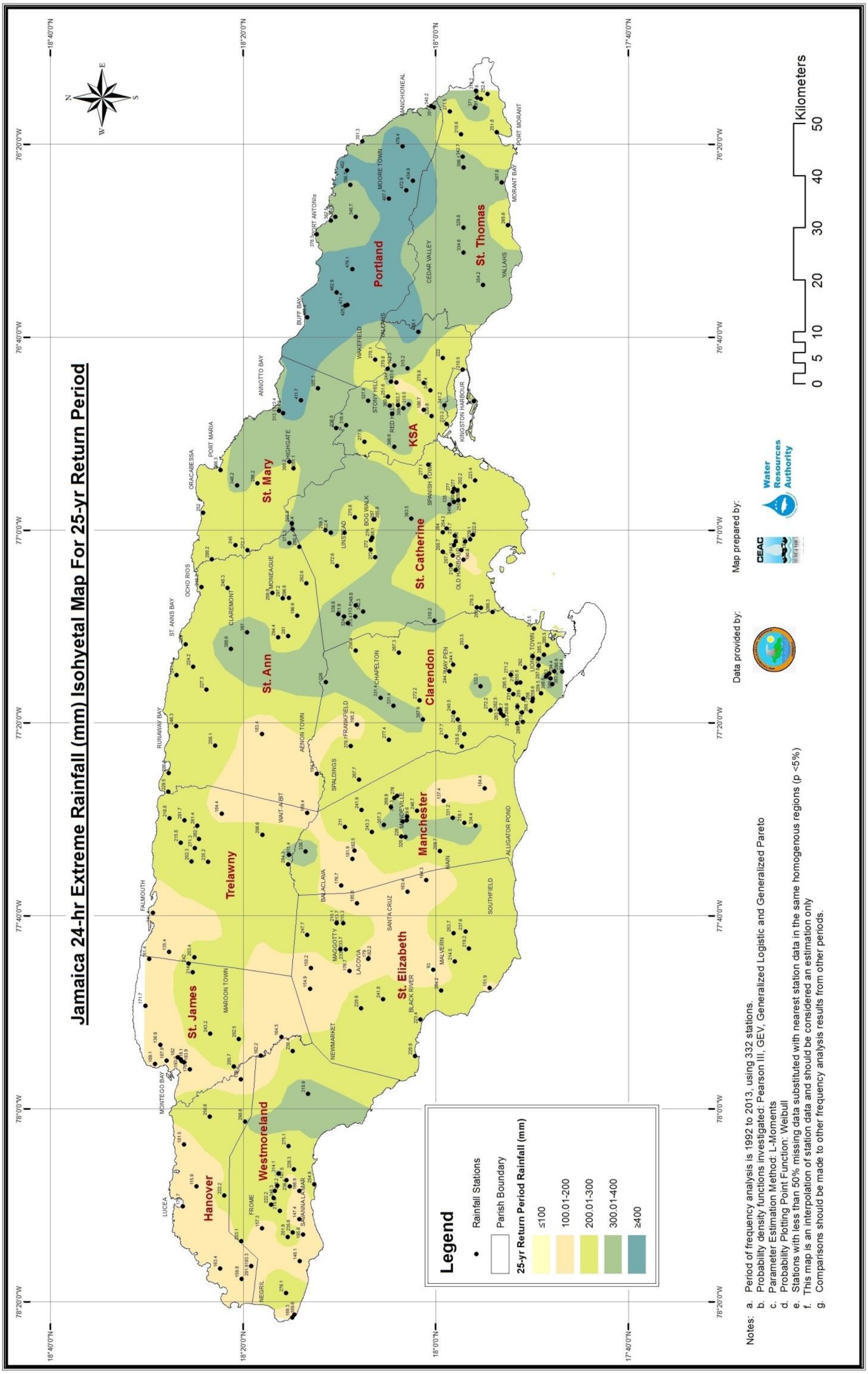


Fig. 7 50 Year – 24 Hour Map

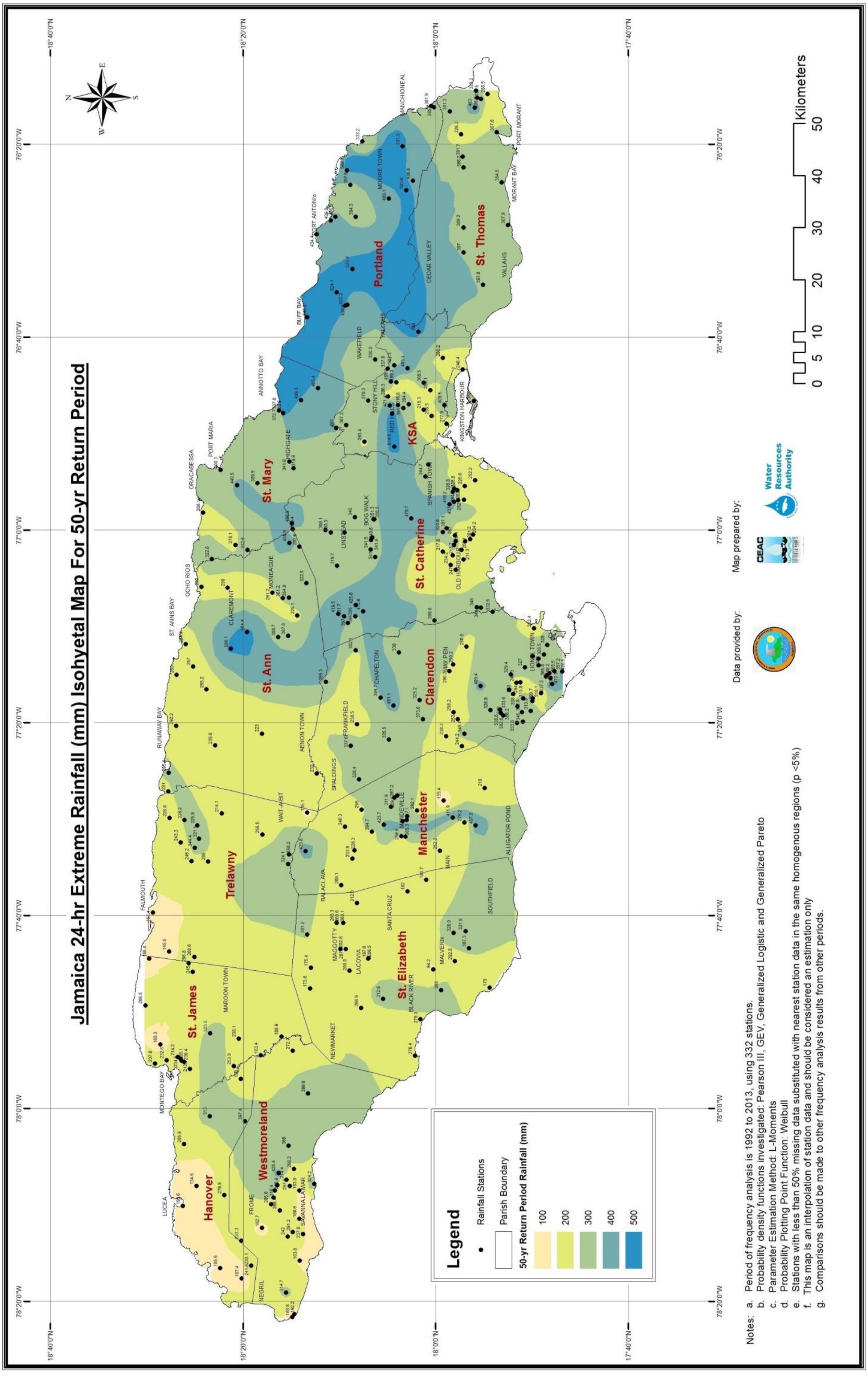
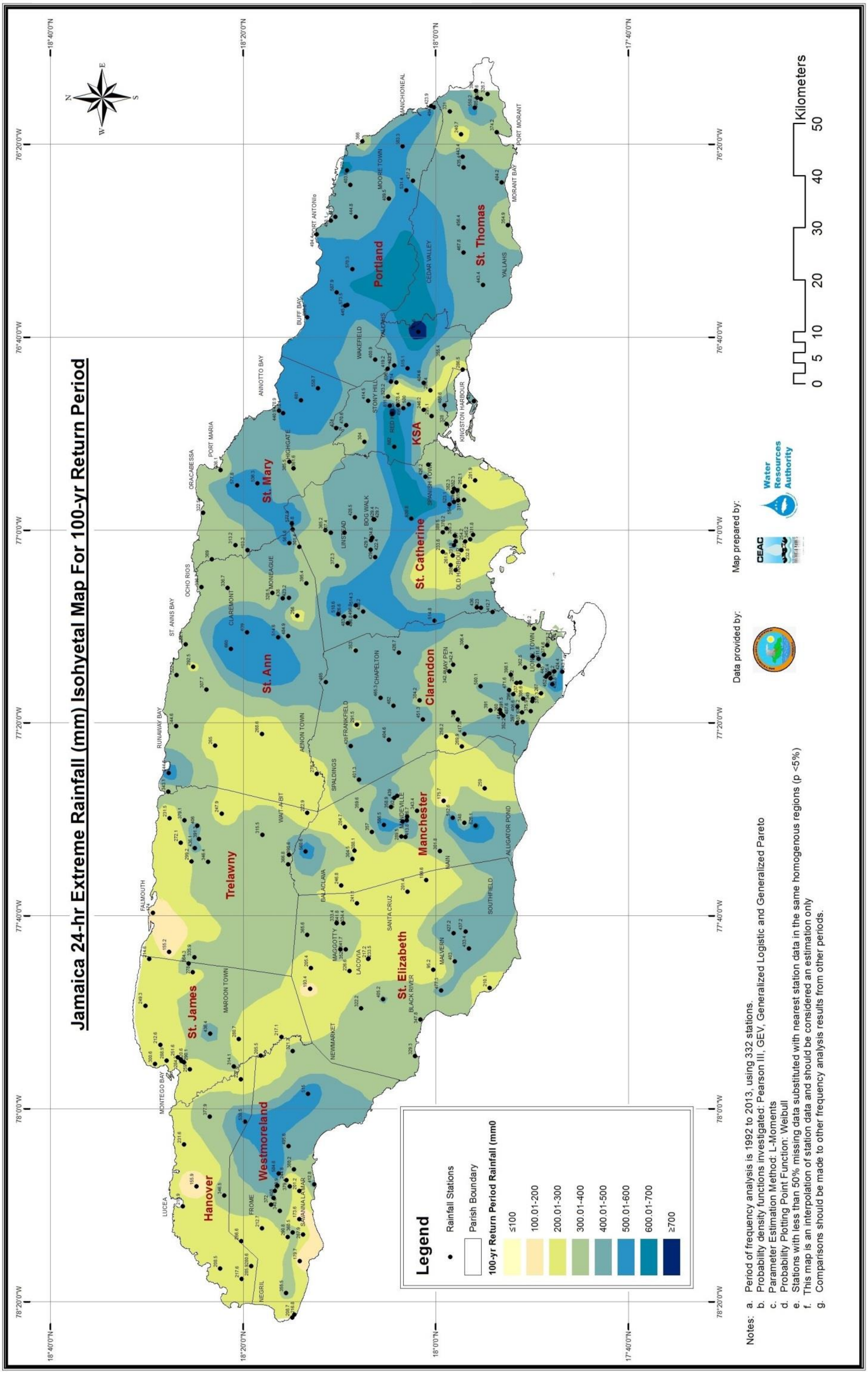


Fig. 8 100 Year – 24 Hour Map



Appendix Ⅳ Checklist for Required Documents

Clause	Items	Contents	Yes	No
1.	**Design philosophy**	Design philosophy including all assumptions		
1.5.1	**Discharging offsite**	Specific permission for offsite discharge from NWA		
1.5.2		Pre-post peak discharge calculation		
1.6.2	**Depression and sinkhole**	Proof for no history of flooding or ponding		
1.6.4		Rainfall volume calculation approved by NWA/ WRA		
1.6.6		Pre-post discharge calculation approved by NWA/WRA		
2.1	**Location map**	With roads, landmarks, highlighted project area and watershed etc.		
2.2	**Conceptual drawing**	With watershed, contours, drainage channels, roads etc.		
2.3	**Grading plan**	New grading plan with new contours, roads etc.		
2.4	**Photographs**	Color photos of pre site conditions with drainages, roads etc.		
2.5	**Design drawings**	Plan, longitudinal and cross section of project area, typical cross section of main structures etc.		
3.1	**Drainage calculation report**	Necessary for all development applications (Area > 900SM)		
3.10	**Hydro numerical modeling**	Name of program and description, boundary conditions and graphical output		
4.2	**Detention basin**	Calculation of detention basin with basin size, freeboard, outfall etc.		

Appendix V Example of Report Outline

NB: The following example is inserted as a guide and may not contain all of the necessary details for some submittals.

Contents

Appendix VI Abbreviations

Units		Organizations	
mm	millimeter	**NEPA**	National Environment and Planning Agency
cm	centimeter	**ODPEM**	Office of Disaster Preparedness and Emergency Management
m	meter		
km	kilometer	**WRA**	Water Resources Authority
m^3	cubic meter	**NWA**	National Works Agency
ha	hectare	**JIE**	Jamaica Institution of Engineers
yr	year	**JICA**	Japan International Cooperation Agency
hr	hour		
min	minute		
sec	second		

Appendix Ⅶ Glossary

Antecedent Moisture Conditions (AMC) - Watershed conditions prevailing prior to an event; normally used to characterize basin wetness, e.g., soil moisture.

Channel (Watercourse) - An open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water.

Climate change - A change in the climate that persists for decades or longer, arising from either natural causes or human activity.

Concentration Time (**Time of Concentration) -** The travel time from the hydraulically furthermost point in a watershed to the outlet.

Depression - A depression is a landform that is completely surrounded by higher ground.

Design Flood - The flood that is chosen as the basis for the design of a hydraulic structure.

Design Storm - Rainfall amount and distribution in time and space used to determine a design flood or design peak discharge.

Detention Basin - Storage facility which delays the conveyance of water downstream. A basin which reduces peak flood flows of a stream through temporary storage.

Dewatering - Removing of water from the soil or from an enclosure (storage facility).

Discharge (Flow) - The volume of water that passes through a given cross-section per unit time;

Drainage Area - The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

Drainage Divide - The Summit (rim) or boundary line separating adjacent drainage basins.

Flood - An overflow or inundation that comes from a river or other body of water, and causes or threatens damage.

Floodway - The channel of a river or stream and those parts of the floodplains adjoining the channel which are reasonably required to carry and discharge the floodwater or flow. The floodplain is kept clear of encumbrances to facilitate the free passage of flood flows.

Freeboard (Hydraulics) - The distance between the maximum water surface elevation anticipated in design and the top of retaining banks or structures.

Gully - Channel deeply eroded by water which flows only due to storm-water runoff.

Hydraulics - Branch of fluid mechanics dealing with the flow of water in conduits and open channels.

Hydrograph - A graph showing stage (elevation), flow, velocity, or other property of water with respect to time.

Hydrology - The study of water; generally focuses on the distribution of water and interaction with the land surface and underlying soils and rocks.

Infiltration - The movement of water from the land surface into the soil.

Inflow - Flow of water into a stream, pond, reservoir, basin, aquifer system, etc.

Karst - Landscape underlain by limestone which has been eroded by dissolution, producing ridges, fissures, sinkholes and other characteristic landforms.

Outlet (outfall) - Opening through which water flows out or is extracted from a reservoir, basin, channel or stream.

Overland Flow – The shallow flow of water over the land surface before combining with additional flow to become channel flow.

Peak Discharge (peak flow) - Maximum instantaneous discharge of a given hydrograph.

Precipitation - As used in hydrology, precipitation is the common process by which atmospheric water becomes surface or subsurface water. Precipitation includes rainfall, snow, hail, and sleet, and is therefore a more general term than rainfall.

Rainfall - The quantity of water that falls as rain only.

Rainfall Intensity - Rate at which rainfall occurs, expressed in units of depth per unit of time.

Rainfall Intensity return period - Average time interval in years between the occurrence of rainfall of a given intensity and that of an equal or greater intensity.

Rational Method - Formula expressing the estimated peak rate of storm runoff as the product of the catchment area, a peak rate of rainfall, and a runoff coefficient.

River Training - Engineering river-works built in order to direct the flow, or to lead it into a prescribed channel, or to increase the water depth for navigation and other uses.

Recurrence Interval (return period) - The average interval of time within which the given flood will be equaled or exceeded once.

Retention Basin - Similar to detention basin but water in storage is permanently obstructed from flowing downstream.

Runoff - Precipitation on the ground that is not captured by evaporation, infiltration, interception, or surface storage. That part of precipitation that appears as streamflow.

Run-off Coefficient - The runoff coefficient (C) is a dimensionless coefficient relating the amount of runoff to the amount of precipitation received. It is a larger value for areas with low infiltration and high runoff (pavement, steep gradient), and lower for permeable, well vegetated areas (forest, flat land).

Run-off Curve Number - An empirically derived relationship between location, soil-type, land use, antecedent moisture conditions, and runoff. The curve number is used in an event-based model to establish the initial soil moisture condition and the infiltration.

Scour - Erosive action - in particular, pronounced local erosion - of water in streams, in excavating and carrying away materials from the bed and banks.

Spillway - A structure used to provide the controlled release of flows from a dam or levee or storage facility into a downstream area.

Storage - Water artificially or naturally detained in surface or underground reservoirs, such as ground water, channel storage, and depression storage.

Storm - A disturbance of normal conditions of the atmosphere which, may include any or all meteorological disturbances, such as wind, rain, snow, hail, or thunder.

Storm Surge - An abnormal rise in sea level accompanying a hurricane or other intense storm, and whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone. Storm surge is usually estimated by subtracting the normal or astronomic high tide from the observed storm tide.

Stream - A general term for a body of flowing water. In hydrology the term is generally applied to the water flowing in a natural channel as distinct from a canal.

Streamflow - The discharge that occurs in a natural channel. Although the term discharge can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course.

Subdivision - The division of a lot, tract or parcel of land into two or more lots for the purpose of sale or development.

Surface Runoff - That part of the runoff that travels over the soil surface to the nearest stream channel. It is also defined as that part of the runoff of a drainage basin that has not passed beneath the surface since precipitation.

Sedimentation - Process of settling and depositing by gravity of suspended matter in water.

Sinkhole - Location where water disappears underground in a limestone region. It generally implies water loss in a closed depression or blind valley.

Tributary - Watercourse flowing into a larger watercourse or water body.

Water Level -Elevation of the free-water surface of a body of water relative to a datum level.

Watershed (drainage basin, catchment) - An area characterized by all direct runoff being conveyed to the same outlet.

Contact Details

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NB: The guidelines are to be reviewed in 2020 or earlier should the need arise.

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