BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

METRO VANCOUVER

REGIONAL IDF CURVES,
METRO VANCOUVER CLIMATE STATIONS:
PHASE 1

FINAL

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BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY
#500-1045 Howe Street
Vancouver, B.C.
Canada V6Z 2A9
Tel: 604.684.5900
Fax: 604.684.5909

December 23, 2009

Project No: 0431-006

Brent Burton, M.A.Sc., P.Eng.
Utility Analysis and Environmental Management Division
Policy and Planning Department
Metro Vancouver
4330 Kingsway Burnaby, BC V5H 4G8

Dear Mr. Burton,

Re: Regional IDF Curves, Metro Vancouver Climate Stations: Phase 1 (FINAL)

Please find attached a copy of our above referenced Final report dated December 23, 2009.

Should you have any questions or comments, please do not hesitate to contact me at the number listed above.

Yours sincerely,

BGC ENGINEERING INC.
per:

Kris Holm, M.Sc., P.Geo.
Project Manager

EXECUTIVE SUMMARY

This study provides Regional Intensity Duration Frequency curves for precipitation zones within the Metro Vancouver Area, based on analysis of data from 93 Metro Vancouver and Environment Canada climate stations. These curves would be considered by Metro Vancouver in estimating design runoff events for a variety of applications, including the planning and design of water and wastewater management infrastructure.

This report completes the first phase of work recommended in an earlier BGC study (BGC 2009), including analysis of precipitation distribution across Metro Vancouver and preparation of Regional IDF Curves for existing conditions. The results provide IDF curves and delineation of 8 zones where the IDF curves provide representative regional-scale estimates of precipitation intensity. Modelled distribution of mean annual precipitation is also provided for a larger ninth zone along the northern study area. Regional IDF Curves are not provided for Zone 9, as precipitation intensities are highly variable due to orographic effects and annual maximums data was available for only one station within the zone.

The results show that mean annual rainfall increases to the northeast by about 300% from Zones 1-8 across the study area, and by approximately 400-500% including Zone 9. Extreme rainfall intensities increase by a factor of ~1.5 – 2.5 for durations of 1 - 72 hours, respectively, from Zones 1-8. Extreme rainfall for durations of less than 1 hour did not show an obvious spatial trend across the study area.

The work herein is for current conditions, and does not account for future changes in precipitation intensities due to anticipated climate change. It does, however, form the basis for estimates of climate-change adapted IDF curves; a study that has begun with a preliminary analysis by BGC (2009). Future study would aim to update the model input from Regional Climate Models and use a larger variety of emission scenarios to provide updated IDF curves for the study region.

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LIMITATIONS OF REPORT

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1.0 INTRODUCTION

Intensity-duration frequency (IDF) curves are graphical representations of the probability that a given average rainfall intensity will occur at a range of return periods, typically from one year to 200 years. They are routinely used in water resource management and form the basis for urban storm water drainage calculations and sizing of culverts, drain pipes and other municipal waste-water infrastructure. Much of this infrastructure is designed to perform as designed for a half a century or more.

BGC's (2009) report titled *Climate Change Adjusted (2050) IDF Curves* provided several recommendations to Metro Vancouver for development of IDF curves for existing and future climate conditions, to assist in water management projects. These recommendations included:

1. Development of regional IDF curves for Metro Vancouver for existing climate conditions;
2. Development of regional IDF curves for Metro Vancouver for future conditions, for the period 2040's to 2070's (referred to as approximately the year 2050); and
3. Quantification and discussion of the sensitivity of the climate-adjusted IDF curves to forecasted changes in precipitation associated with different emissions model runs and emission scenarios.

This report completes the first phase of recommended work, including preparation of regional IDF curves for existing conditions.

The principal objective of this exercise is to create a Metro Vancouver-wide map with approximately homogenous IDF curves that in turn are based on reasonable durations of record. This will standardize the use of IDF curves and provide better quality output and avoid extrapolation of records that are too short to yield reliable results. It also allows an identification of areas that are underrepresented and where additional rain gauges may be of value. Finally it will facilitate estimation of climate change-adjusted IDF curves by limiting the number of curves used while ascertaining that the curves are applicable over the entire zone delineated.

Work tasks completed are outlined in Table 1-1. Chapters 1.1 and 2.0 provide background and a description of analysis methodology. Results are outlined in Chapter 3.0. Chapters 4.0 and 5.0 provide discussion and recommendations for further work.

Table 1-1. Overview of Phase 1 work tasks

Task No.	Work Component	Individual work task descriptions
1	Project Management	
2	Data Acquisition	• Review rain and compile gauge and IDF data for Metro Vancouver and Environment Canada climate stations.
3	Data Analysis	• Construct basemap with rainfall distribution data. • Spatial analysis of patterns of rainfall intensity, Vancouver area. • Spatial analysis (clustering) of IDF data, existing conditions. • Construction of regional IDF curves for representative areas.
4	Reporting	• Summary maps showing Metro Vancouver rainfall distribution. • Regional IDF curves for representative areas, existing conditions.

1.1 Background: Regional Mapping of Rainfall Intensity

1.1.1 Spatial Interpolation of Rainfall

While climate station rainfall IDF curves provide estimates of average rainfall intensity at different return periods for particular climate stations, they fail to characterize the distribution of rainfall across a region. As such, rainfall estimates at sites distant to the gauged location are associated with some degree of uncertainty. It may also be unclear which station close to a project site provides the most representative data, which depends on both rainfall distribution and the length and quality of record.

To reduce these limitations and allow reliable estimation of design rainfall intensities at ungauged sites, spatial statistics can be used to create quasi-homogenous zones of extreme rainfall across a region. Several such approaches have been applied to solve this problem, such as Thiessen polygons (Thiessen, 1911) or Inverse Square Distance that consider proximity to the nearest climate station, or more advanced procedures such as kriging that consider the entire dataset when interpolating rainfall distribution (Dubois 1998).

Geostatistical procedures have been used in various projects to map rainfall distribution at a regional scale, such as in the UK (Faulkner and Prudhomme 1998), for the Swiss Alps (Lang et al. 1998), in Greece (Loukas et al. 2001), and in Portugal (Goovaerts 2000). Modelling that also included secondary variables (e.g. topography and data from weather models) has also been undertaken with a resulting increase in analysis complexity and input data requirements (Goovaerts 2000, Wotling et al. 2000).

1.1.2 Regional Frequency Analysis

Hosking and Wallis (1997) describe a regional frequency analysis approach that involves subdivision of a study area into zones with statistically homogenous rainfall characteristics, and development of IDF curves for each zone based on combined data from all stations within each zone. This approach has been taken here to obtain regional IDF curves for defined areas within Metro Vancouver. The analysis method involves three primary steps:

1) Data collection and screening;
2) Delineation of homogenous precipitation zones; and
3) Generation of regional IDF curves for each zone.

Further details on analysis methodology for each of the three steps are described in Section 2.0. The zones provide a useful way to select a particular IDF curve for a certain project site, while the use of combined data reduces uncertainty when estimating longer term extreme rainfall from shorter term data sets.

2.0 METHODS

2.1 Data Collection and Screening

Precipitation data used for analysis of precipitation zones included total monthly and annual precipitation (rainfall + snow water equivalent) values from 93 active climate stations in Metro Vancouver, including 51 Metro Vancouver stations and 42 Environment Canada stations (Table 2-1, Drawing 1). Environment Canada stations used in analysis included all stations with a normals code of “D” or higher, corresponding to stations with at least 15 years of data.

Climate station IDF curves and annual maximums were available for 48 Metro Vancouver stations, but only 15 Environment Canada stations within the study area. Annual maxima from these subset of stations were used to generate the Regional IDF Curves. A detailed list of stations used in the analysis is provided in Appendix I.

Table 2-1. Data Summary

Data Source	Precipitation Data Type
Metro Vancouver	• Station locations; • IDF curves and tables; • Monthly and annual maximum intensities (5 minutes to 72 hours); • Monthly and annual total precipitation
Environment Canada	• Station locations; • Yearly maximum intensities (5 minutes to 24 hours) • Monthly and annual total precipitation

Data was manually screened for outliers showing unrealistically high or low results. Most outliers were unrealistically low monthly precipitation data for months known to have high precipitation, suggesting missing data. Monthly data provided by Metro Vancouver had already been subject to internal data screening.

2.2 Delineation of Homogenous Precipitation Zones

Delineation of homogenous precipitation zones involves mapping the distribution of rainfall within a region, followed by subdivision of the region into zones that are considered statistically homogenous with respect to rainfall characteristics.

Rainfall characteristics across Metro Vancouver were quantified based on mean annual precipitation values at each station, interpolated to a continuous surface using universal Kriging within a Geographic Information System (GIS) (Drawing 2). Kriging is a statistical method that models a surface from a scattered set of points, based on the assumption that the distance between sample points reflects a spatial correlation that can be used to explain variation in the surface. Universal Linear Kriging (ULK) assumes the data mean varies in space across the study area. This approach was used due to the well-documented and orographically-explained south to north trend of increasing rainfall amounts within Metro Vancouver.

The precipitation surface was then classified into nine zones. Zone boundaries were based approximately on 200 mm precipitation contour intervals, with manual smoothing and editing completed where irregularities would have impaired practical use (Drawing 3). These zone resolutions were chosen to reflect a reasonable compromise between statistical homogeneity and minimizing complexity.

The ninth zone extends to the northern edge of the study area. Zone 9 lies mostly outside Metro Vancouver and covers a broad, mostly undeveloped area of steep slopes on the North Shore with highly variable rainfall characteristics and few climate stations. Further work is needed to analyse extreme rainfall distribution in this area. Zone 9 is shown on Drawing 2 to show modelled mean annual precipitation in this area. However, it has been excluded from analysis of Regional IDF curves given the poor representation of climate station data and wide mean annual precipitation range (~2000-4500 mm annually) across this area. Annual maxima were also available for only one station (DN16) within Zone 9. Further work is required to estimate extreme precipitation and analyse uncertainties within this area.

2.3 Test of Data Homogeneity

Tests of data homogeneity assess whether the zones selected are physically meaningful. They test whether data within a zone are sufficiently homogenous, and whether some adjoining zones might be similar enough to be further combined. Although it is described here for clarity as a separate step, in practice this procedure is done iteratively as part of the zone selection process. Moreover, while the objective is to check zone homogeneity, the test itself is technically a measure of data *heterogeneity*.

Precipitation data heterogeneity within each zone was analyzed based on the L-Moment approach described by Hosking and Wallis (1997). An “L-Moment” test examines the frequency distribution of data within a zone, and uses a measure, the “L-moment”, to examine whether the frequency distribution is approximately constant. In brief, “moments” of a distribution describe its shape; other examples of moment descriptors are the mean, standard deviation, and skew. L-moments are an alternative to describe the shape of a probability distribution including measures of the location, scale and shape. It is considered more reliable than conventional tests for examining data homogeneity, with less dependence on extreme outliers (Hosking and Wallis 1997). Total monthly rainfall from each station was used to test data heterogeneity.

To assess heterogeneity, between-site variations in sample L-moments are compared for a group of sites to what would be expected for a homogenous region. “What would be expected” is defined as a comparison of the data dispersion to a simulated homogenous region that has record lengths similar to the data being analyzed; for example:

$$\frac{\text{(observed dispersion)} - \text{(mean of simulations)}}{\text{(standard deviation of simulations)}} \qquad (1)$$

The heterogeneity of a proposed region can be tested using three Hosking-Wallis heterogeneity statistics based on the L-coefficient of variation (H_1 statistic), L-skewness (H_2 statistic) and L-kurtosis (H_3 statistic). The H_1 test generally has more statistical power than the H_2 and H_3 tests and was used in this application to test for heterogeneity (Hosking and Wallis 1997). A region is considered “acceptably homogeneous” if H_1 <1, “possibly heterogeneous” if 1 ≤ H_1 ≥ 2 and “definitely heterogeneous” if H_1 > 2.

2.4 Regional IDF Curves

Regional IDF curves were generated from combined data sets of all climate stations within Zones 1-8. The analysis was based on Gumbel distributions of max precipitation values for 5 minute, 10 minute, 15 minute, 30 minute, 1 hour, 6 hour, 12 hour, 24 hour, 48 hour, and 72 hour durations. Appendix 1 provides a list of climate stations within each zone that were compiled for analysis. The original Excel spreadsheet files used to generate the IDF curves can be provided upon request.

3.0 RESULTS

3.1 Precipitation Zones

Drawing 2 shows annual mean precipitation distribution across the Metro Vancouver study area, based on universal kriging interpolation between climate stations. The drawing shows the strong orographic effect of the North Shore Mountains over the Metro Vancouver region, with rainfall increasing over 460% from Zones 1-9.

Drawing 2 also shows Metro Vancouver subdivided into nine precipitation zones. Zones 1-8 were analysed for station homogeneity. Station 9 was excluded from analysis given the high rainfall magnitude range and poor representation of climate stations across the zone.

Consistent with the northeast trend of increasing precipitation, all zones form approximately parallel northwest-southeast striking bands across the study area. Mean precipitation values and the Hosking-Wallis heterogeneity statistic (H_1) for each zone are shown in Table 3-1.

Based on the H_1 test statistic, all the regions are considered "acceptably homogeneous" as defined by $H_1 < 1$. Negative values of H_1 were observed for a majority of the regions, possibly due to a positive correlation between sites, or excessive regularity in the data set from the use of monthly (rather than daily) averages. Negative H_1 values are not uncommon, and have been report in similar studies to indicate homogeneous regions (e.g. Kysely et al. 2007). Hosking and Wallis (1997) recommends further investigation of the dataset if $H_1 < -2$.

Table 3-1. Metro Vancouver Precipitation Zones

Zone	No. Climate Stations	H_1[1]	Mean Precipitation[2]
1	5	-0.81	858
2	8	-1.04	1003
3	17	-1.49	1325
4	11	-1.98	1445
5	18	-1.70	1717
6	12	-1.45	1857
7	10	-1.59	2115
8	9	0.99	2419
9	3	n/a	3981[3]

[1] $H_1 < 1$ indicates "acceptably homogenous" zones.
[2] Average of means for each station within the zone.
[3] Based on mean of three stations in the vicinity of Seymour Dam, and likely is higher for the entire zone. Maximum modelled precipitation in Zone 9 is 4600 mm.

3.2 Regional IDF Curves

Regional IDF curves for Zones 1-8 are provided in Drawings 3-6. Figure 3-1 to Figure 3-3 show graphs of 100-year rainfall for 5 minute to 72 hour durations, for Zones 1-8, as an example of extreme rainfall distribution across zones. For durations of at least 1 hour, the results show a trend of increasing extreme rainfall intensity towards the northeast. For example, the 24-hour rainfall intensity increases by a factor of approximately two from Zones 1-8. Note that although the plotted trends for 12 - 24-hour durations appear exponential in shape, the X-axis shows zone categories, not scaled distance, and further work would be needed to examine this possibility. Similar trends of increased rainfall intensity towards the North Shore exist for the other return periods displayed on the IDF graphs for durations of 1 hour or longer. Durations shorter than 1 hour showed a weaker trend across rainfall zones, while duration of less than one hour showed no trend at all. The reason for this is uncertain but may be related to the influence of convectional disturbances producing short term, intense rainfall with greater variability across the study area. Further work including analysis of extreme rainfall during periods where synoptic disturbances were most dominant (e.g. winter) would be necessary to further examine this hypothesis.

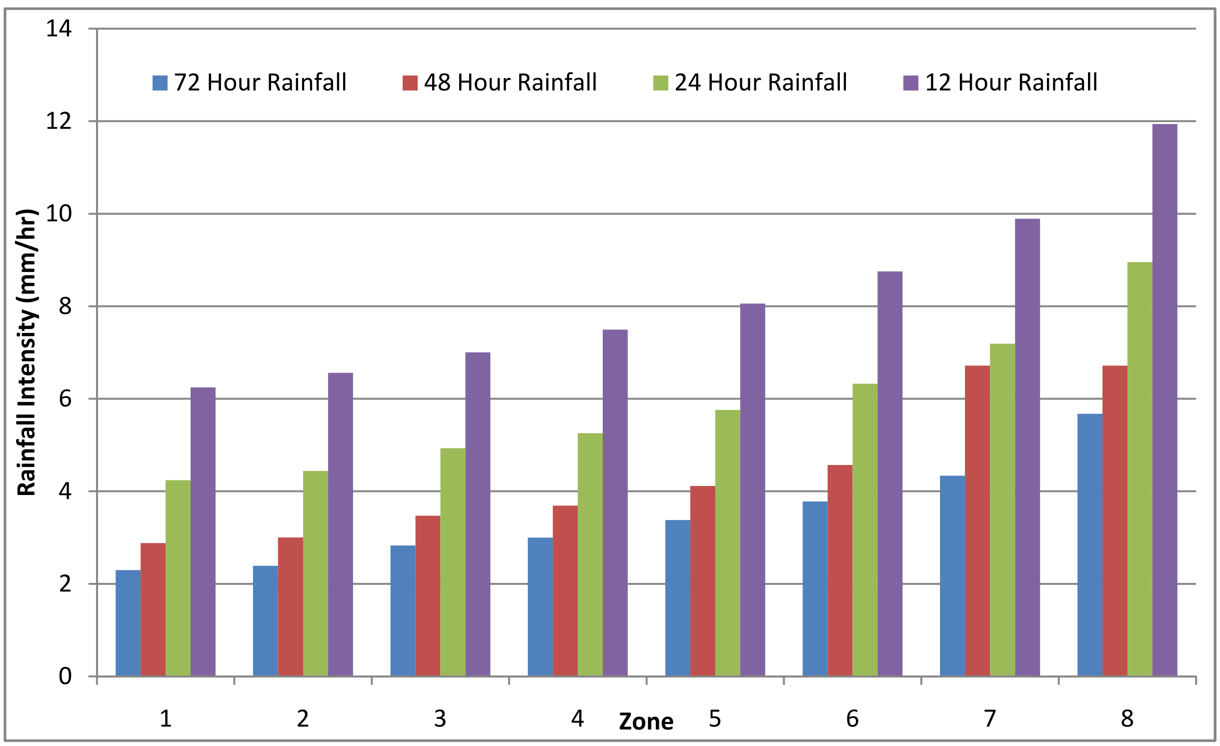

Figure 3-1. 12 to 72-hour, 100-year rainfall intensities, Zones 1-8.

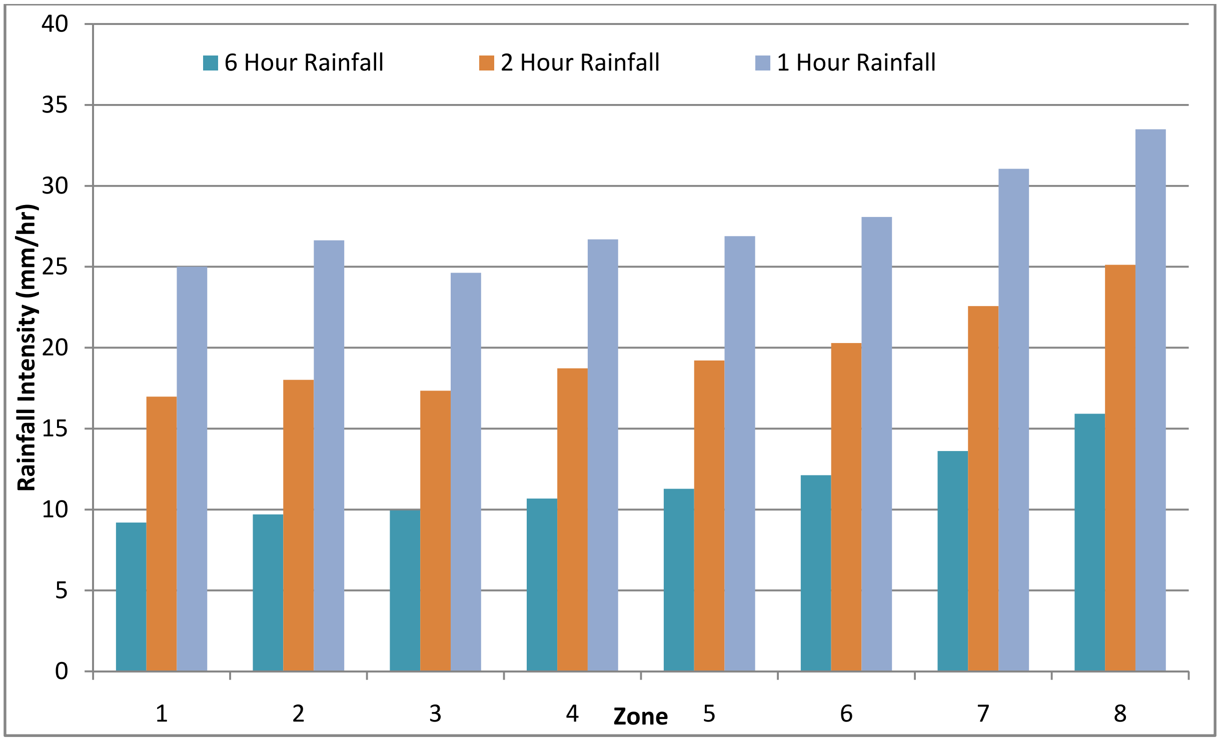

Figure 3-2. One to 6-hour, 100-year rainfall intensities, Zones 1-8.

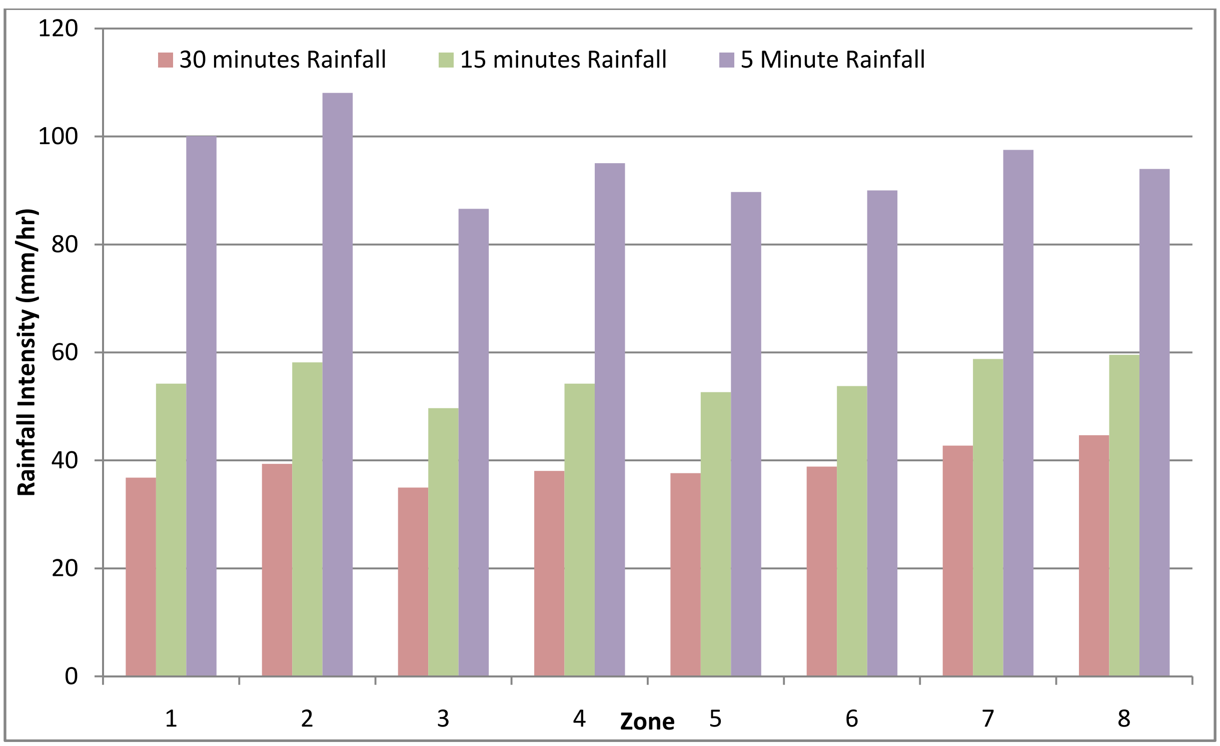

Figure 3-3. Five minute to 30 minute, 100-year rainfall intensities, Zones 1-8.

4.0 DISCUSSION

By identifying statistically homogenous rainfall zones and producing IDF curves based on combined data within each zone, the resulting IDF curves can be based on larger data sets than individual stations (Hosking and Wallis 1997). However, while the zones are within the statistical threshold for heterogeneity and appropriate for practical application at the scale of study, zone boundaries represent transitions, rather than sharp boundaries, and a continuous trend of increased precipitation exists towards the northeast. Moreover, while the spatial concentration and length of record for climate stations within the study area is high compared to most regions in Canada, within-zone variability will exist due to factors such as the northeast trend in increased precipitation and detailed scale climate variability not identified by regional interpolation.

Consistent with the northeast trend of increased rainfall towards the North Shore Mountains, annual mean rainfall at each stations correlates with elevation due to the orographic effect. Figure 4-1 shows a linear trend line fitted to elevation plotted with mean annual rainfall, for all stations within the study area. This correlation was implicitly included in kriging interpolation of rainfall distribution because the higher elevation stations generally have higher rainfall. However, regional topography has not yet been explicitly included as a variable when interpolating spatial rainfall distribution across ungauged areas. More sophisticated multivariate analyses that consider topography as a secondary predictor variable, such as co-kriging, may further improve the boundary delineation of rainfall zones. In particular, these analyses may improve precipitation estimates for Zone 9, which contains a strong elevation and precipitation gradient towards the north. Further work is needed to test this hypothesis.

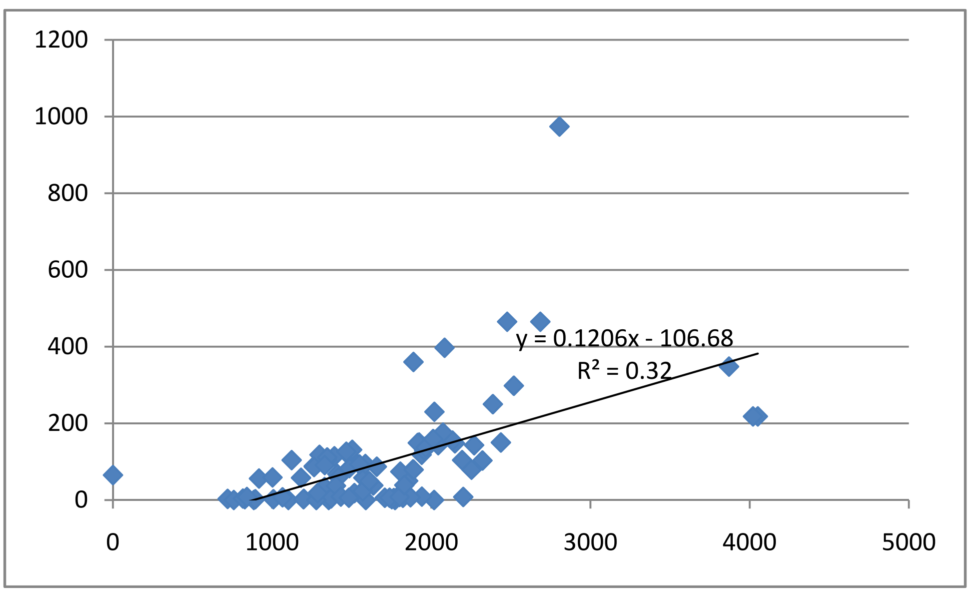

Figure 4-1. Elevation plotted with Average Annual Precipitation.

For Environment Canada stations, data on annual maximums for different rainfall durations was available for only 15 of 48 stations, leading to gaps in data for certain areas. This is particularly the case for Zone 1, which contains two Metro Vancouver stations and three Environment Canada stations. The Zone 1 Regional IDF Curve provided herein is based on analysis of data from just the Metro Vancouver stations, which contain data collected only since 1998. Redoing the Regional IDF curve analysis with data compiled from the missing 33 Stations would improve the data on which the IDF curves are based.

5.0 CONCLUSION AND RECOMMENDATIONS

This report completes the first phase of work recommended in BGC 2009, including analysis of precipitation distribution across Metro Vancouver and preparation of Regional IDF Curves for existing conditions. The results provide IDF curves and delineation of the areas where they provide representative estimates of extreme precipitation intensity.

The results show that mean annual rainfall increases to the northeast by about 300% from Zones 1-8 across the study area, and by approximately 400-500% including Zone 9. Extreme rainfall intensities increase by a factor of ~1.5 – 2.5 for durations of 1-72 hours, respectively, from Zones 1-8. Extreme rainfall for durations of less than 1 hour did not show an obvious trend across the study area.

In the case of Zone 9, a Regional IDF curve was not created due to data scarcity. Pending development of a regionally representative curve following additional data collection and analysis, Metro Vancouver Station DN16 (AES Seymour Falls Dam) may provide conservative estimates of extreme rainfall for locations in Zone 9 lower in elevation than this station site (< 200 m).

The work herein is for current conditions, and does not account for future changes in precipitations due to climate change. It does, however, form the necessary basis for estimates of future conditions, along with the previous climate change analysis completed in BGC (2009).

For current conditions, BGC recommends the following additional work:

1. Obtaining the annual maximums data (if available) that is missing for 33 Environment Canada climate stations within the study area, and redoing the Regional IDF Curve analysis once this data has been obtained.
2. Obtain climate station data for Cypress, Grouse, Seymour, and Hemlock Valley Ski Areas, and review the availability of additional climate station data at higher elevations on the northern side of the study area.
3. Review the suitability of weather model data for the North Shore as a possible supplement to climate station data for modelling of average precipitation distribution across data-scarce areas.
4. Further multivariate statistical analysis of rainfall distribution with explicit consideration of topography and possibly weather model data as analysis variable(s).
5. Review obtaining Regional IDF curve(s) for the area encompassing Zone 9 if permitted by additional data gathering and analysis.

In the case of recommendation #4, it is important to note that while much of Zone 9 lies north of Metro Vancouver, inclusion of this area in the study is nonetheless important because precipitation-triggered processes such as landslides and floods occurring in this area have the potential to impact locations within the Metro Vancouver boundary.

BGC recommends preparation of regional IDF curves for future conditions within the same area, as recommended also in BGC (2009). This includes:

1. Development of estimated regional IDF curves for Metro Vancouver for the period 2040's to 2070's; and
2. discussion of the sensitivity of the climate-adjusted IDF curves to forecasted changes in precipitation associated with different emissions models and scenarios.

6.0 CLOSURE

We hope that the foregoing satisfies the requirements of the analysis you requested. Please do not hesitate to contact the undersigned if you have any questions or require additional information.

Yours sincerely,

BGC ENGINEERING INC.
per:

Kris Holm, M.Sc., P.Geo.
Project Manager

Reviewed by:

Matthias Jakob, Ph.D., P.Geo.
Senior Geoscientist

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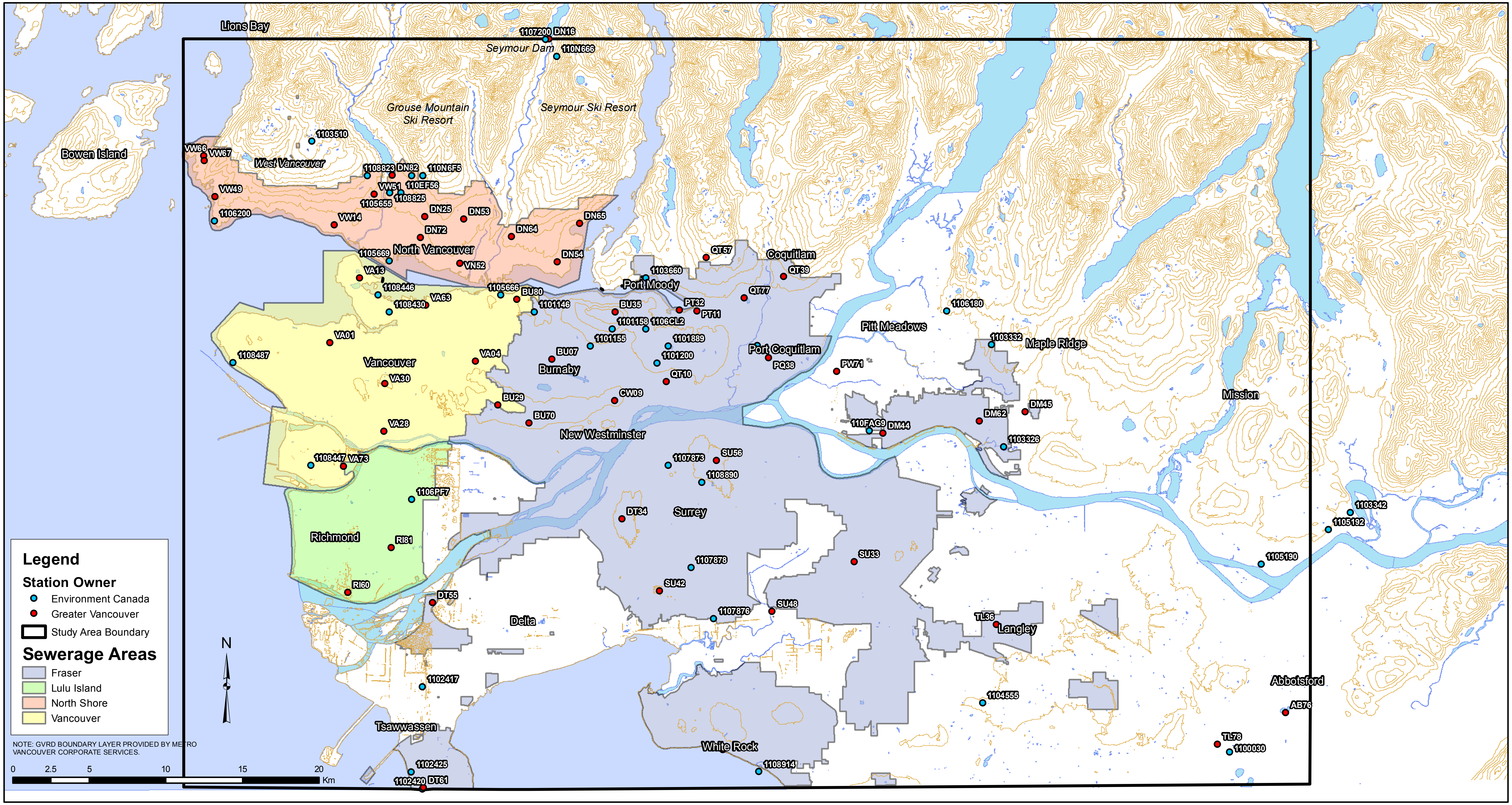
APPENDIX I
LIST OF CLIMATE STATIONS IN EACH PRECIPITATION ZONE

SITE_CODE	ZONE	OWNER	NAME	UTM X	UTM Y	Mean Annual Precip (mm)
1102425	01	Env Can	DELTA TSAWWASSEN BEACH	493418	5428571	918
1102417	01	Env Can	DELTA LADNER SOUTH	494156	5434129	1008
RI60	01	Metro Van	Lulu Island WWTP	489279	5440286	720
1102420	01	Env Can	DELTA PEBBLE HILL	494149	5427459	885
DT61	01	Metro Van	Pebble Hill Reservoir	494204	5427559	759
1108447	02	Env Can	VANCOUVER INT'L A	486885	5448593	1199
1108914	02	Env Can	WHITE ROCK STP	516088	5428591	1102
1106PF7	02	Env Can	RICHMOND NATURE PARK	493440	5446358	1277
DT55	02	Metro Van	Ferry Road	494804	5439621	828
RI81	02	Metro Van	Richmond	492119	5443210	816
VA28	02	Metro Van	Kent Ave. Pump Station	491629	5450802	1066
VA73	02	Metro Van	Vancouver International Airport	489011	5448522	894
WK47	02	Metro Van	White Rock Pump Station	513749	5430034	841
AB76	03	Metro Van	ABBOTSFORD	550445	5432441	1002
VA01	03	Metro Van	Kitsilano High School	488103	5456596	1330
1100030	03	Env Can	ABBOTSFORD A	546792	5429876	1573
1106200	03	Env Can	POINT ATKINSON	481105	5463062	1356
1107878	03	Env Can	SURREY NEWTON	511672	5441920	1409
1107876	03	Env Can	SURREY MUNICIPAL HALL	513139	5438588	1370
1104555	03	Env Can	LANGLEY LOCHIEL	530689	5433099	1487
DT34	03	Metro Van	Hellings Reservoir	507165	5445096	1391
SU42	03	Metro Van	Newton Reservoir	509618	5440376	1123
SU48	03	Metro Van	Cloverdale Pump Station	516966	5439069	1197
TL36	03	Metro Van	Langley Central	531605	5438203	1261
TL78	03	Metro Van	31790 Walmsley Rd., Aldergrove	546000	5430400	1181
VA30	03	Metro Van	Kersland Reservoir	491704	5453913	1343
VW49	03	Metro Van	Gleneagles Pump Station No. 5	480621	5466118	1417
1108487	03	Env Can	VANCOUVER UBC	481806	5455278	1277
VW66	03	Metro Van	Gleneagles Pump Station No. 2	479880	5468789	1401
VW67	03	Metro Van	HORSESHOE BAY	479916	5468468	1401
VA13	04	Metro Van	Stanley Park	490063	5460797	1562
VA04	04	Metro Van	Renfrew Elementary School	497604	5455373	1485
1107873	04	Env Can	SURREY KWANTLEN PARK	510201	5448587	1586
1108890	04	Env Can	WHALLEY FOREST NURSERY	512389	5447480	1549
1108430	04	Env Can	VANCOUVER CITY HALL	492000	5458589	1286
1108446	04	Env Can	VANCOUVER HARBOUR CS	491274	5459701	1589
BU29	04	Metro Van	Central Park Reservoir	499064	5452527	1503

SITE_CODE	ZONE	OWNER	NAME	UTM X	UTM Y	Mean Annual Precip (mm)
BU70	04	Metro Van	Burnaby South	501098	5451355	1298
SU33	04	Metro Van	Surrey East	522315	5442297	1263
SU56	04	Metro Van	Whalley Reservoir	513340	5448894	1346
VA63	04	Metro Van	Harbour Pump Station	494368	5459033	1432
BU07	05	Metro Van	Sperling Ave. Pump Station	502593	5455508	1517
CW09	05	Metro Van	Westburnco Reservoir	506691	5452816	1466
VW14	05	Metro Van	West Vancouver Municipal Hall	488405	5464282	1636
1101146	05	Env Can	BURNABY CAPITOL HILL	501455	5458583	1940
1103326	05	Env Can	HANEY EAST	532054	5449782	1788
1105666	05	Env Can	N VANCOUVER 2ND NARROWS	499273	5459695	1855
1105669	05	Env Can	N VANCOUVER WHARVES	492004	5461924	1772
1101155	05	Env Can	BURNABY MTN TERMINAL	505093	5456362	1885
1101200	05	Env Can	BURQUITLAM VANCOUVER GOLF COURSE	509461	5455256	1962
1105190	05	Env Can	MISSION	548878	5442124	1764
110FAG9	05	Env Can	PITT MEADOWS STP	523307	5450850	1708
BU80	05	Metro Van	North Burnaby	500303	5459417	1330
DM44	05	Metro Van	Katzie Pump Station	524199	5450687	1482
PQ38	05	Metro Van	Port Coquitlam Pump Station	516734	5455602	1822
PW71	05	Metro Van	Meadowlands Elementary School	521170	5454698	1752
QT10	05	Metro Van	Coquitlam City Hall	510053	5454056	1569
VN52	05	Metro Van	Lynn Pump Station	496590	5461772	1738
1101889	05	Env Can	COQUITLAM COMO LAKE AVE	510187	5456369	1924
1101158	06	Env Can	BURNABY SIMON FRASER U	506547	5457475	2019
1106CL2	06	Env Can	PORT MOODY GLENAYRE	508730	5457478	1955
1103660	06	Env Can	IOCO REFINERY	508724	5460813	2018
1106256	06	Env Can	PORT COQUITLAM CITY YARD	516007	5456383	1941
BU35	06	Metro Van	Burnaby Mountain, SFU	506729	5458583	1888
DM45	06	Metro Van	Maple Ridge Reservoir	533470	5452073	1658
DM62	06	Metro Van	Golden Ears Elementary School	530493	5451465	1610
DN72	06	Metro Van	Mahon Park	494014	5463430	1806
PT11	06	Metro Van	Port Moody Pump Station	512066	5458639	1870
PT32	06	Metro Van	Rocky Point Park	510922	5458705	1801
QT77	06	Metro Van	Douglas College	515150	5459499	1831
DN54	06	Metro Van	Seymour Golf and Country Club	502947	5461869	1889
1107680	07	Env Can	STAVE FALLS	546595	5453221	2322
1103332	07	Env Can	HANEY UBC RF ADMIN	531287	5456448	2194
1105655	07	Env Can	N VANCOUVER CAPILANO	492011	5466371	2044

SITE_CODE	ZONE	OWNER	NAME	UTM X	UTM Y	Mean Annual Precip (mm)
1108825	07	Env Can	W VANC CAPILANO GCC	492011	5466371	2269
DN25	07	Metro Van	Dist North Van Municipal Hall	494325	5464824	1915
DN53	07	Metro Van	Lynn Valley Firehall	496842	5464650	2148
DN64	07	Metro Van	Blueridge Elementary School	499953	5463504	1965
QT39	07	Metro Van	Burke Mountain Firehall	517719	5460892	2134
QT57	07	Metro Van	Westwood Plateau	512664	5462132	2084
VW51	07	Metro Van	Capilano Golf and Country Club	491003	5466265	2073
1106180	08	Env Can	PITT POLDER	528365	5458656	2253
1103510	08	Env Can	HOLLYBURN RIDGE	486935	5469716	2805
1105658	08	Env Can	N VANC GROUSE MTN RESORT	494191	5467480	2685
110N6F5	08	Env Can	N VANCOUVER REDONDA DR	494191	5467480	2477
110N6FF	08	Env Can	N VANC SONORA DR	493465	5467480	2387
1108823	08	Env Can	W VANC BALLANTREE PLACE	490560	5467485	2519
DN82	08	Metro Van	Cleveland Dam - Parking Lot	492195	5467498	2012
DN65	08	Metro Van	SeaCove Marina	504404	5464370	2201
110EF56	08	Env Can	N VANCOUVER CLEVELAND	492737	5466370	2437
DN16	09	Metro Van	AES Seymour Falls Dam	502395	5476401	4052
1107200	09	Env Can	SEYMOUR FALLS	502175	5476371	4022
110N666	09	Env Can	N VAN SEYMOUR HATCHERY	502900	5475259	3870

DRAWINGS



NAD 1983 UTM Zone 10N

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REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	1:250,000
DATE:	DEC 2009
DRAWN:	JVC
DESIGNED:	KH
CHECKED:	KH
APPROVED:	MJ

PROFESSIONAL SEAL:

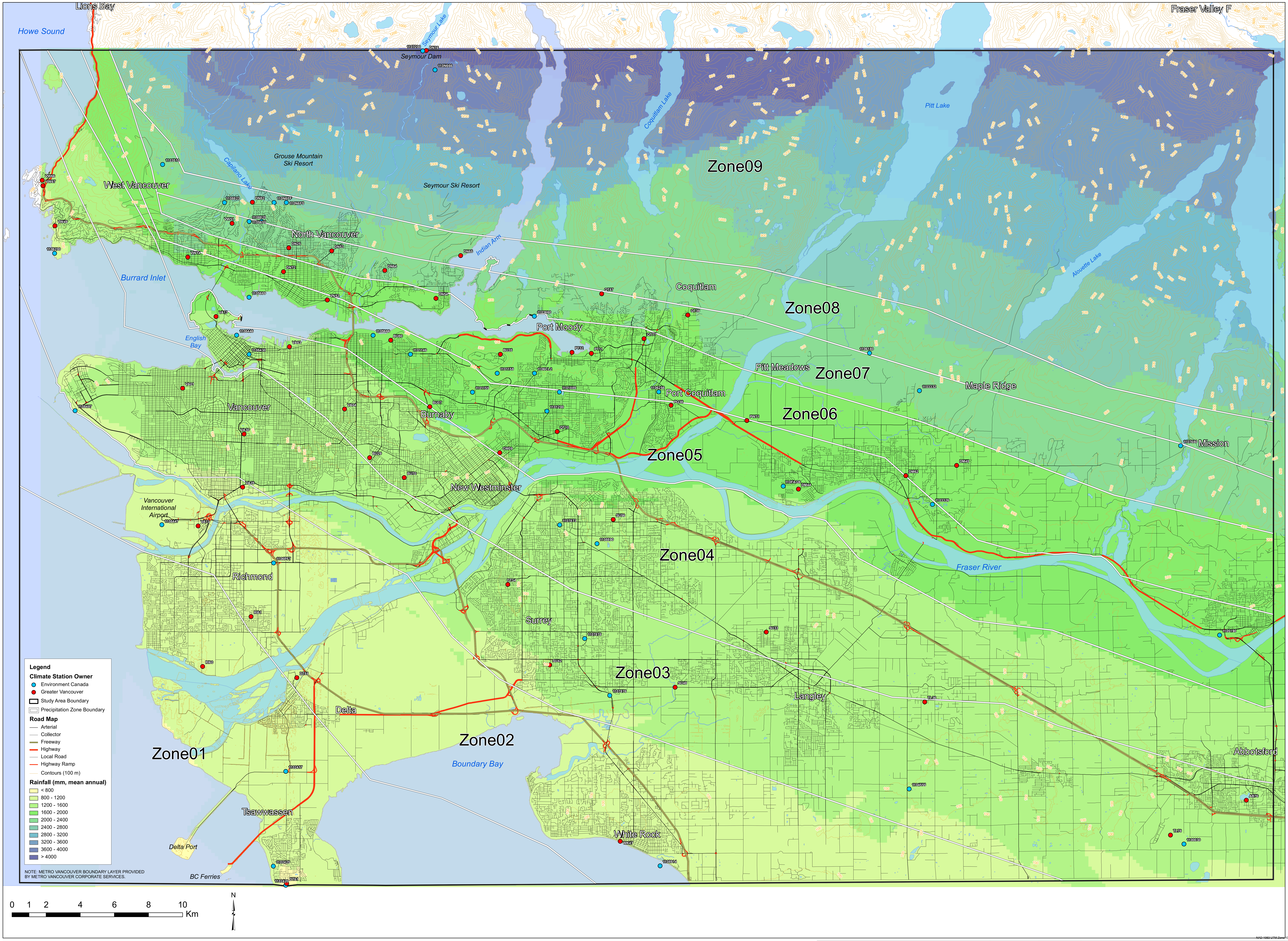
BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: Metro Vancouver

PROJECT: METRO VANCOUVER REGIONAL IDF CURVES

TITLE: STUDY AREA

PROJECT No.:	FIG No.:	REV.:
0431-007	1	



NAD 1983 UTM Zone 10N

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	1:70,000
DATE:	DEC 2009
DRAWN:	JVC
DESIGNED:	KH
CHECKED:	KH
APPROVED:	MJ

PROFESSIONAL SEAL:

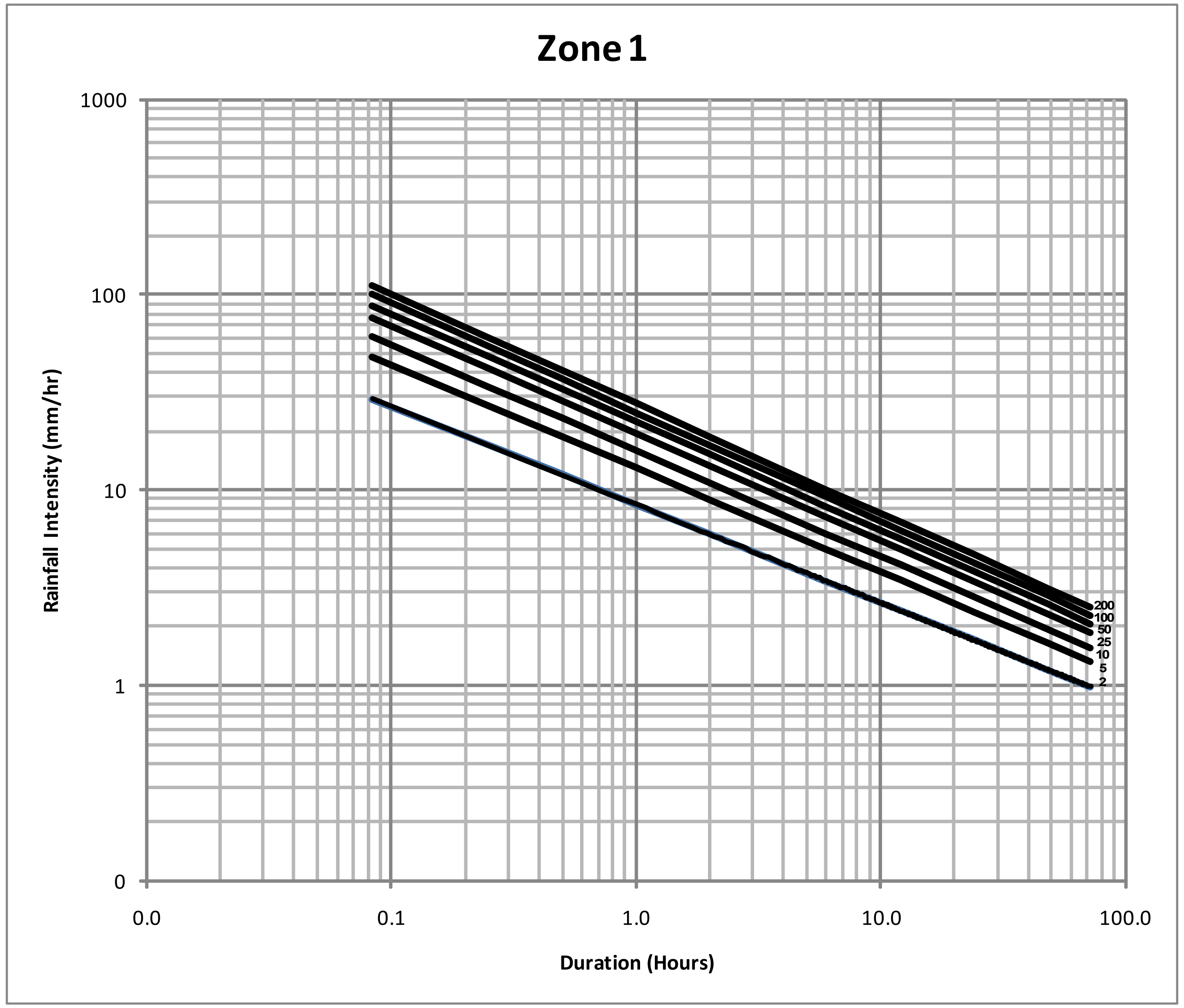
BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

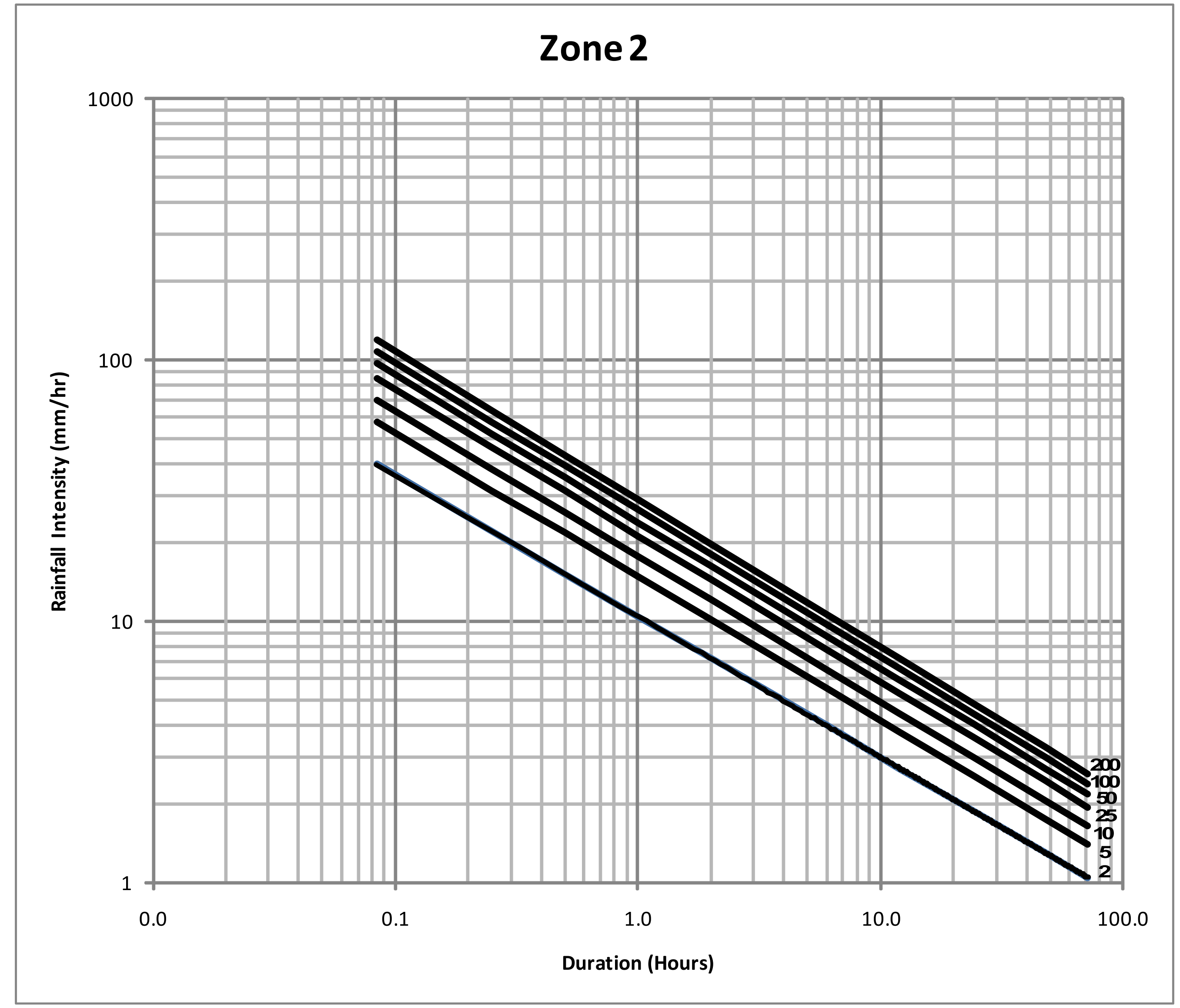
CLIENT: Metro Vancouver

PROJECT: METRO VANCOUVER REGIONAL IDF CURVES

TITLE: PRECIPITATION DISTRIBUTION AND REGIONAL IDF CURVE ZONES

PROJECT No.:	FIG No.:	REV.:
0431-007	2	





Duration	2 year	5 year	10 year	25 year	50 year	100 year	200 year
5 min	29.3	48.5	61.0	76.8	88.5	100.1	111.6
15 min	16.9	27.0	33.7	42.0	48.1	54.2	60.3
30 min	11.9	18.7	23.1	28.7	32.8	36.8	40.8
1 h	8.4	12.9	15.9	19.6	22.3	25.0	27.7
2 h	5.9	9.0	10.9	13.4	15.2	17.0	18.8
6 h	3.4	5.0	6.0	7.3	8.3	9.2	10.1
12 h	2.4	3.5	4.1	5.0	5.6	6.2	6.9
24 h	1.7	2.4	2.8	3.4	3.8	4.2	4.7
48 h	1.2	1.7	2.0	2.3	2.6	2.9	3.2
72 h	1.0	1.3	1.6	1.9	2.1	2.3	2.5

Duration	2 year	5 year	10 year	25 year	50 year	100 year	200 year
5 min	39.7	58.0	70.1	85.4	96.8	108.1	119.3
15 min	22.0	31.7	38.1	46.2	52.2	58.2	64.1
30 min	15.1	21.6	25.9	31.4	35.4	39.4	43.3
1 h	10.4	14.8	17.7	21.3	24.0	26.6	29.3
2 h	7.2	10.1	12.0	14.4	16.2	18.0	19.8
6 h	4.0	5.5	6.5	7.8	8.8	9.7	10.6
12 h	2.7	3.8	4.4	5.3	5.9	6.6	7.2
24 h	1.9	2.6	3.0	3.6	4.0	4.4	4.9
48 h	1.3	1.8	2.1	2.4	2.7	3.0	3.3
72 h	1.0	1.4	1.6	1.9	2.2	2.4	2.6

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE: NTS
DATE: DEC 2009
DRAWN: KH
DESIGNED: KH
CHECKED: KH
APPROVED: MJ

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: Metro Vancouver

PROJECT: Metro Vancouver Regional IDF Curves

TITLE: Rainfall Zone IDF Curves

PROJECT No.: 0431-007
DWG No.: 3
REV.:

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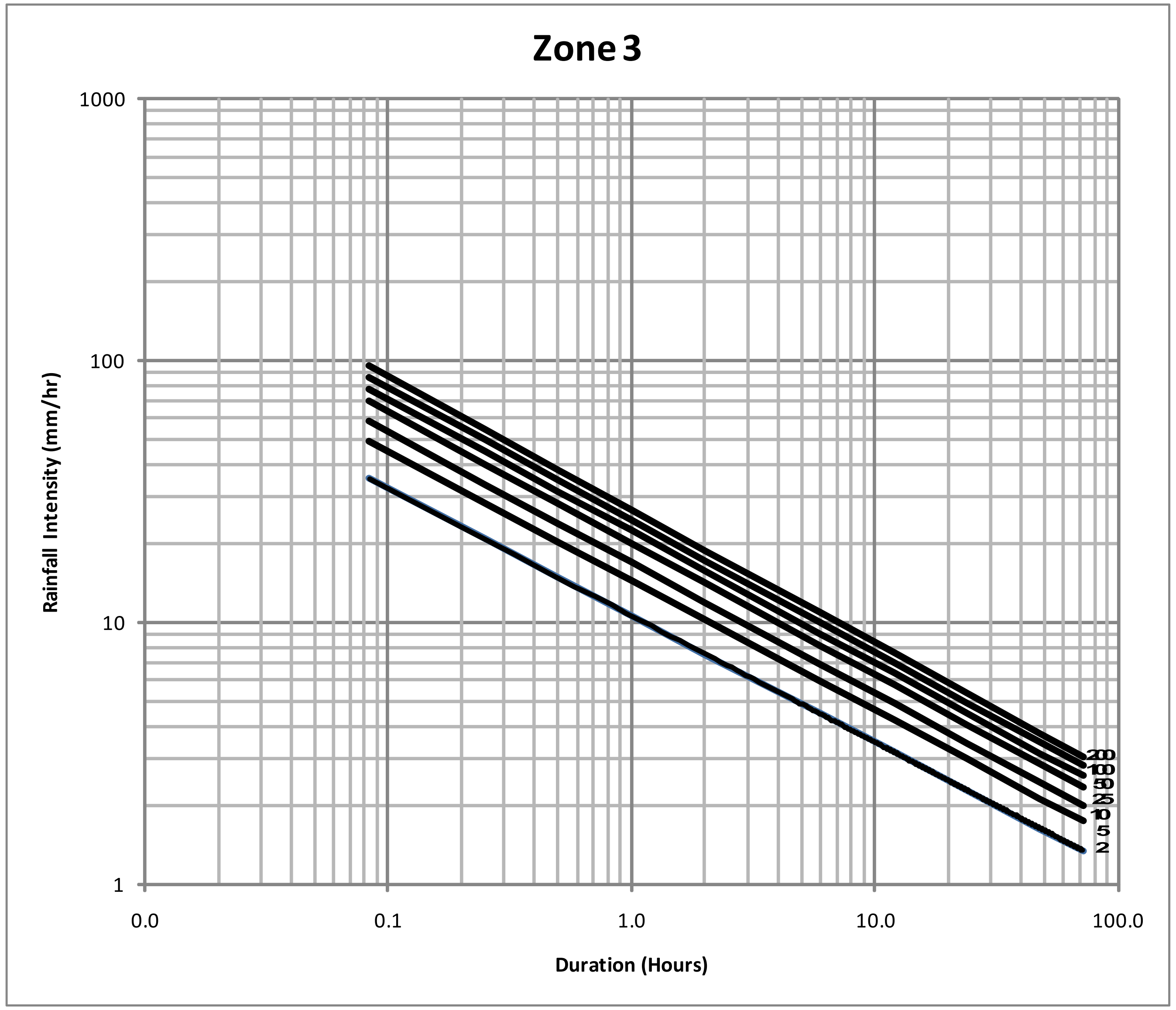
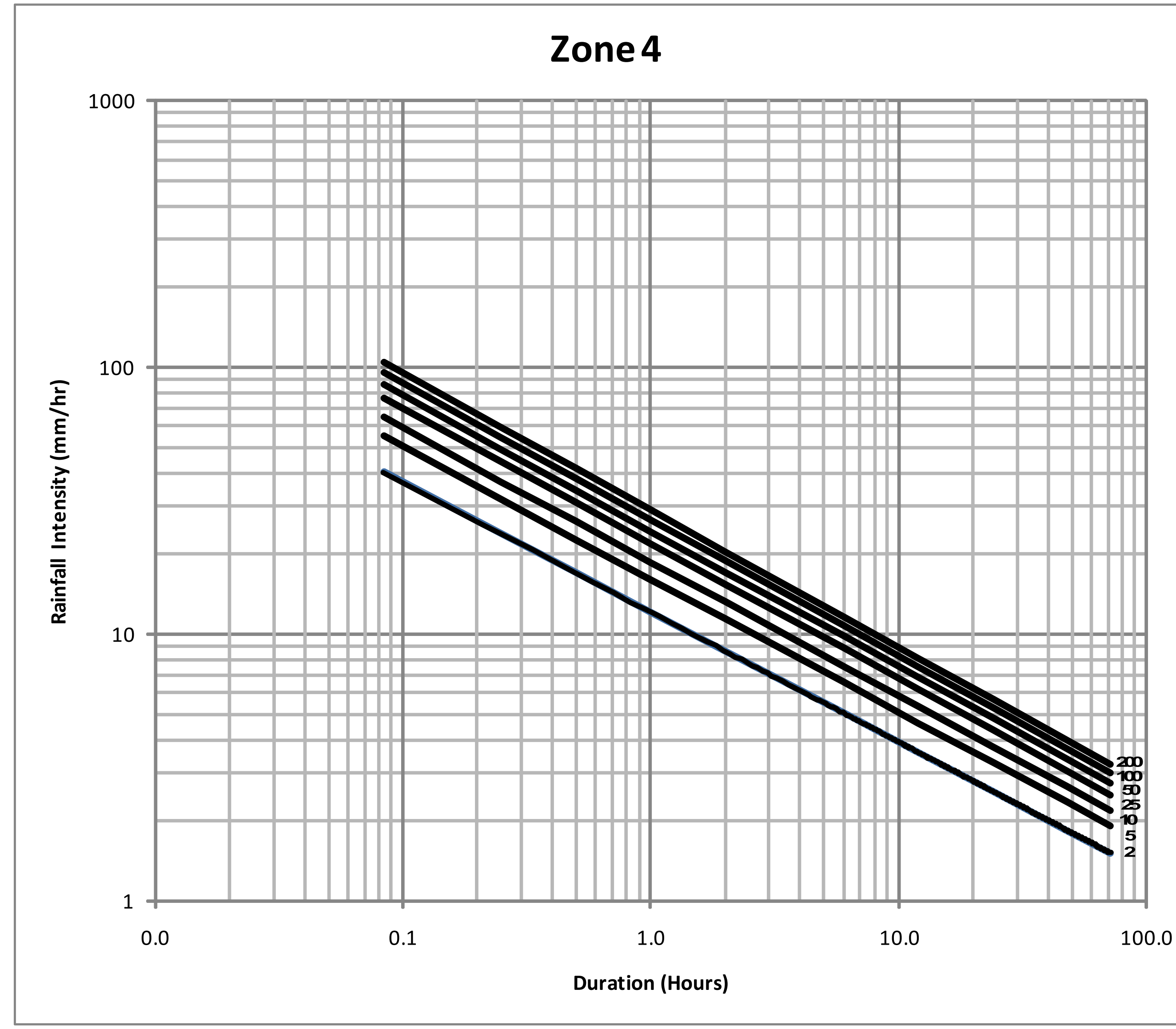


Duration	2 year	5 year	10 year	25 year	50 year	100 year	200 year
5 min	35.3	49.2	58.3	69.7	78.2	86.6	95.0
15 min	20.7	28.6	33.7	40.2	44.9	49.7	54.4
30 min	14.8	20.3	23.9	28.4	31.7	35.0	38.3
1 h	10.6	14.4	16.9	20.0	22.3	24.6	26.9
2 h	7.6	10.2	12.0	14.1	15.7	17.3	18.9
6 h	4.5	5.9	6.9	8.1	9.0	9.9	10.8
12 h	3.2	4.2	4.9	5.7	6.4	7.0	7.6
24 h	2.3	3.0	3.5	4.1	4.5	4.9	5.4
48 h	1.6	2.1	2.5	2.9	3.2	3.5	3.8
72 h	1.3	1.7	2.0	2.3	2.6	2.8	3.1



Duration	2 year	5 year	10 year	25 year	50 year	100 year	200 year
5 min	40.4	55.1	64.8	77.0	86.1	95.1	104.0
15 min	23.7	31.9	37.3	44.1	49.2	54.2	59.2
30 min	16.9	22.6	26.3	31.1	34.6	38.0	41.5
1 h	12.1	16.0	18.6	21.9	24.3	26.7	29.1
2 h	8.6	11.3	13.1	15.4	17.1	18.7	20.4
6 h	5.0	6.6	7.6	8.8	9.8	10.7	11.6
12 h	3.6	4.6	5.3	6.2	6.9	7.5	8.1
24 h	2.6	3.3	3.8	4.4	4.8	5.3	5.7
48 h	1.8	2.3	2.7	3.1	3.4	3.7	4.0
72 h	1.5	1.9	2.2	2.5	2.8	3.0	3.2

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	NTS
DATE:	DEC 2009
DRAWN:	KH
DESIGNED:	KH
CHECKED:	KH
APPROVED:	MJ

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: Metro Vancouver

PROJECT: Metro Vancouver Regional IDF Curves

TITLE: Rainfall Zone IDF Curves

PROJECT No.:	DWG No.:	REV.:
0431-007	4	

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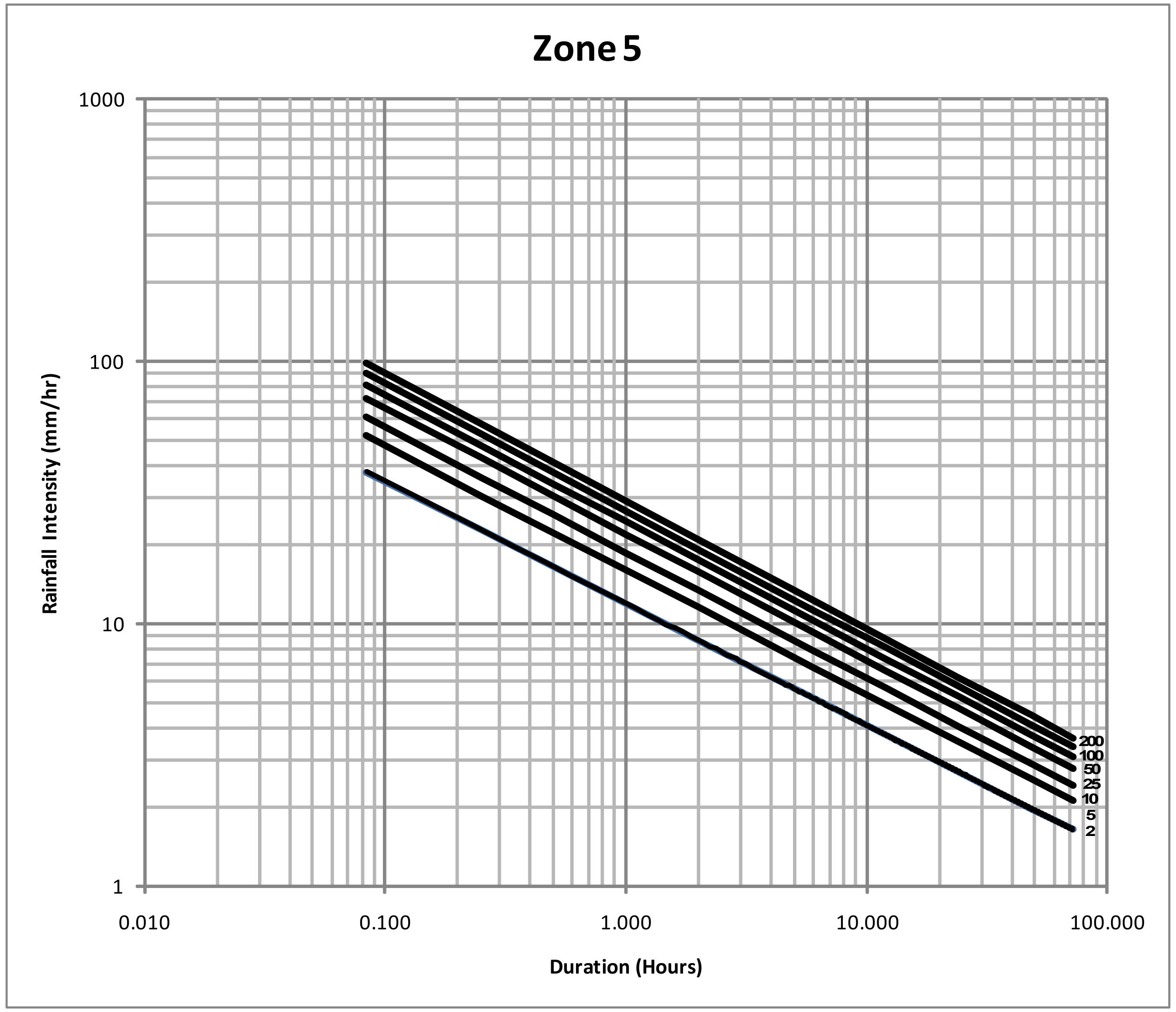

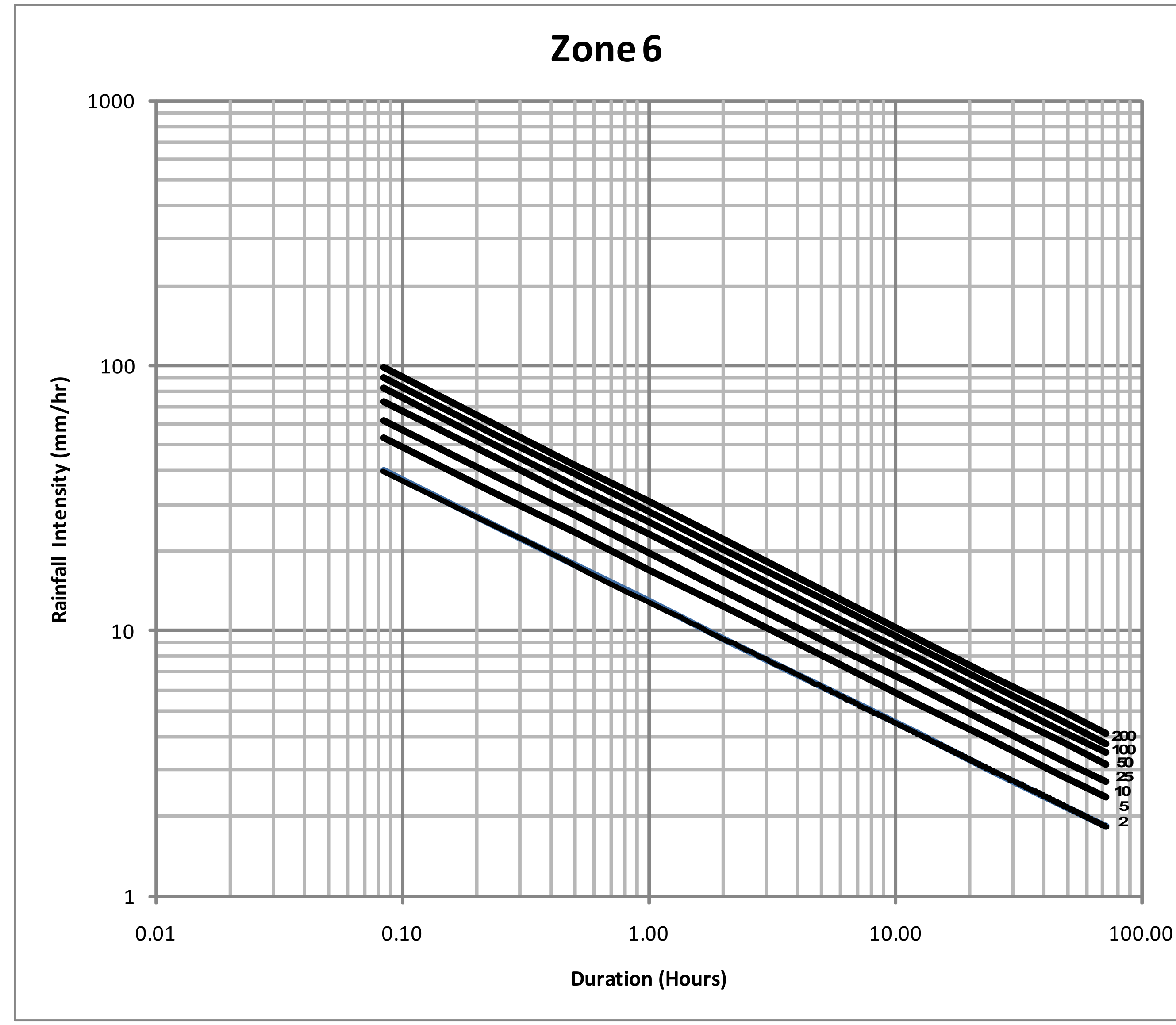

Duration	2 year	5 year	10 year	25 year	50 year	100 year	200 year
5 min	37.8	51.8	61.0	72.6	81.2	89.7	98.2
15 min	22.7	30.8	36.1	42.8	47.7	52.7	57.6
30 min	16.5	22.2	25.9	30.6	34.2	37.6	41.1
1 h	11.9	16.0	18.6	22.0	24.4	26.9	29.3
2 h	8.6	11.5	13.4	15.7	17.5	19.2	20.9
6 h	5.2	6.8	7.9	9.3	10.3	11.3	12.3
12 h	3.8	4.9	5.7	6.6	7.4	8.1	8.8
24 h	2.7	3.5	4.1	4.8	5.3	5.8	6.3
48 h	2.0	2.5	2.9	3.4	3.8	4.1	4.5
72 h	1.6	2.1	2.4	2.8	3.1	3.4	3.7

Duration	2 year	5 year	10 year	25 year	50 year	100 year	200 year
5 min	40.0	53.4	62.3	73.5	81.8	90.0	98.2
15 min	24.2	32.2	37.4	44.0	48.9	53.8	58.6
30 min	17.7	23.4	27.1	31.9	35.4	38.9	42.3
1 h	12.9	17.0	19.7	23.1	25.6	28.1	30.6
2 h	9.4	12.3	14.2	16.7	18.5	20.3	22.1
6 h	5.7	7.4	8.6	10.0	11.1	12.1	13.2
12 h	4.1	5.4	6.2	7.2	8.0	8.8	9.5
24 h	3.0	3.9	4.5	5.2	5.8	6.3	6.9
48 h	2.2	2.8	3.3	3.8	4.2	4.6	5.0
72 h	1.8	2.4	2.7	3.1	3.5	3.8	4.1

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	
DATE:	DEC 2009
DRAWN:	KH
DESIGNED:	KH
CHECKED:	KH
APPROVED:	MJ

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: Metro Vancouver

PROJECT: Metro Vancouver Regional IDF Curves

TITLE: Rainfall Zone IDF Curves

PROJECT No.:	DWG No.:	REV.:
0431-007	5	

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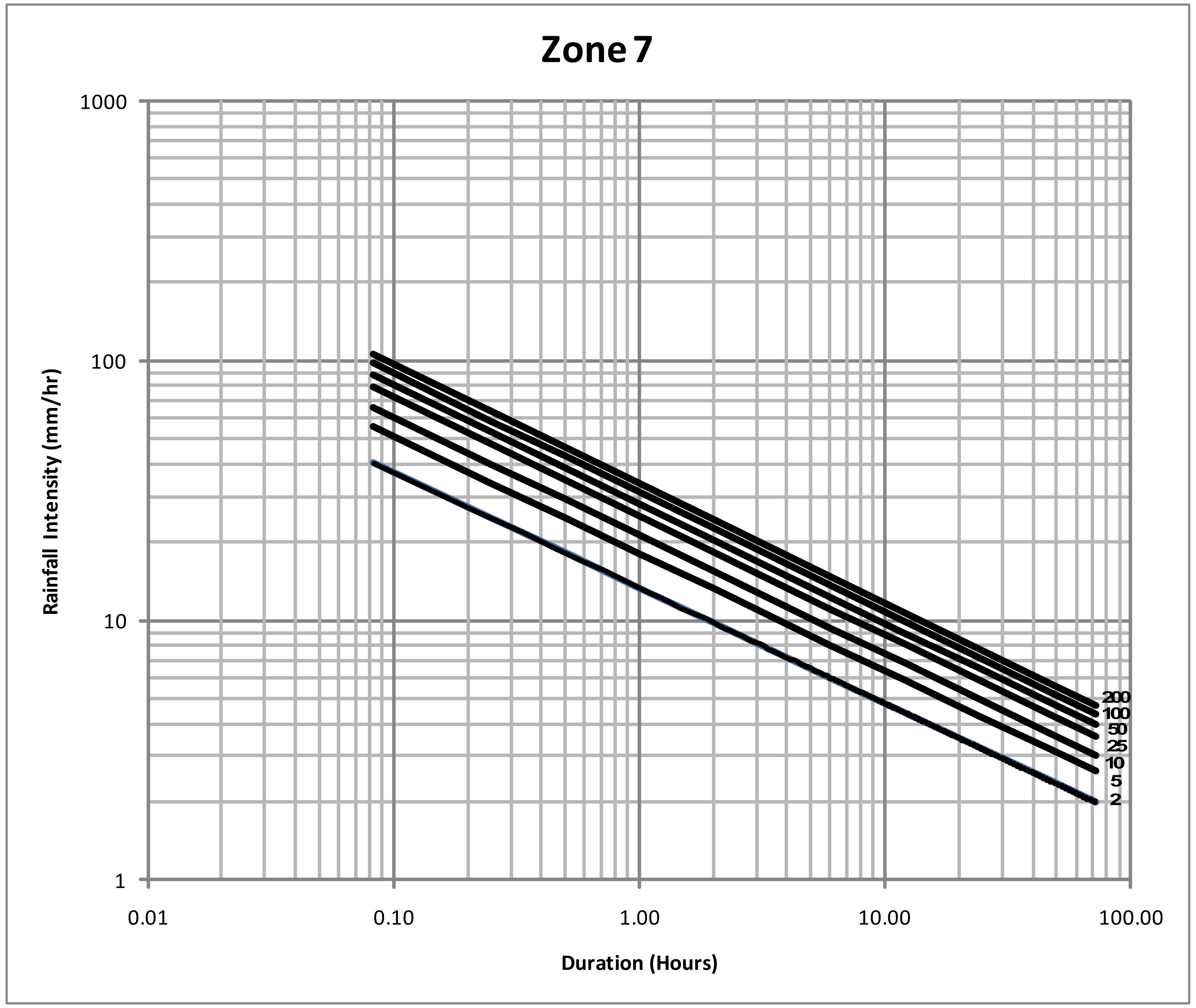
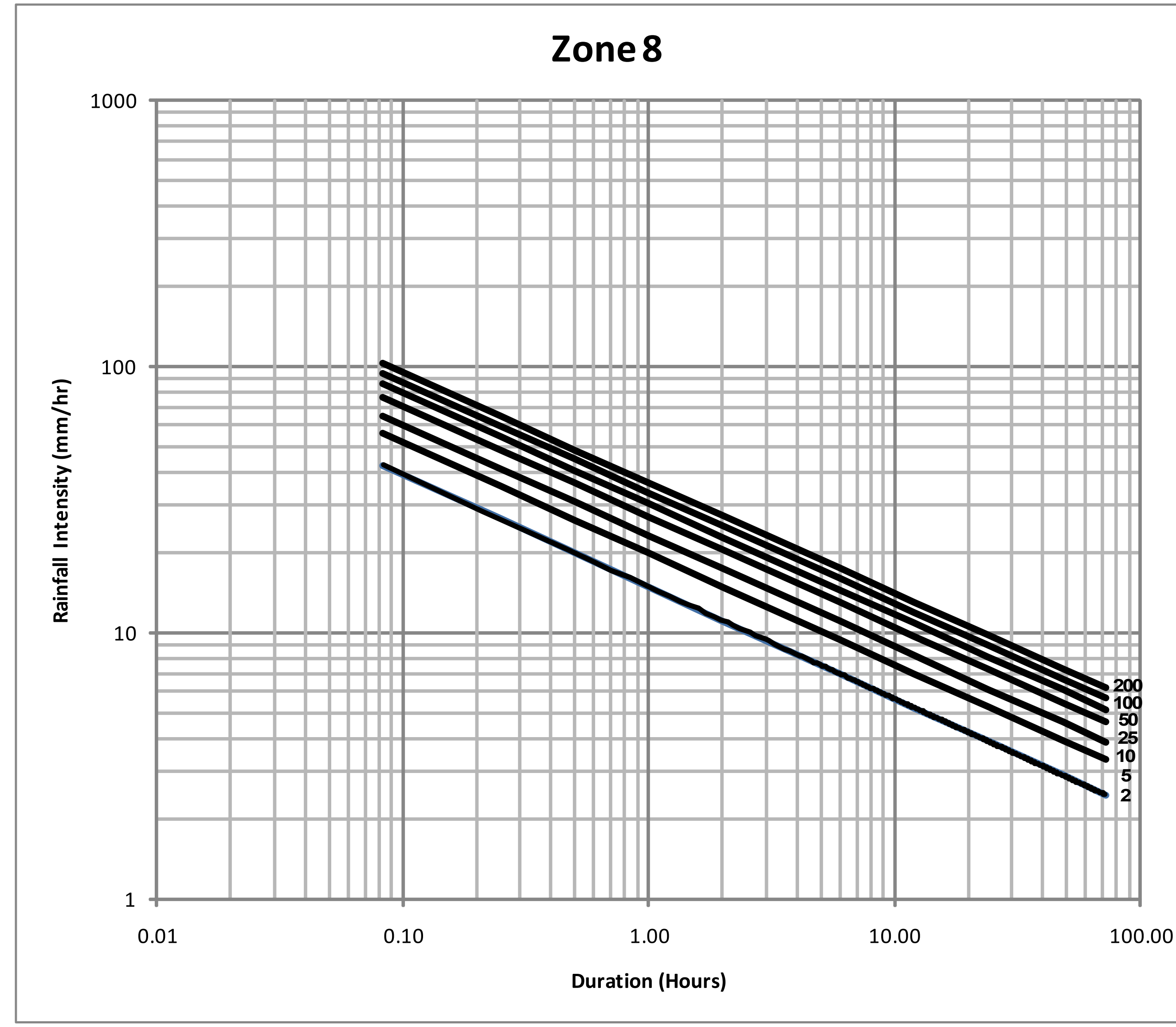


Duration	2 year	5 year	10 year	25 year	50 year	100 year	200 year
5 min	40.4	55.8	66.0	78.7	88.2	97.5	106.8
15 min	24.8	34.0	40.0	47.6	53.2	58.8	64.3
30 min	18.2	24.8	29.2	34.7	38.7	42.7	46.7
1 h	13.4	18.1	21.3	25.2	28.2	31.1	33.9
2 h	9.8	13.3	15.5	18.4	20.5	22.6	24.7
6 h	6.0	8.1	9.4	11.1	12.4	13.6	14.8
12 h	4.4	5.9	6.9	8.1	9.0	9.9	10.8
24 h	3.2	4.3	5.0	5.9	6.5	7.2	7.8
48 h	2.4	3.1	3.7	4.3	4.8	5.2	5.7
72 h	2.0	2.6	3.0	3.6	4.0	4.3	4.7



Duration	2 year	5 year	10 year	25 year	50 year	100 year	200 year
5 min	42.4	56.3	65.4	77.0	85.5	94.0	102.4
15 min	26.7	35.5	41.4	48.7	54.2	59.6	64.9
30 min	19.9	26.6	31.0	36.5	40.6	44.7	48.7
1 h	14.9	19.9	23.2	27.4	30.4	33.5	36.5
2 h	11.1	14.9	17.4	20.5	22.8	25.1	27.4
6 h	7.0	9.4	11.0	13.0	14.5	15.9	17.4
12 h	5.2	7.0	8.2	9.7	10.8	11.9	13.0
24 h	3.9	5.3	6.2	7.3	8.1	9.0	9.8
48 h	2.9	3.9	4.6	5.5	6.1	6.7	7.3
72 h	2.5	3.3	3.9	4.6	5.1	5.7	6.2

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	NTS
DATE:	DEC 2009
DRAWN:	KH
DESIGNED:	KH
CHECKED:	KH
APPROVED:	MJ

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: Metro Vancouver

PROJECT: Metro Vancouver Regional IDF Curves

TITLE: Rainfall Zone IDF Curves

PROJECT No.:	DWG No.:	REV.:
0431-007	6	

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